Department of Natural Resources
MARYLAND GEOLOGICAL SURVEY
Kenneth N. Weaver, Director

REPORT OF INVESTIGATIONS NO. 41

FIRST REPORT ON THE HYDROLOGIC EFFECTS OF UNDERGROUND COAL MINING IN SOUTHERN GARRETT COUNTY, MARYLAND

by

Mark T. Duigon
and
Michael J. Smigaj

Prepared in cooperation with the
United States Department of the Interior
Geological Survey
and the
Maryland Bureau of Mines

1985

CONVERSION FACTORS

For use of readers who prefer to use metric units, conversion factors for terms used in this report are listed below:

Multiply	By	To obtain
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
gallon (gal)	0.003785	cubic meter (m^3)
gallon per minute (gal/min)	0.0631	liter per second (L/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
gallon per minute per foot [(gal/min)/ft]	0.2070	liter per second per meter [(L/s)/m]
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
micromho per centimeter at 25° Celsius (μmho/cm at 25°C)	1.000	microsiemens per centimeter at 25° Celsius (μS/cm at 25°C)

National Geodetic Vertical Datum of 1929 (NGVD 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 mean sea level. NGVD of 1929 is referred to as sea level in this report.

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FIRST REPORT ON THE HYDROLOGIC EFFECTS OF UNDERGROUND COAL MINING IN SOUTHERN GARRETT COUNTY, MARYLAND

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ABSTRACT

Recent increased demand for coal is expected to increase surface and underground mining activities in the coal basins of western Maryland. This report describes preliminary findings on the hydrogeologic system in southwestern Garrett County, Maryland, where a large underground coal-mining operation had recently begun. A network was established to gather streamflow, water-level, and water-quality data. It is presently planned to continue data collection throughout the period of mining and reclamation.

Shallow (less than about 100 feet deep), intermediate (about 100 to 400 feet deep), and deep (greater than about 400 feet deep) ground-water flow systems are present in the study area, and all are characterized by low, secondary permeability. Hydraulic conductivity (less than 2 feet per day) of the shallow system is about two orders of magnitude greater than the deeper systems. Deep ground-water flow is part of a regional system whose boundaries are miles beyond the study area. The base of the fresh ground-water system was found at one site in the study area at a depth of 940 feet below land surface.

Drainage from earlier mining activities was found to contribute substantially to surface-water quality. Measurements of pH in Laurel Run ranged from 2.4 to 3.8, dissolved aluminum ranged from 1.7 to 6.9 milligrams per liter, and dissolved sulfate ranged from 42 to 250 milligrams per liter. The North Fork and the South Fork of Sand Run were less severely affected by earlier mining; however, the South Fork was receiving about 1 million gallons per day of treated acid mine drainage from the current mining operation.

Well-water samples and a sample collected inside the mine had pH values above 6 and generally low levels of dissolved solids. Samples collected from underground-mine discharge points had low (2.6 to 4.0) pH and high (1,000 to 3,430 milligrams per liter residue) dissolved-solids content.

Dewatering of the underground mines has affected ground water and surface water in the study area. Water levels at one cluster of observation wells dropped from 77 to 350 feet as mining approached to within several hundred feet of the cluster. Total runoff in the Laurel Run basin decreased as mine dewatering occurred in the basin. Discharge of water pumped from the mines into South Fork increased total runoff in that basin.

INTRODUCTION

Purpose and Scope

The Mettiki Coal Corporation has begun a large operation in the Upper Potomac coal basin in southwestern Garrett County, Md. (fig. 1; see fig. 5 for location of coal basin). The impact that this operation will have on the hydrologic system of the area is not fully known. The purpose of this study is to describe the effect of a large underground coal mine on the present hydrologic system. A data-collection network was set up to measure ground-water levels, stream discharges, water chemistry, and stream-aquifer relationships. Three drainage basins were intensively studied from May through September 1981 to determine discharge and water quality of principal streams draining the study area. Ground-water/surface-water relationships were evaluated by measuring stream discharge, stream seepage, ground-water levels, and quality of ground and surface water. Measurements of ground-water levels, pumping rates and (or) discharges, water quality, geophysical properties, and other pertinent characteristics were made at 24 wells, 3 underground-mine discharge sites, and 4 springs in the study area. Measurements of precipitation also were made for use in a water-budget analysis of the study area. Data were collected during early phases of mining and will continue to be collected in order to document changes that may occur with continued mining.

Location

The study area is located in southwestern Garrett County, Md. (fig. 1). It is bounded on the northwest by Backbone Mountain and on the southeast by the North Branch of the Potomac River. The area includes the drainage basins of Sand Run (North and South Forks), Laurel Run, and minor streams to the southwest.

Methods of Study

Various kinds of data were collected at the sites shown in figure 2. Three clusters of wells were drilled across the geologic structure of the study area (four wells at sites 1 and 2, and five wells at site 3). Water-level recorders were installed on each well and additional water-level measurements were made periodically in the coal company's observation wells. Three stream gages were constructed and instrumented to monitor stage, temperature, and specific conductance. Additional stream sites were selected for miscellaneous measurements. The data describe existing hydrologic conditions (in an area that is already affected by abandoned coal mines), comprising a baseline with which later measurements can be compared to determine the magnitude of impacts due to mining recently begun by Mettiki Coal Corporation. Seepage runs were performed to increase understanding of ground- and surface-water interactions and to supplement other streamflow data. Geologic sections, water-level data, and aquifer properties determined from pumping tests provide insight into the local ground-water flow system. Field and laboratory analyses of water-quality parameters were obtained over a range of flow conditions and time.

Previous Investigations

Geologic investigations in Garrett County were begun in the first quarter of the 19th century. The early investigations came about as a consequence of the area's location along transportation routes and, later, because of interest in the coal resources. Many of these reports are included in Martin's (1902) review of Garrett County geology. The coal beds and associated strata have subsequently been discussed by Clark and others (1905), Swartz and Baker (1920), Swartz, Price, and Bassler (1919), Toenges and others (1949), Waagé (1950), and Amsden (1954). Depositional environments have been described by Meckel (1967) and Presley (1979).

Overbeck (1954) discussed the occurrence of ground water, and Martin (1954) discussed the occurrence of surface water in Garrett County. These works are mostly inventories and compilations of records. Nutter and others (1980) expanded the collection of basic data for the county. Carswell and Bennett (1963) and Poth (1963) gave somewhat more detailed interpretations for geologically similar areas in western Pennsylvania, although they conceded that not enough information was available to establish details of the hydrologic system.

Documentation of water affected by acid mine drainage (AMD) includes Biesecker and George (1966), Federal Water Pollution Control Administration (FWPCA) (1969), and Hopkins (1966a, 1966b, 1966c). Efforts to gain a better understanding of production of acid mine drainage and its hydrologic effects include Emrich and Thompson (1968), Hollyday and McKenzie (1973), Barnes and Clarke (1964), Minear and Tschantz (1976), and Knight and Newton (1977).

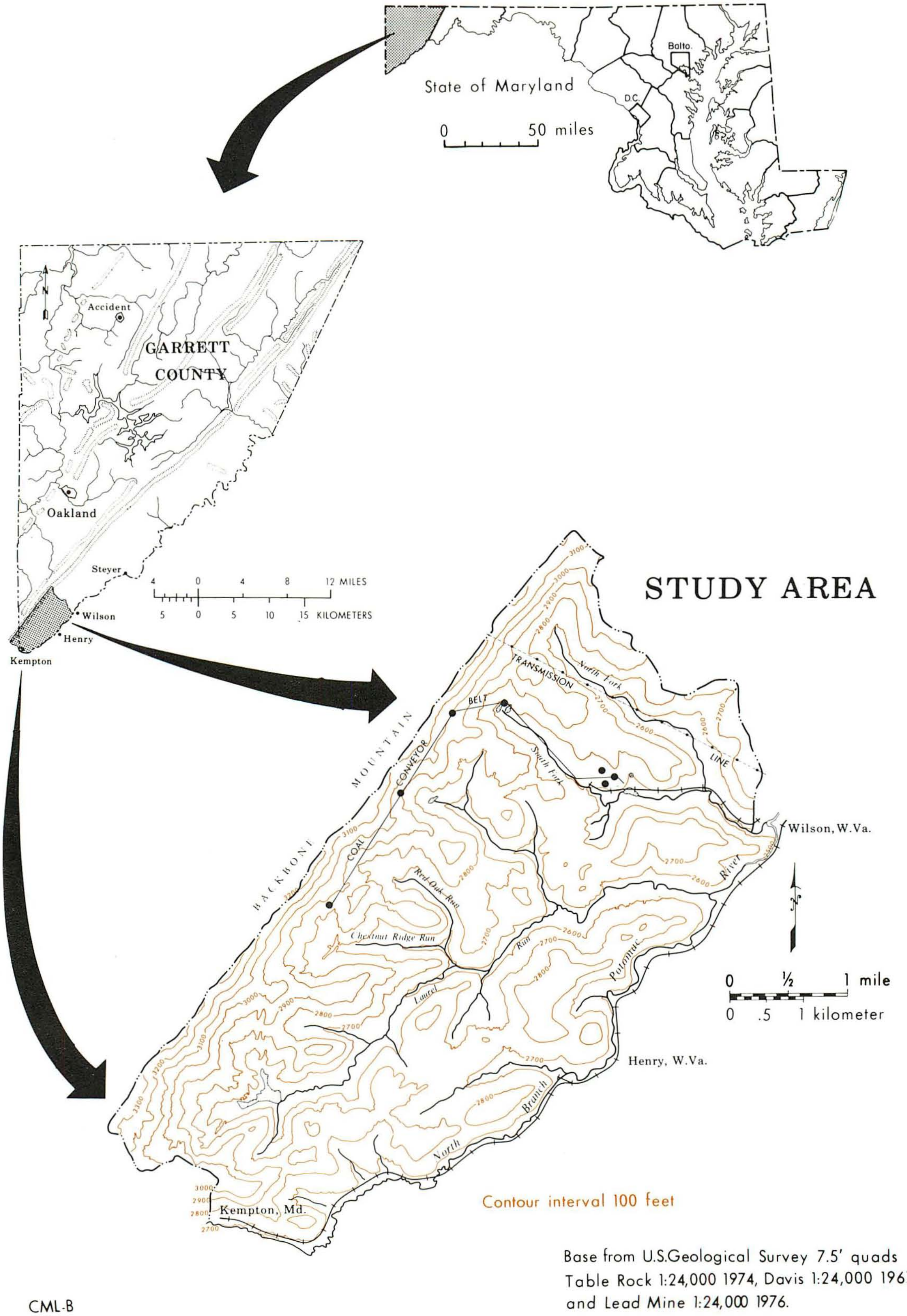


Figure 1.—Location of the study area.

Figure 2.—Data-collection network.

Acknowledgments

The authors are grateful to the Mettiki Coal Corporation for their cooperation and the assistance of Blucher Allison, Chief Engineer; Lonnie Waller, former Chief Engineer; David Thomas, Environmental Coordinator; and George Kutchman, General Superintendent. Appreciation is expressed to the property owners who granted permission for test drilling and stream-gage construction, and the valuable information and cooperation provided by many residents. Ward Staubitz, U.S. Geological Survey, provided additional discharge and quality measurements for some streams in the project area.

This project was initiated by Larry J. Nutter, formerly of the U.S. Geological Survey, and was completed under the supervision of Herbert J. Freiberger, District Chief, U.S. Geological Survey, in cooperation with the Maryland Geological Survey, Kenneth N. Weaver, Director. Additional funding was provided by the Maryland Bureau of Mines, Anthony F. Abar, Director.

GEOGRAPHY

Physiographic Setting

The study area is located in the Allegheny Plateau division of the Appalachian physiographic province. The Allegheny Plateau is a broad upland with some northeast-southwest trending ridges, underlain by sandstones, siltstones, shales, and some limestone. Broad folding has left strata with gentle to moderate dips. The maximum dip in the study area is about 18° to the southeast. The beds dip more gently on the southeast limb of the syncline in the study area.

Rock units in the stratigraphic column vary in resistance to erosion. Shales have low resistance to erosion and now form stream valleys. Highly resistant rocks, such as the basal conglomerates of the Pottsville Formation, form ridges such as Backbone Mountain. The parallel line of knobs along its southeast flank consists of remnants from a later, lower surface that has not yet been obliterated by more recent headward stream incision.

Basin Geomorphology

The Allegheny Plateau in southwestern Garrett County has been deeply incised by streams. Drainage in the study area is of a somewhat rectangular pattern, with several reaches of some streams perpendicular to each other. The major streams draining the study area are Laurel Run and Sand Run, both of which discharge into the North Branch of the Potomac River. Sand Run is formed by the confluence of the North Fork and South Fork. Land slopes are quite steep along portions of some streams and along Backbone Mountain. (Slope maps at a scale of 1:24,000 are available for the Table Rock and Davis quadrangles from Maryland Geological Survey in Baltimore, Md.). The profiles of the major stream channels are shown in figure 3. Beaver dams have ponded several reaches of the main streams, and additional ponds were constructed by the Mettiki Coal Corporation for water-supply and water-quality-control purposes.

Three drainage basins were selected for detailed study (North and South Forks of Sand Run, and Laurel Run), and their boundaries drawn using 1:24,000-scale topographic maps (fig. 4). Three stream-gaging stations were constructed for this study in order to monitor the output generated by the area upstream from each gage.

A number of processes are at work in each of the drainage basins. These include the components of the hydrologic cycle—precipitation, runoff, evaporation, and transpiration—that are, in turn, affected by other factors such as temperature, wind velocity, and soil characteristics. Some of the hydrologic-cycle processes affect other features of the basins through erosion, sedimentation, swamp formation, and chemical reactions. Some of man's activities have altered the rates and relative importance of some of these natural processes.

The present study is concerned with the impact of the Mettiki mines, but the effects of earlier activities in creating current basin conditions must be considered. The most significant impacts in the area, prior to the Mettiki operations, came about as the result of earlier underground coal mining near Kempton (fig. 11). These workings, extending over an area greater than 4 mi^2, drain into Laurel Run, providing a significant portion of its flow and exerting a powerful influence on the chemistry of this stream.

Other impacts of early mining include drainage divides relocated by strip mining, water transported from one basin to another, altered infiltration characteristics of soil and accelerated rates of chemical reactions between water and minerals resulting in corrosive, acid streams flowing out of the mined area.

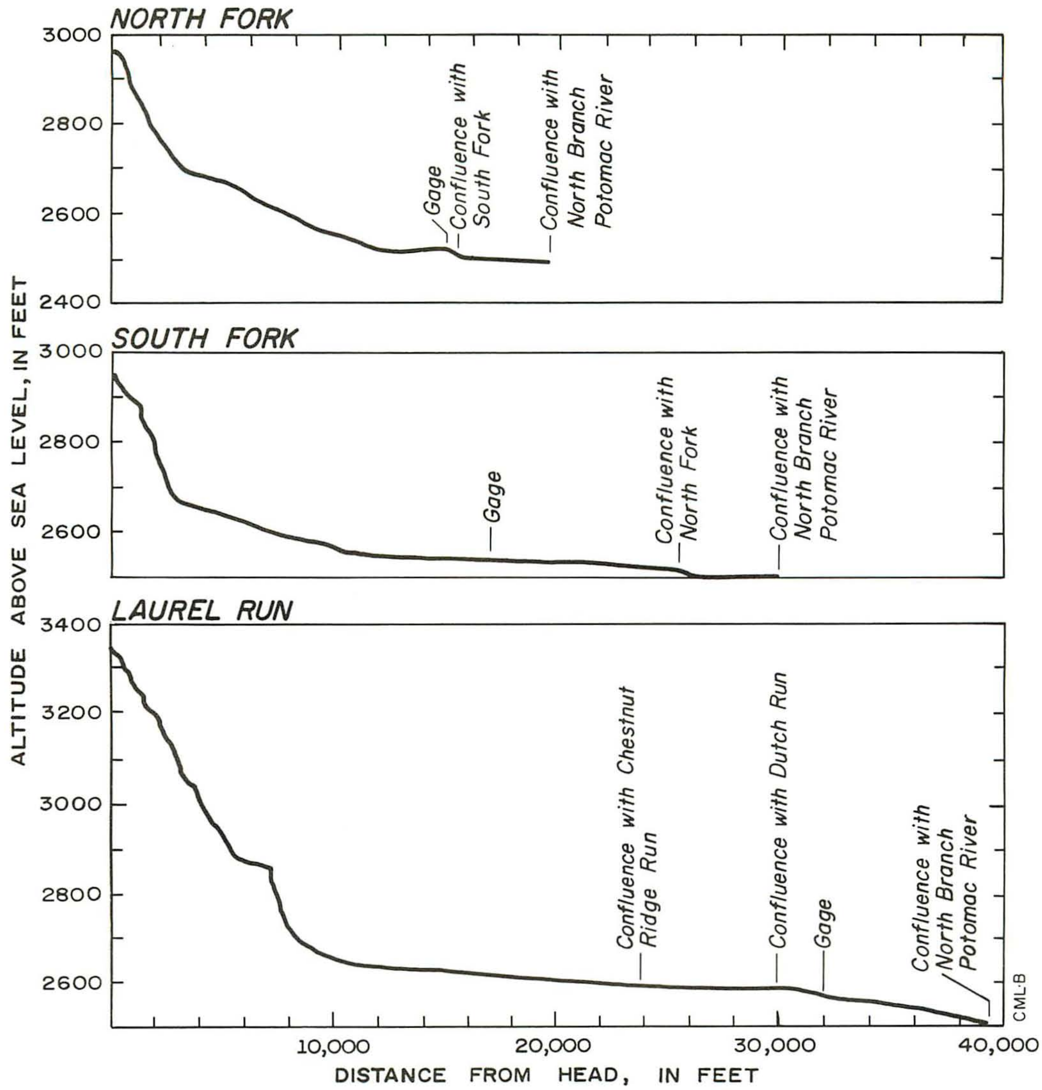


Figure 3.—Channel profiles of North Fork, South Fork, and Laurel Run.

Drainage basins can be described by a number of geomorphic characteristics (table 1). These can be measured in the field or from a map, or can be computed from measured values. The characteristics in table 1 describe the size and shape of each of the three basins and the degree of stream development in each. Such factors have a bearing on how effectively water is routed through the basin. For stream-length measurements, stream lines were extended to the furthest notched contour (Morisawa, 1957). The stream lengths in table 1 were measured from those shown in figure 5, but at the original scale of 1:24,000. The tabulated parameters are for those portions of the drainage basins above the outlet gaging stations.

Laurel Run appears to have the highest drainage density of the three basins, and the North Fork, the least. It may be expected, therefore, that Laurel Run would have the greatest annual runoff and the greatest high flows per square mile. However, the data (table 3) indicate that the highest daily mean flows per square mile occur in the South Fork. This is probably due to discharges to the South Fork from the acid mine drainage (AMD) treatment facility, which includes mine pumpage from the Laurel run basin.

Some investigators (Carlston, 1963) have found base flow to be inversely proportional to drainage density. Low flows per square mile in Laurel Run appear generally higher than in the other two streams. Again, water transfers in the South Fork basin overshadow that stream's flow characteristics. Flow in Laurel Run during periods of generally low flow may be elevated by the contribution from the Kempton mine drainage.

Figure 4.—Drainage basin boundaries for North Fork, South Fork, and Laurel Run.

Figure 5.—Stream-channel traces derived from topographic map.

Table 1.—Geomorphic characteristics of the North Fork, South Fork, and Laurel Run basins.

Basin	Distance of gage above mouth (mi)	Order at gage[1]	Number of first-order streams above gage	Drainage area at gage (mi^2)	Basin perimeter at gage (mi)	Circularity ratio[2]	Main channel length (mi) to gage	Drainage density (mi/mi^2)	Average channel slope (ft/mi)	Altitude (ft)			Maximum relief (ft)	Relief ratio[3]	Hypsometric integral[4]
										Maximum	Minimum (at gage)	Median			
North Fork	0.05	3	22	1.91	7.9	0.38	2.77	6.73	161	3,252	2,515	2,737	737	0.06	0.3585
South Fork	.48	3	35	1.55	6.7	.43	3.15	9.30	129	3,250	2,535	2,704	710	.07	.2761
Laurel Run	1.18	5	343	8.23	13.9	.54	6.04	10.47	127	3,410	2,575	2,771	835	.04	.2822

[1] Strahler (1954) system of stream ordering.
[2] Miller, 1953, p. 8.
[3] Schumm, 1956, p. 612.
[4] Strahler, 1952.

Climate

Air masses from the North American interior provide Garrett County with a humid, continental climate. The prevailing winds are west to northwest, becoming more southerly in the summer.

The National Weather Service station in Oakland, Md., is approximately 11 mi from the center of the study area. Table 2 shows mean monthly and mean annual temperatures recorded at this station (NOAA, 1973). The mean annual temperature reported for the period 1941-70 is 47.8°F.

Table 2.—Mean temperatures and precipitation at Oakland, Md., for the period 1941-70

Month	Mean temperature (°F)	Mean precipitation (in.)
January	27.5	3.84
February	28.8	3.33
March	36.0	4.68
April	47.7	4.28
May	56.7	4.48
June	64.3	4.28
July	67.4	4.78
August	66.5	4.36
September	60.2	3.09
October	50.4	2.91
November	39.4	3.27
December	29.2	3.81
Annual	47.8	47.11

The mean annual precipitation reported at Oakland, Md., is 47.11 in. (table 2). Mean monthly precipitation for March through August exceeds the average mean monthly (3.93 in.); mean monthly precipitation for the rest of the year, although below that average, is still abundant.

Much of the year's precipitation falls as snow, which may occur as early as September and as late as May. Snow cover can be several feet.

A rain gage is maintained at the main office of the Mettiki mine, and daily records were provided by the company. The location of the gage is shown in figure 2.

Soils and Vegetation

The study area is located within the Dekalb-Gilpin-Cookport soil association, which closely corresponds with the Upper Potomac and Georges Creek structural basins. This soil association consists of gently sloping to steep, moderately deep, well-drained and moderately well-drained, very stony soils that formed over acid, gray to yellowish sandstone and shale (Stone and Matthews, 1974, p. 5). The Cookport soils are characterized by a fragipan, which impedes drainage and results in seasonally perched water. Steep slopes and stoniness limit suitability for cultivation. Areas that have been strip mined for coal or have been covered with spoil from underground mining operations are also unsuitable. However, some of the abandoned strip-mine areas have recently been improved by regrading and seeding.

The native timber in the study area has long since been cut, and much of the area has been replanted with hardwoods and conifers (Curran, 1902). Mountain laurel is still common in some parts of the study area. A sphagnum bog exists in the south-central area, but is not large enough to be of commercial interest. Areas cleared for agriculture are used mainly for pasture and hay.

Stratigraphy

The rocks exposed in the study area are all of the Pennsylvanian System (fig. 6) and represent a transition from an alluvial plain to a shallow marine environment. The stratigraphic interval is described by Swartz and Baker (1920). A drilling program conducted by the U.S. Bureau of Mines in 1945-46 provided additional information on the stratigraphy and lithologies of the coal basins (Toenges and others, 1949). More recently, stratigraphic work and depositional environment studies have been carried out in Pennsylvania (Flint, 1965), West Virginia (Donaldson and others, 1979), and Maryland (Harvey, 1974). The stratigraphic nomenclature used in this report is that of recent workers in Maryland and does not necessarily follow the usage of the U.S. Geological Survey.

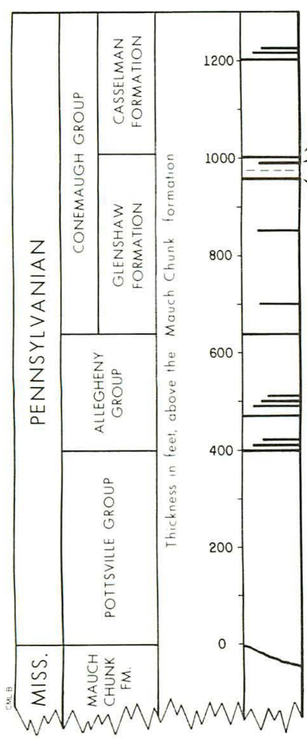


Figure 6.—Generalized geologic column for study area.

The environmental transitions that resulted in the deposition of the various formations found in the study area are shown in figure 7. The oldest rocks exposed belong to the Pottsville Group, which lies disconformably on the Mississippian Mauch Chunk Formation. This unit consists primarily of sandstone and siltstone and includes some thin coalbeds that are not economically important. The Pottsville Group was formed by sediments distributed by a braided fluvial depositional system (Presley, 1979). Well-indurated sandstone of this unit forms the Backbone Mountain ridge.

The Allegheny Group is exposed downslope from the Pottsville, but the two are similar and can be difficult to distinguish. The Allegheny Group has some thick coalbeds, but only the Upper Freeport is economically significant in the study area. Allegheny sediments in Maryland represent the upward transition from a braided fluvial system to a delta plain system, which formed as the shoreline receded southeastward (Presley, 1979).

The Conemaugh Group underlies the rest of the study area (southeast of the strip mines), but erosion has removed much of its upper portion. The highest part of the stratigraphic section found during this study was at site 3, which is on a hilltop. At this site, a coalbed (tentatively identified as the Middle Hoffman coal) was penetrated about 25 ft below land surface. The Conemaugh Group consists of siltstone, sandstone, shale, and coal, and represents the shallow marine stage in the Pennsylvania transgressional sequence (Presley, 1979). The marine influence was not as strong during Conemaugh deposition as it was to the west and northwest of the study area. An indication of this is that the Ames Member in the study area, where present, is a thin shale. To the northwest, however, it is a limestone. The stratigraphic boundary between the lower Glenshaw Formation and the upper Casselman Formation has usually been put at the top of the Barton Coal (Elk Lick of Pennsylvania-West Virginia). However, some workers consider the absence of marine beds above the Ames marine shale (which lies on top of the Harlem coal) a justification for placing the boundary at the Ames, as proposed by Flint (1965, p. 70-73). Red shales characteristic of the Conemaugh are absent in the Allegheny and Pottsville Groups. The Lower Bakerstown coal is the only coal in the Conemaugh Group of economic importance in the study area, but is of a mineable thickness in less than one-third of this area.

Recent deposits include floodplain sediments and colluvial deposits at the toeslopes of hills, but these are of limited extent. Organic deposits occur in several small bogs.

Lithologic and geophysical logs for some of the wells drilled for this study are in appendix B. The logs do not indicate sharp contrasts between groups, but do show considerable variation within groups.

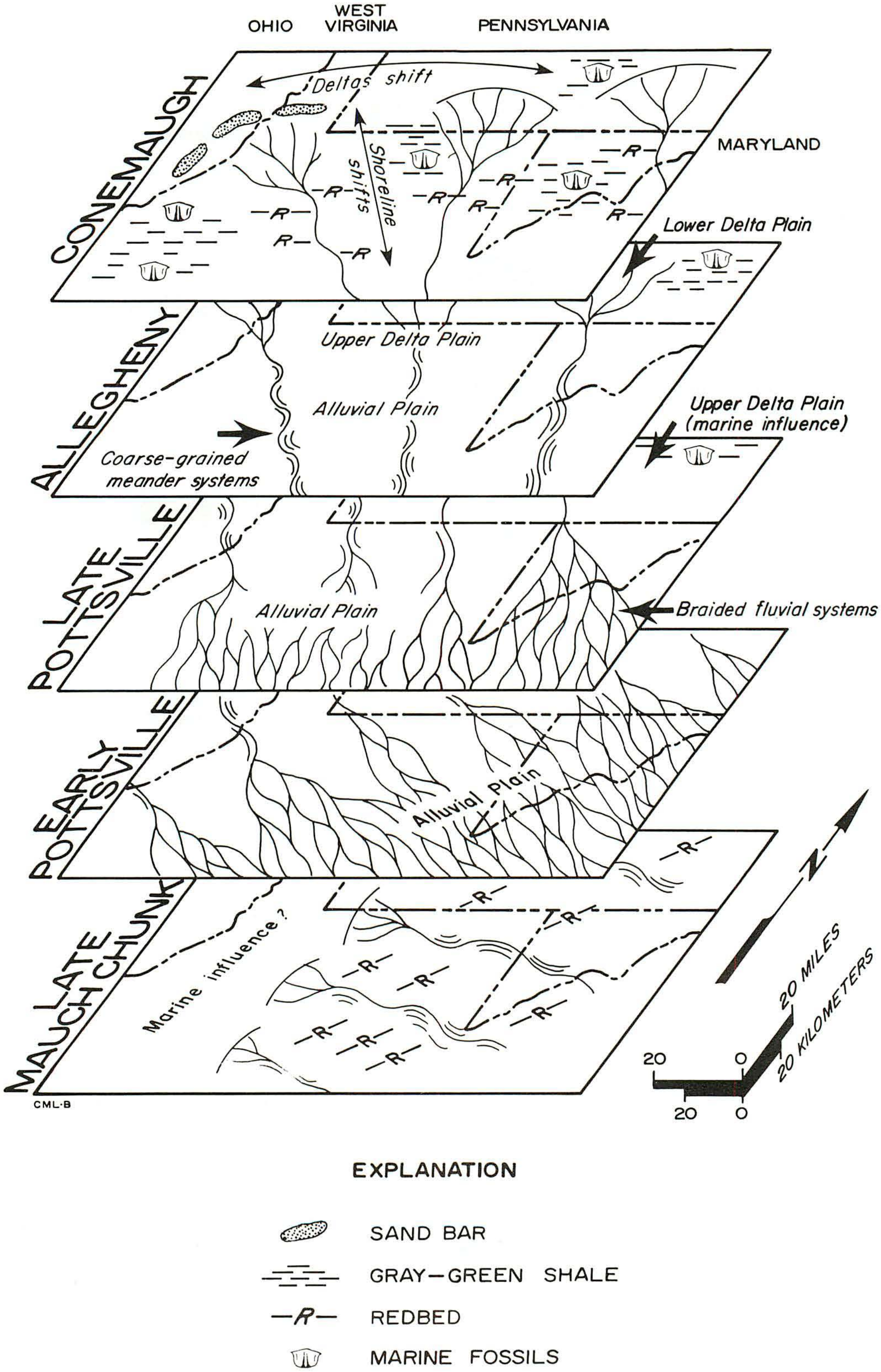


Figure 7.—Environmental transitions from late Mauch Chunk through early Conemaugh time (from Presley, 1979).

Geologic Structure

The geologic structure of Garrett County was described by Darton and Taff (1896), and by Martin (1902). The strata have been uplifted and pushed into low folds, forming five synclines (coal basins) and three anticlines (fig. 8). The study area lies within the Upper Potomac syncline, which has a shallow northeast plunge in the study area. This syncline is evident in figure 9 from the structure contours drawn on the base of the Upper Freeport coal.

No significant faults are present in the study area, but the rocks are jointed. Fracture traces, drawn from linear features visible on aerial photographs, are shown in figure 10. The accompanying rose diagram of fracture orientations indicates a preferred north-northwest/south-southeast orientation, and a scarcity of northeast-southwest fractures. Larger linear features detected on satellite photographs indicate tectonic stress fracturing, and some of these may correspond to zones of weak roof rocks and concentrated zones of water seepage into the mines.

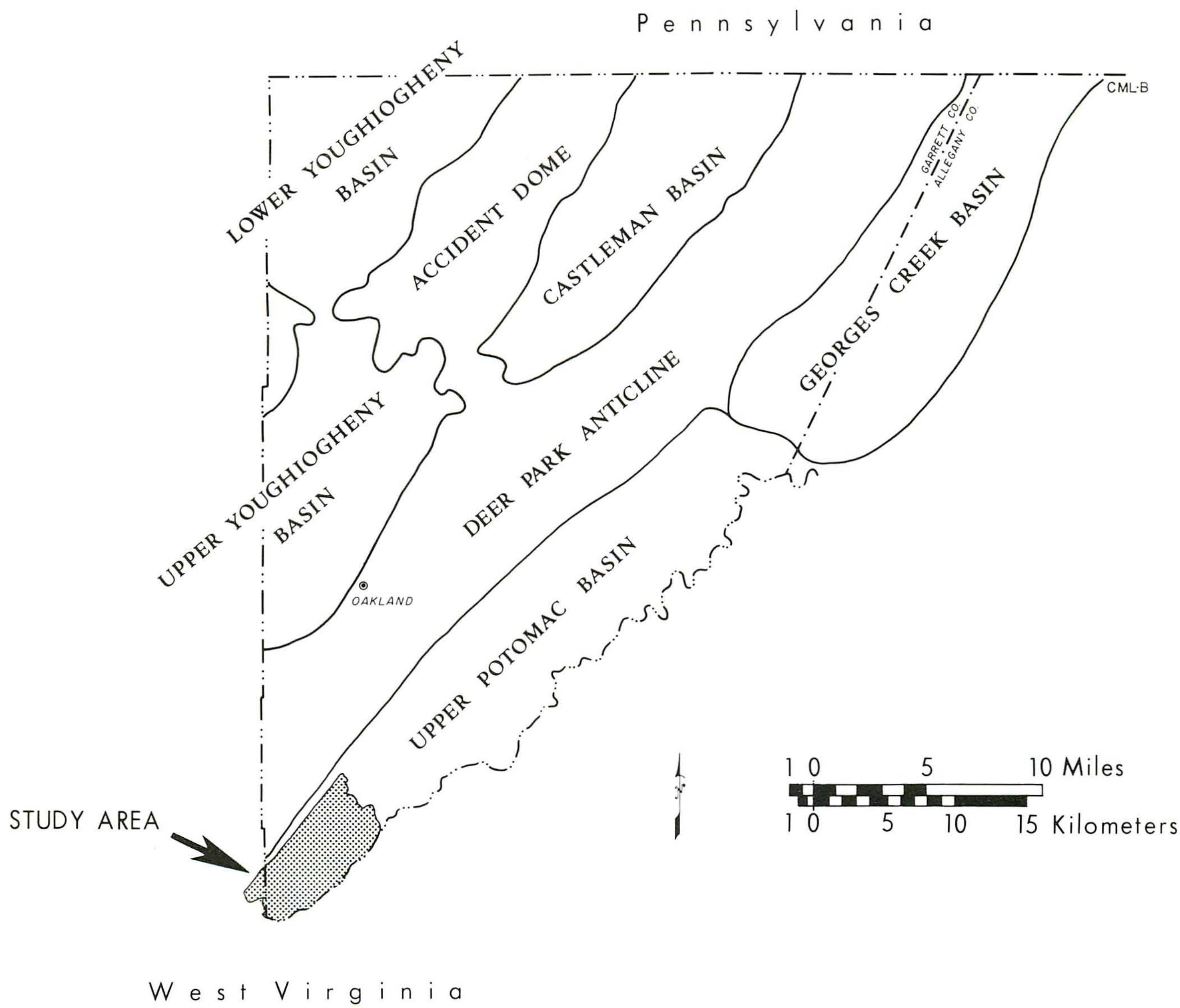


Figure 8.—Geologic structure of Garrett County, Md.

Figure 9.—Altitude of the base of the Upper Freeport coal of the Allegheny Group.

Figure 10.—Linear features (fracture traces), and fracture orientation-frequency rosette.

COAL MINING

Previous Mining Activity

Commercial coal mining in western Maryland began around 1830 in the Georges Creek basin. Because of transportation difficulties, mining did not begin in Garrett County until near the end of the century. There are several abandoned mines in the study area (fig. 11). The Upper Freeport coal was surface-mined along its outcrop area near the base of Backbone Mountain. Beginning in 1914, the Davis Coke and Coal Company's Kempton Mine, located in the southwestern part of the study area, extracted coal from depths ranging from about 50 to 700 ft using the room-and-panel system of mining. Mine shafts were located in Kempton and mining followed approximately the strike of the coal into West Virginia. The Upper Freeport coal was also mined in West Virginia across the North Branch of the Potomac River from the study area (Mine No. 33). The Lower Bakerstown coal, which is about 150 to 200 ft above the Upper Freeport, has been mined by underground methods in both the northern (Buffalo Coal Company Mine No. 1) and the southeastern (Davis Coke and Coal Company Mine No. 22) parts of the study area.

Current Mining Activity

The Mettiki Coal Corporation operates the only active mine in the study area. The Mettiki mine actually consists of three separate mines (fig. 12): Beaver Run (A Mine), Gobblers Knob (B Mine), and Big George (C Mine). Mining is being done by the room-and-pillar method, with extraction of pillars upon completion of the side entries. Retreating is being done in the downslope direction. All the Upper Freeport coal within the boundaries shown in figure 12 is to be removed, except for some areas below existing structures (subsidence control blocks, where regulations allow only 50 percent extraction), and at the mine boundaries, where barrier pillars of various widths (approximately 50 to 200 ft) will remain intact. The company also may mine the Lower Bakerstown coal, which is thinner, shallower, less extensive, but of higher quality than the Upper Freeport coal. If the Lower Bakerstown is mined, it will be done before the Upper Freeport extraction operations reach those areas.

Mettiki began operation in the summer of 1977 (A Mine) and plans to operate for approximately 20 years. The B Mine started up about 6 months after A, and the C Mine began about 1 year after A. Full production capacity (about 600 tons per shift) was reached in May 1980. Full employment involves about 535 persons. Figure 13 shows the extent of mining near the beginning (Aug. 1978) and at the end of the study period (July 1981). Significant progress not only in coal extraction, but also in the construction and operation of related facilities had been made before the data network was completed. About one-third of Mettiki's output is steam coal, which is sold locally and exported through Baltimore, Md. The rest is exported under contract for use in steel production. The Mettiki holdings constitute approximately 4.8 percent of Maryland's recoverable coal reserves (Kosnett, 1981, p. 38).

The Buffalo Coal Company, although not operating any mines within the study area, does operate a tipple near Wilson, W. Va. Coal from five West Virginia mines is loaded here.

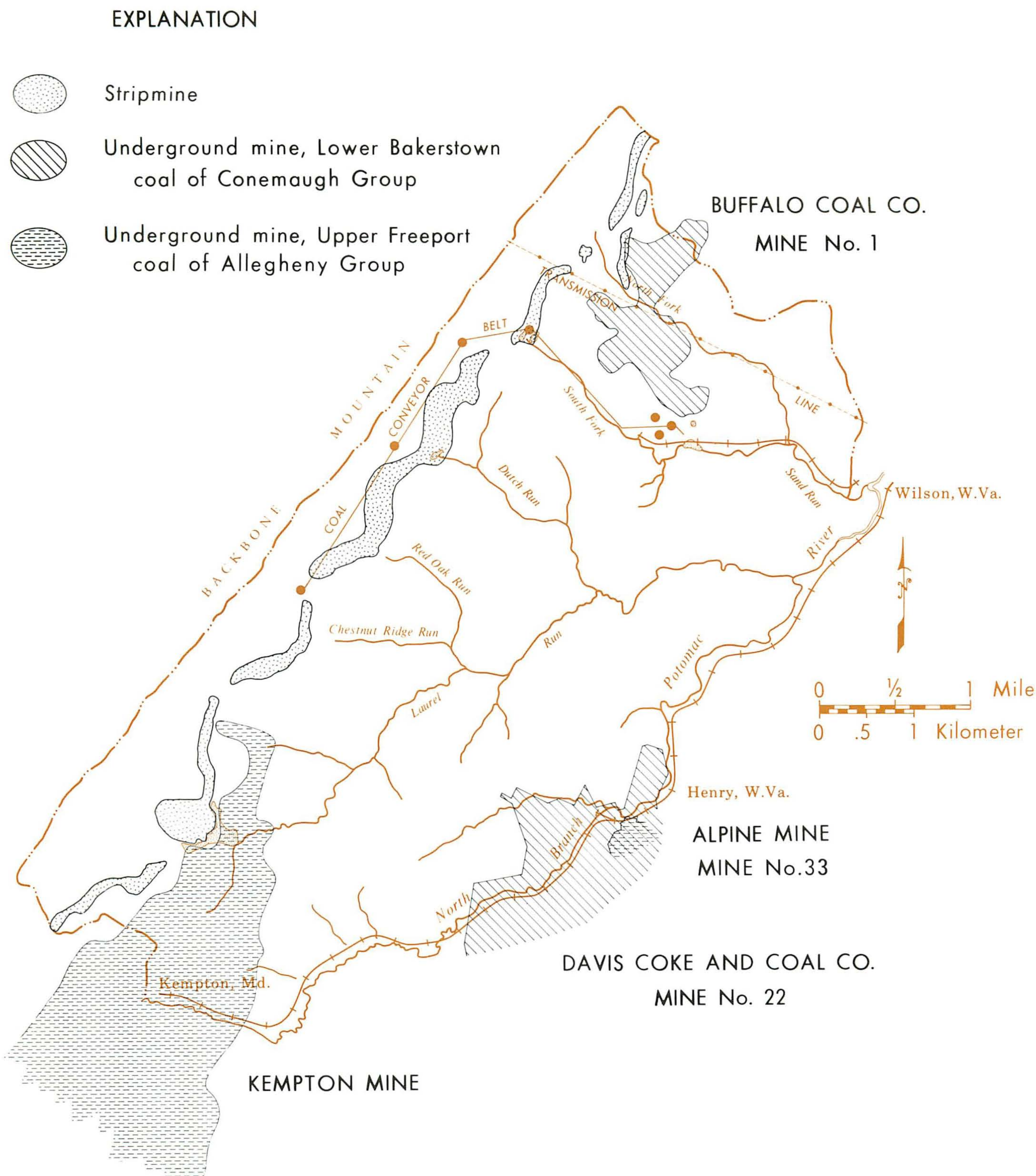


Figure 11.—Abandoned surface and underground coal mines.

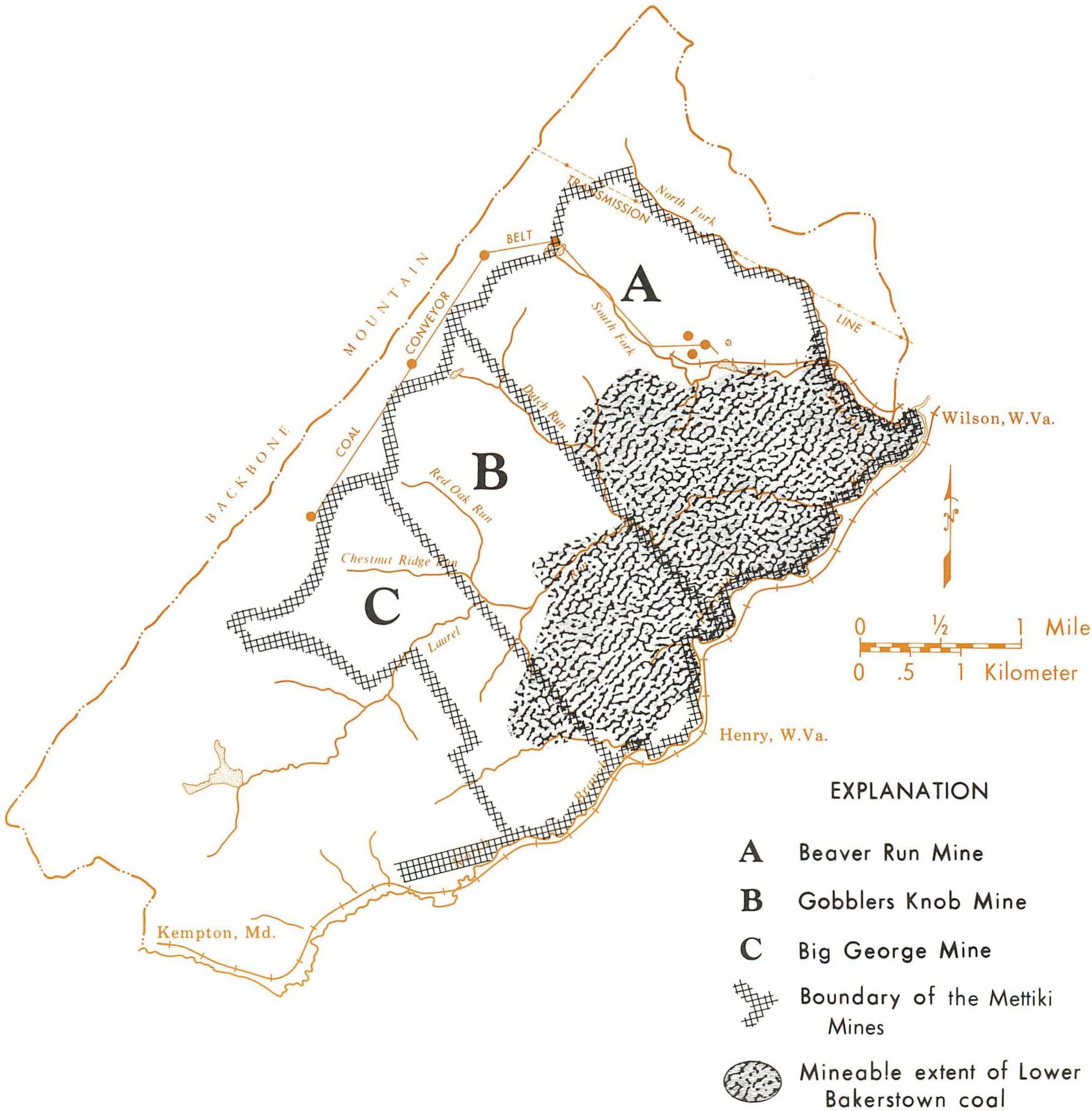


Figure 12.—Boundaries of the Mettiki Mine (Upper Freeport coal of the Allegheny Group) and approximate extent of mineable Lower Bakerstown coal of the Conemaugh Group.

Figure 13.—Extent of Mettiki mines at the beginning and end of the study period.

STREAM CHARACTERISTICS

Components of Streamflow

Streamflow is derived from several sources—direct precipitation onto the stream channel; overland flow, which reaches a channel without having infiltrated into the ground; interflow, which infiltrates into the ground and moves laterally through the soil without having reached the ground-water body; and ground-water (base) flow, the slowest moving portion of contributing flow, which enters the stream channel if the channel intersects a ground-water body having a hydraulic gradient toward the stream.

In Garrett County, precipitation is generally abundant throughout the year and major contributions to streamflow come from small areas adjacent to the lower-order streams. Saturated conditions are maintained in these areas by frequent precipitation, so excess moisture cannot infiltrate during storms but flows over the surface toward the stream channel. Rain falling on areas distant from stream channels primarily replenishes soil moisture but, if of sufficient quantity, percolates downward to the zone of saturation. Overland flow is more extensive in winter when frozen ground prevents infiltration. Infiltration characteristics have been altered in areas that were strip mined and depend upon the degree of compaction and reworking of the spoil material.

The natural streamflow components have been modified in the study area. Laurel Run and the North Fork receive water discharged from abandoned coal mines (fig. 2). These discharges may be considered additions to base flow because they involve the main ground-water system and flow rather consistently. The mine voids do, however, act as conduits and allow more rapid flow than do the natural geological materials. Laurel Run and the South Fork receive discharge of treated mine water, and coal-treatment process water is removed from the South Fork. Water is lost through evaporation during this process, and also is used for dust control of coal loaded on railroad cars. Water that drains off the coal piles is piped to the AMD treatment plant. These contributions and withdrawals modify the shape of the natural hydrograph.

Flow Characteristics

Occasional streamflow measurements began in June 1979. Gaging stations on the three main streams (fig. 2) began operation in the spring of 1980, as did measurements at other noninstrumented sites. Discharge hydrographs, precipitation, and mine pumpage records for the period May 1, 1980, to Sept. 30, 1981, are shown in figure 14. The low flows in January and July-August were not due to lack of precipitation. The low flows in January were due to storage of precipitation as snow cover, while those of July-August resulted from precipitation replenishing soil moisture that had been depleted by transpiration and evaporation.

Table 3 summarizes streamflow at the three gaging stations for the 1981 water year (Oct. 1, 1980, to Sept. 30, 1981). As discussed in the previous section, streamflows have been affected by mining operations, and routing of inputs and withdrawals needs to be considered for making interpretations of flow processes, streamflow statistics, and water chemistry. Inputs related to mining operations include approximately 4,000 to 5,000 gal/d (535 to 670 ft^3/d) of sewage from each mine's facility, and about 700,000 gal/d (90,000 ft^3/d) each from A and B Mine dewatering that are treated and discharged into the South Fork. Pumpage from the C Mine (about 700,000 gal/d, or 90,000 ft^3/d) is treated in a separate plant and discharged into Chestnut Ridge Run, a tributary of Laurel Run (David Thomas, Environmental Coordinator of Mettiki Coal Corp., oral commun., 1981). Mine pumpage is reported monthly (fig. 14), but pumpage may vary considerably from day to day.

Table 3.—Summary of streamflow in North Fork, South Fork, and Laurel Run, for water year 1981

Station	Highest daily mean		Lowest daily mean		Annual mean		Annual runoff
	ft^3/s	$(ft^3/s)mi^2$	ft^3/s	$(ft^3/s)mi^2$	ft^3/s	$(ft^3/s)mi^2$	in./yr
North Fork	47	24.6	0.32	0.168	4.79	2.51	33.7
South Fork	52	33.5	.02	.013	3.7	2.4	33*
Laurel Run	260	31.6	3.4	.413	26.4	3.21	43.1

*Estimated; record incomplete.

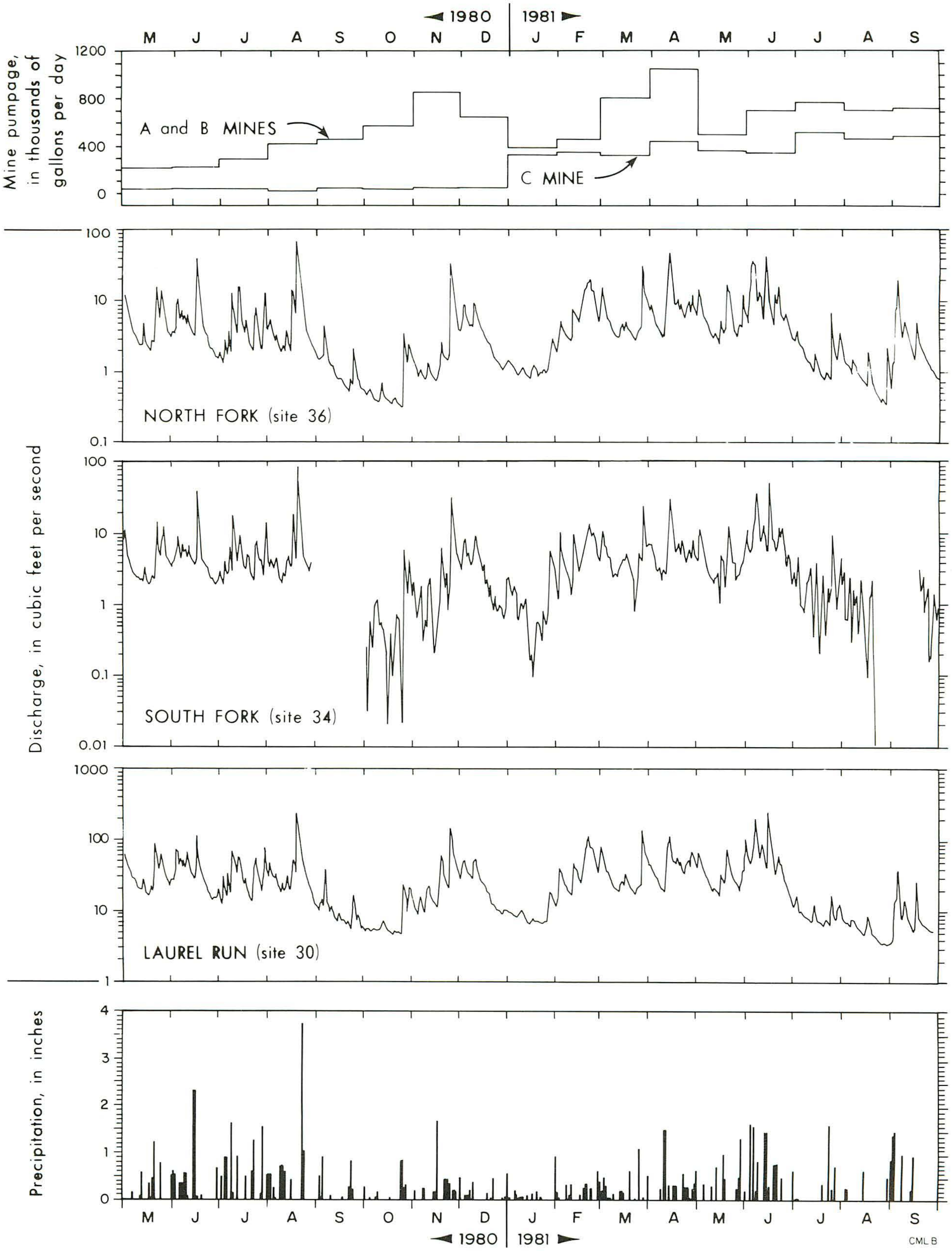


Figure 14.—Mine pumpage, stream discharge, and precipitation for the period May 1, 1980, to September 30, 1981.

Monthly discharge values are shown for the period May 1, 1980, to September 30, 1981, in table 4. The lowest 7-consecutive-day low flows for the same period are shown in table 5. Flow modifications in the study area are too great to allow accurate estimation of recurrence intervals; therefore, only the flows measured during the period of the study are presented. Figure 15 indicates the percentage of daily mean discharges for the period May 1, 1980, to September 30, 1981, that equaled or exceeded the indicated flow, and does not imply the recurrence interval of flow.

Flow was measured periodically at five additional sites to help determine tributary contributions to total discharge measured at the gaging stations. Figure 16 shows flows at upstream and tributary sites related to flows at the gaging stations. These relationships should be linear, under natural circumstances, because the tributary or upstream site represents a constant fraction

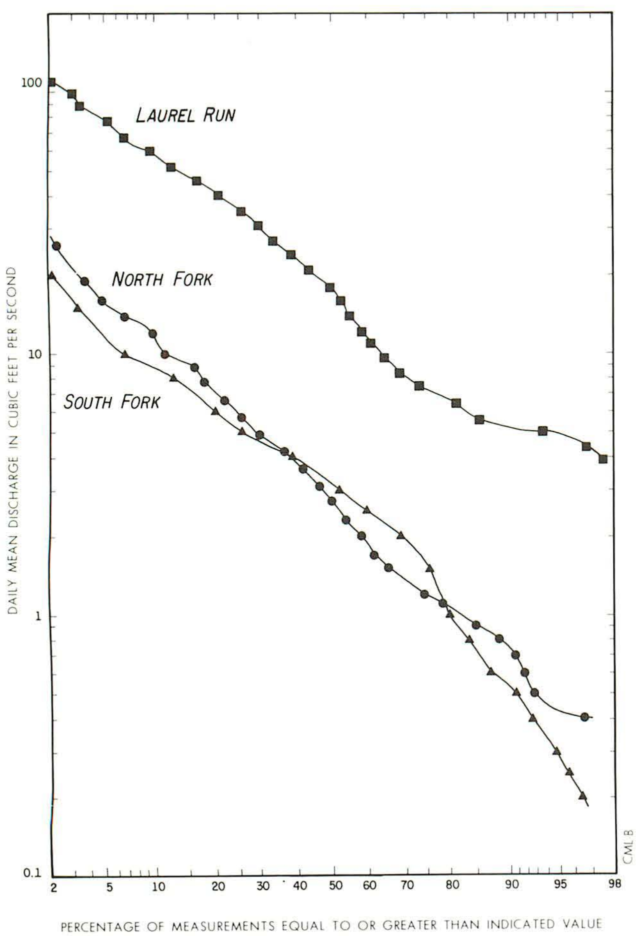


Figure 15.—Flow frequencies of North Fork, South Fork, and Laurel Run for the period May 1, 1980, to September 30, 1981.

Table 4.—Monthly mean discharge at North Fork, South Fork, and Laurel Run

Date	Discharge, in cubic feet per second		
	North Fork	South Fork	Laurel Run
1980			
May	5.31	4.12	32.4
June	6.12	5.30	37.2
July	5.26	4.96	32.3
August	7.91	7.15	40.2
September	1.14	(1)	9.66
October	.82	.97	7.90
November	3.77	3.41	28.8
December	3.79	3.25	24.4
1981			
January	1.18	1.26	8.85
February	7.14	5.90	44.5
March	6.50	5.10	36.1
April	9.54	6.69	44.8
May	5.81	4.57	34.8
June	12.7	10.1	62.8
July	1.91	2.11	8.72
August	.92	(1)	5.14
September	3.42	(1)	9.56

[1]Record incomplete for these months.

of the drainage basin. The deviation from linearity between the South Fork sites is probably due to additions of treated mine-drainage water and withdrawals from the makeup water pond located between the two sites.

Stream-Seepage Investigation

Seepage measurements were made during low-flow conditions on November 5-6, 1980; June 30-July 1, 1981; and August 12-13, 1981. During the first run, streamflow measurements were made at 18 sites (8 in the Sand Run basin and 10 in the Laurel Run basin). For subsequent runs, two sites were added to the Sand Run basin and three were added to the Laurel Run basin. The second run was interrupted by heavy rain (0.63 in. on July 1, 1981), so all 23 sites were measured again on August 12-13, 1981. Temperature, specific conductance, pH, and dissolved oxygen were measured at all sites, and samples for field alkalinity and laboratory analyses were obtained from several sites.

Streamflow and water-quality data from the three seepage runs are shown in table 6. Site locations and values of discharge, pH, and specific conductance measured during the November 1980 and August 1981

Table 5.—Lowest 7-day flows at North Fork, South Fork, and Laurel Run, May 1, 1980, to September 30, 1981

Station	Discharge (ft^3/s)	Discharge/ basin area [$(ft^3/s)/mi^2$]	Period
North Fork	0.37	0.193	10/18/81 — 10/24/81
South Fork*	.20	.130	10/13/81 — 10/19/81
Laurel Run	3.50	.425	8/24/81 — 8/30/81

*Record missing for period August 21, 1981, to September 16, 1981; also August 24, 1980, to August 31, 1980.

investigations are shown in figure 17. Drainage areas (totals and increments) are included in the tables. In some cases, however, streamflow includes mine drainage or treated wastewater discharge which is derived in whole or in part from outside the drainage basin of that stream. The first and third runs show a losing reach above the gage on the South Fork (site I), with the August 1981 loss being quite substantial. During the June 30, 1981, run, a release from the AMD treatment plant, located upstream of site H, was included in the discharge measurements at sites H and I. During the August 12, 1981, run, the plant released treated water after site I was measured, but before site H was measured, accounting for the apparent large loss between those sites. If site H is not considered for the August 12 run, a small but positive gain occurred between sites G and I.

Treated AMD is discharged into the South Fork above the makeup water pond from which water is withdrawn to wash coal, mix a latex spray for the coal loaded on the train, and for other purposes, such as watering revegetated areas. Lack of detailed metering of these preclude accurate seepage determinations along this reach. Although seepage losses were clearly not evident during the seepage runs, the level of water in well FB 25 (about 5 ft below the stream level) and the elevated sulfate content of the well water suggest that the South Fork may, at times, be losing water between stations H and J.

The reach between sites T and U and U and V on Laurel Run also showed losses for the August 1981 run. About 2,000 ft of Laurel Run above site U had been undermined (main and side headings — no pillars removed) and mine headings approached within several hundred feet below the reach from U to V since the November 1980 seepage run. Nearby Chestnut Ridge Run may also have lost water through its bed, but it receives treated AMD from the C Mine, which may overshadow seepage losses.

Discharge into Laurel Run from the Kempton Mine at site L was the same (1.34 ft^3/s) for the November 1980 and the August 1981 runs, even though streamflow was considerably less in August. This suggests a uniform discharge from the abandoned Kempton mine. Hollyday and McKenzie (1973) measured a discharge of 3.7 ft^3/s in August 1970 from another larger opening about 1,500 ft away. That site was inaccessible during this study.

Surface-Water Quality

Previous mining activities have had an impact on surface-water quality, and such impacts are most pronounced in Laurel Run. According to local residents, Laurel Run once supported trout (which are intolerant of low pH water); now, however, only the headwaters of the stream above the old strip-mined area and drainage from the Kempton Mine support fish. The input from the Kempton Mine discharge exerts a strong control on that stream's chemistry, as discussed below. The North Fork also receives drainage from an underground mine, but evidently this contribution is a smaller proportion of the stream's total flow, at least for most of the time. The South Fork receives treated AMD, averaging about 1 Mgal/d. Water is removed intermittently from the makeup water pond located just upstream from the gaging station. This water is used chiefly for processing the coal. Some is also used for mixing with latex for coal-dust control of loaded railroad cars and some is used for seeding the reclaimed areas in the summer. These withdrawals were not metered during the period of the study. At the lower end of Sand Run, just upstream of Wilson, runoff from the coal piles at the loading area of another coal company entered the stream. Efforts made to neutralize this runoff by spreading lime and soda briquettes where drainage concentrated were not adequate. Finally, in-

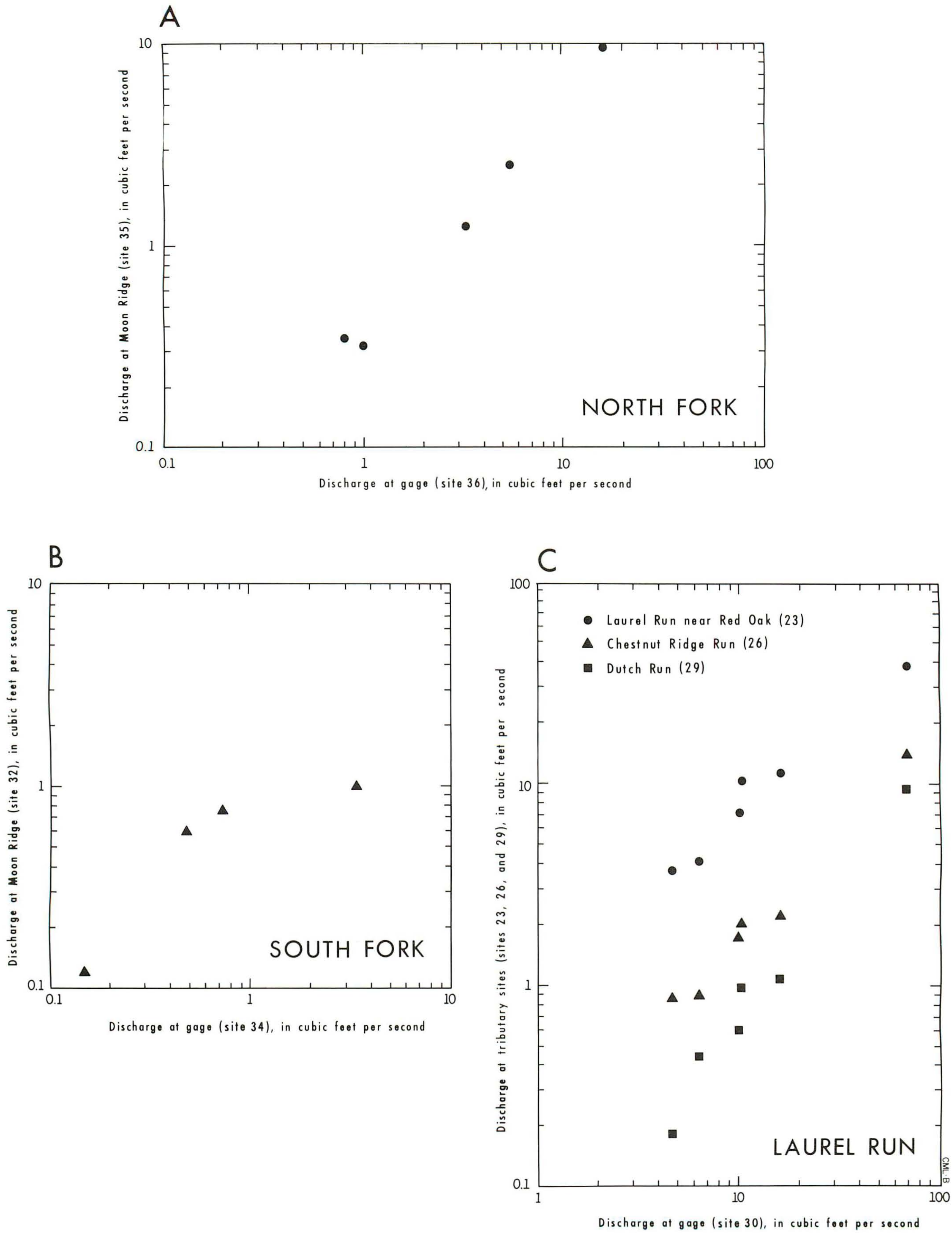


Figure 16.—Relation of streamflows at upstream and tributary sites to streamflows at the gaging stations.

Table 6.—Results of stream-seepage investigation.

Site	Stream	Total discharge Q (ft³/s)	Incremental discharge Q' (ft³/s)	Total drainage area A (mi²)	Incremental drainage area A' (mi²)	Ratios: Q/A [(ft³/s)/mi²]	Ratios: Q'/A' [(ft³/s)/mi²]	Ratios: Q'/mi of reach [(ft³/s)/mi]	Temperature, water (°C)	pH	Specific conductance (µmhos)	Oxygen, dissolved (mg/L)
	NOVEMBER 5, 1980											
A	North Fork upstream from Moon Ridge	0.26	0.26	0.53	0.53	0.49	0.49	--	7.3	5.1	56	9.8
B	North Fork at Moon Ridge	.32	.06	.96	.43	.33	.14	0.14	6.7	3.9	122	11.0
C	North Fork upstream from gage	.73	.41	1.66	.70	.44	.59	.43	5.8	5.7	211	10.4
D	North Fork near Wilson	1.77	1.04	1.91	.25	.93	4.16	2.74	6.1	6.3	185	11.0
E	Buffalo Coal Mine discharge	--	--	--	--	--	--	--	--	--	--	--
F	South Fork at Pole #15	.09	.09	.58	.58	.16	.16	--	6.2	6.9	487	9.7
G	South Fork at Moon Ridge	.59	.50	.91	.33	.65	1.52	.83	5.7	6.9	315	9.7
H	South Fork between AMD and pond	--	--	--	--	--	--	--	--	--	--	--
I	South Fork near Wilson	.48	-.11	1.55	.64	.30	-.17	-.16	6.3	6.9	620	9.2
J	Sand Run at Wilson	2.63	1.69	3.94	.48	.67	3.52	--	5.7	6.9	447	9.9
	NOVEMBER 6, 1980											
K	Laurel Run, Kempton strip mine area	--	--	--	--	--	--	--	--	--	--	--
L	Kempton Mine discharge	1.34	1.34	--	--	--	--	--	10.2	3.1	862	0.7
M	Tributary to left bank, Laurel Run	.23	.23	.34	.34	.68	.68	--	4.1	5.9	23	10.5
N	Tributary to right bank, Laurel Run	.14	.14	.15	.15	.93	.93	--	4.9	5.6	20	10.5
O	Chestnut Ridge Run near Red Oak	1.68	1.68	1.98	1.98	.85	.85	--	4.0	5.9	168	10.5
P	2nd. tributary to right bank, Laurel Run	--	--	--	--	--	--	--	--	--	--	--
Q	Dutch Run near Red Oak	.60	.60	1.39	1.39	.43	.43	--	5.3	4.9	120	10.3
R	Dutch Run at confluence, Laurel Run	.88	.28	1.51	.12	.58	2.33	--	5.0	5.4	109	10.9
S	Laurel Run headwaters, downstream from Site L	.31	.31	.32	.32	.97	.97	--	5.6	6.2	32	10.2
T	Laurel Run, near Mettiki boundary	--	--	--	--	--	--	--	--	--	--	--
U	Laurel Run near Red Oak	7.08	5.06	3.31	2.50	2.14	2.02	2.42	2.2	3.1	541	11.4
V	Laurel Run at Dobbin Road	10.2	.56	8.23	3.15	1.24	.18	.37	4.0	3.0	406	11.6
W	Laurel Run, near confluence of North Branch Potomac River	10.9	.7	8.87	.64	1.23	1.09	.62	3.7	2.9	388	12.7
	JUNE 30, 1981											
A	North Fork upstream from Moon Ridge	1.03	1.03	.53	.53	1.94	1.94	--	18.0	4.1	32	8.2
B	North Fork at Moon Ridge	1.26	.23	.96	.43	1.31	.53	.53	19.6	--	56	7.0
C	North Fork upstream from gage	3.16	1.90	1.66	.70	1.14	2.71	1.86	18.0	5.4	144	7.9
D	North Fork near Wilson	3.33	.17	1.91	.25	1.74	.68	.44	15.5	5.1	133	8.1
E	Buffalo Coal Mine discharge	.13	.13	--	--	--	--	--	--	--	--	--
F	South Fork at Pole #15	.62	.62	.58	.58	1.07	1.07	--	19.3	6.4	235	8.1
G	South Fork at Moon Ridge	.99	.37	.91	.33	1.09	1.12	.62	17.0	6.7	206	8.4
H	South Fork between AMD and pond	2.67*	1.68	--	--	--	--	--	19.4	6.5	924	8.4
I	South Fork near Wilson	3.38	.71	1.55	.21	2.18	3.38	1.73	18.9	6.6	570	8.4
J	Sand Run at Wilson	7.01	.30	3.94	.48	1.78	.63	--	17.8	7.8	405	8.6

* AMD Plant release

Table 6.—Results of stream-seepage investigation—Continued.

Site	Stream	Total discharge Q (ft^3/s)	Incremental discharge Q' (ft^3/s)	Total drainage area A (mi^2)	Incremental drainage area A' (mi^2)	Ratios: Q/A [(ft^3/s)/mi^2]	Ratios: Q'/A' [(ft^3/s)/mi^2]	Ratios: Q'/mi of reach [(ft^3/s)/mi]	Temperature, water (°C)	pH	Specific conductance (µmhos)	Oxygen, dissolved (mg/L)
	JULY 1, 1981											
	Discontinued because of rain											
O	Chestnut Ridge Run near Red Oak	2.0	2.0	1.98	1.98	1.01	1.01	--	15.2	5.7	178	8.2
P	2nd. tributary to right bank, Laurel Run	0.25	0.25	0.51	0.51	--	--	--	15.1	4.9	16	--
Q	Dutch Run near Red Oak	.96	.96	1.39	1.39	0.69	0.69	--	18.2	5.3	127	7.2
R	Dutch Run at confluence, Laurel Run	1.12	.16	1.51	.12	.74	1.33	--	18.2	5.0	97	--
U	Laurel Run near Red Oak	10.4	--	3.31	--	3.14	--	--	14.2	2.6	731	8.8
V	Laurel Run near Dobbin Road	10.4	--	8.23	--	1.27	--	--	15.5	2.8	568	8.8
W	Laurel Run, near confluence of North Branch Potomac River	13.7	3.3	8.87	.64	1.54	5.16	--	16.8	2.6	533	--
	AUGUST 12, 1981											
A	North Fork upstream from Moon Ridge	.03	.03	.53	.53	.057	.057	--	19.3	5.9	31	4.1
B	North Fork at Moon Ridge	.35	.32	.96	.43	.365	.744	0.74	20.2	6.5	46	8.1
C	North Fork upstream from gage	.42	.07	1.66	.70	.253	.100	.07	21.8	5.7	227	7.6
D	North Fork near Wilson	.80	.38	1.91	.25	.419	1.520	1.31	19.1	6.0	165	8.3
E	Buffalo Coal Mine discharge	.00	.00	--	--	--	--	--	--	--	--	--
F	South Fork at Pole #15	.12	.12	.58	.58	.207	.207	--	18.8	5.3	847	7.4
G	South Fork at Moon Ridge	.12	.00	.91	.33	.132	.000	0	19.8	6.8	678	9.5
H	South Fork between AMD and pond	2.58*	2.46	--	--	--	--	--	21.6	7.3	1,211	8.4
I	South Fork near Wilson	.15	.03	1.55	.64	.097	.05	-5.85	21.3	6.0	959	6.6
J	Sand Run at Wilson	1.22	.27	3.94	.48	.310	.56	--	19.3	7.1	535	8.6
	AUGUST 13, 1981											
K	Laurel Run, Kempton strip mine area	.10	.10	.82	.82	--	--	--	15.7	3.5	148	8.6
L	Kempton Mine discharge	1.34	1.34	--	--	--	--	--	10.3	3.8	773	0.5
M	Tributary to left bank, Laurel Run	.04	.04	.34	.34	.118	.118	--	15.2	5.7	21	8.3
N	Tributary to right bank, Laurel Run	.01	.01	.15	.15	.067	.067	--	--	--	--	--
O	Chestnut Ridge Run near Red Oak	.85	.85	1.98	1.98	.429	.429	--	20.2	4.0	780	11.8
P	2nd. tributary to right bank, Laurel Run	.05	.05	.51	.51	--	--	--	16.4	5.9	23	7.5
Q	Dutch Run near Red Oak	.18	.18	1.39	1.39	.129	.129	--	20.7	5.6	135	6.0
R	Dutch Run at confluence, Laurel Run	.26	.08	1.51	.12	.172	.667	--	18.4	5.9	128	5.6
S	Laurel Run headwaters, downstream from Site L	.03	.03	.32	.32	.094	.094	--	16.8	6.7	71	8.9
T	Laurel Run, near Mettiki boundary	4.01	--	2.33	1.21	--	--	2.31	18.9	2.7	926	8.6
U	Laurel Run near Red Oak	3.67	-.39	3.31	.42	1.109	--	-.39	18.6	2.4	1,001	7.1
V	Laurel Run at Dobbin Road	4.67	-1.16	8.23	1.43	.567	--	-.76	18.3	2.6	872	9.0
W	Laurel Run, near confluence of North Branch Potomac River	5.39	.72	8.87	.64	.608	1.125	.64	18.0	4.3	836	8.7

* AMD Plant release

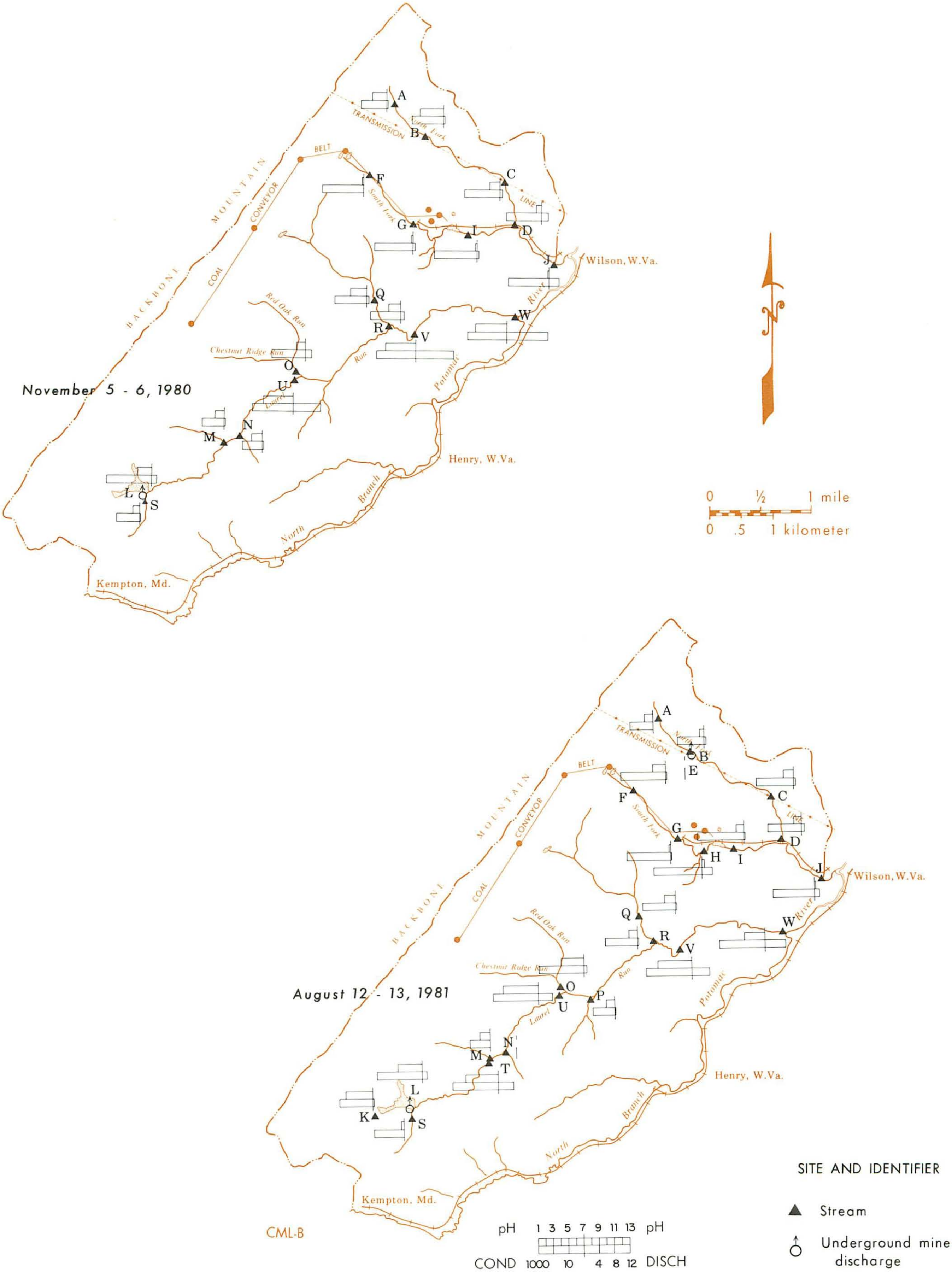


Figure 17.—pH, specific conductance, and discharge at the seepage-investigation sites.

Table 7.—Summary of surface-water quality at gaged and ungaged sites in the study area. [Numbers following the station location refer to location on figure 2]

	NUMBER OF SAMPLES	MAXIMUM	MINIMUM	MEDIAN	MEAN
LAUREL RUN NEAR RED OAK, MARYLAND (Site 23)					
pH	6	3.1	2.6	3.1	--
Specific conductance (μmhos)	6	915	297	652	631
Alkalinity field (mg/L as $CaCO_3$)	0	--	--	--	--
Acidity (mg/L as $CaCO_3$)	5	159	74	104	108
Solids, sum of constituents (dissolved)	6	397	139	285	279
Turbidity (Nephelometric Turbidity Units)	1	6	6	6	6
Calcium, dissolved (mg/L as Ca)	6	41	14	29	28.6
Magnesium, dissolved (mg/l as Mg)	6	17	5.9	11.5	11.8
Sodium, dissolved (mg/L as Na)	6	5	1.4	3.1	3.1
Potassium, dissolved (mg/l as K)	6	2.6	1.1	1.9	1.9
Iron, dissolved (mg/L as Fe)	6	12	7.2	10.5	10.2
Aluminum, dissolved (μg/L as Al)	0	--	--	--	--
Manganese, dissolved (mg/L as Mn)	6	1.6	0.57	1.2	1.2
Sulfate, dissolved (mg/L as SO_4)	6	290	91	200	199
Chloride, dissolved (mg/L as Cl)	6	2	.8	1.8	1.6
Oxygen, dissolved (mg/L)	3	23	8.8	10.3	14
Silica, dissolved (mg/L as SiO_2)	6	25	11	19	18.7
Nitrogen, $NO_2 + NO_3$, dissolved (mg/L as N)	6	1.1	.04	0.22	.33
CHESTNUT RIDGE RUN NEAR RED OAK, MARYLAND (Site 26)					
pH	7	6.9	4.0	5.7	--
Specific conductance (μmhos)	6	540	78	162.5	208.5
Alkalinity field (mg/L as $CaCO_3$)	1	8	8	8	8
Acidity (mg/L as $CaCO_3$)	6	10	5	5	5.8
Solids, sum of constituents (dissolved)	6	364	53	102.5	134.8
Turbidity (Nephelometric Turbidity Units)	1	8.1	8.1	8.1	8.1
Calcium, dissolved (mg/L as Ca)	6	73	8.5	18.5	25.4
Magnesium, dissolved (mg/L as Mg)	6	15	2.6	4.5	4.6
Sodium, dissolved (mg/L as Na)	6	7.3	0.8	2.2	2.7
Potassium, dissolved (mg/L as K)	6	3.6	.8	1.3	1.6
Iron, dissolved (mg/L as Fe)	6	0.22	.09	0.16	0.16
Aluminum, dissolved (μg/L as Al)	0	--	--	--	--
Manganese, dissolved (mg/L as Mn)	6	1.4	.31	.48	.59
Sulfate, dissolved (mg/L as SO_4)	6	250	26	56.5	83.3
Chloride, dissolved (mg/L as Cl)	6	3.5	1.3	2	2.2
Oxygen, dissolved (mg/L)	4	12	7.6	10.6	10.2
Silica, dissolved (mg/L as SiO_2)	6	6.9	4.2	4.9	5.1
Nitrogen, $NO_2 + NO_3$, dissolved (mg/L as N)	6	1.3	.3	.6	.7
DUTCH RUN AT RED OAK, MARYLAND (Site 29)					
pH	6	6.4	4.5	5.1	--
Specific conductance (μmhos)	5	165	98	120	125
Alkalinity field (mg/L as $CaCO_3$)	0	--	--	--	--
Acidity (mg/L as $CaCO_3$)	4	10	5	5	6
Solids, sum of constituents (dissolved)	4	102	67	73	79
Turbidity (Nephelometric Turbidity Units)	0	--	--	--	--
Calcium, dissolved (mg/L as Ca)	5	18	9.4	13	12.9
Magnesium, dissolved (mg/L as Mg)	5	4.8	2.9	3.8	3.8
Sodium, dissolved (mg/L as Na)	5	1.5	0.7	0.9	1.0
Potassium, dissolved (mg/L as K)	5	1.7	.8	.9	1.1
Iron, dissolved (mg/L as Fe)	5	1.3	.26	.85	0.78
Aluminum, dissolved (μg/L as Al)	0	--	--	--	--
Manganese, dissolved (mg/L as Mn)	5	1.3	.89	1.2	1.2
Sulfate, dissolved (mg/L as SO_4)	5	61	36	43	44.2
Chloride, dissolved (mg/L as Cl)	5	2.4	1.4	1.4	1.7
Oxygen, dissolved (mg/L)	5	10.3	5.4	6.0	7.1
Silica, dissolved (mg/L as SiO_2)	5	5.2	4.5	4.8	4.9
Nitrogen, $NO_2 + NO_3$, dissolved (mg/L as N)	5	0.9	.1	.3	.4

Table 7.—Summary of surface-water quality at gaged and ungaged sites in the study area—Continued.
[Numbers following the station location refer to location on figure 2]

	NUMBER OF SAMPLES	MAXIMUM	MINIMUM	MEDIAN	MEAN
LAUREL RUN AT DOBBIN ROAD NEAR WILSON, MARYLAND (Site 30)					
pH	21	3.8	2.4	3.0	--
Specific conductance (μmhos)	20	745	143	433	454.7
Alkalinity field (mg/L as $CaCO_3$)	9	16	0	1	2.3
Acidity (mg/L as $CaCO_3$)	18	149	10	70	69.6
Solids, sum of constituents (dissolved)	16	357	69	208.5	210.9
Turbidity (Nephelometric Turbidity Units)	11	19	.4	4.9	6.7
Calcium, dissolved (mg/L as Ca)	18	42	9.8	24	23.9
Magnesium, dissolved (mg/l as Mg)	18	14	3	8.4	8.6
Sodium, dissolved (mg/L as Na)	18	14	.8	2.2	3.0
Potassium, dissolved (mg/l as K)	18	2.5	.8	1.6	1.5
Iron, dissolved (mg/L as Fe)	19	11	1.6	5	5.3
Aluminum, dissolved (μg/L as Al)	5	6,900	1,700	5,100	5,040
Manganese, dissolved (mg/L as Mn)	20	1.4	.47	0.97	0.97
Sulfate, dissolved (mg/L as SO_4)	20	250	42	145	146.2
Chloride, dissolved (mg/L as Cl)	17	3.8	.9	1.6	1.7
Oxygen, dissolved (mg/L)	16	12.3	4.9	9.9	9.9
Silica, dissolved (mg/L as SiO_2)	18	20	5.3	13	13.4
Nitrogen, NO_2 + NO_3, dissolved (mg/L as N)	14	1.1	.16	.32	.38
NORTH BRANCH POTOMAC RIVER AT WILSON, MARYLAND (Site 31)					
pH	7	4.8	3.5	4.4	--
Specific conductance (μmhos)	7	2,000	189	588	772
Alkalinity field (mg/L as $CaCO_3$)	5	2	0	0	0.4
Acidity (mg/L as $CaCO_3$)	6	41	5	23.1	23.2
Solids, sum of constituents (dissolved)	1	110	110	110	110
Turbidity (Nephelometric Turbidity Units)	0	--	--	--	--
Calcium, dissolved (mg/L as Ca)	1	28	28	28	28
Magnesium, dissolved (mg/L as Mg)	1	3	3	3	3
Sodium, dissolved (mg/L as Na)	1	1.1	1.1	1.1	1.1
Potassium, dissolved (mg/L as K)	1	0.9	.9	.9	.9
Iron, dissolved (mg/L as Fe)	7	2	.18	.87	.90
Aluminum, dissolved (μg/L as Al)	0	--	--	--	--
Manganese, dissolved (mg/L as Mn)	7	.86	.24	.50	.52
Sulfate, dissolved (mg/L as SO_4)	7	800	68	240	325.4
Chloride, dissolved (mg/L as Cl)	1	.9	.9	.9	.9
Oxygen, dissolved (mg/L)	7	12.5	7.7	9.1	9.8
Silica, dissolved (mg/L as SiO_2)	1	4.1	4.1	4.1	4.1
Nitrogen, NO_2 + NO_3, dissolved (mg/L as N)	1	.47	.47	.47	.47
SOUTH FORK AT MOON RIDGE, MARYLAND (Site 32)					
pH	5	7.0	6.3	6.8	--
Specific conductance (μmhos)	4	678	183	261	346
Alkalinity field (mg/L as $CaCO_3$)	0	--	--	--	--
Acidity (mg/L as $CaCO_3$)	2	5	0	2.5	2.5
Solids, sum of constituents (dissolved)	4	457	111	158	221
Turbidity (Nephelometric Turbidity Units)	0	--	--	--	--
Calcium, dissolved (mg/L as Ca)	4	71	21	28.5	37.3
Magnesium, dissolved (mg/L as Mg)	4	14	4	4.9	6.9
Sodium, dissolved (mg/L as Na)	4	48	3.1	17.1	21.3
Potassium, dissolved (mg/L as K)	4	3	1.1	1.7	1.9
Iron, dissolved (mg/L as Fe)	4	0.18	.06	0.11	0.12
Aluminum, dissolved (μg/L as Al)	0	--	--	--	--
Manganese, dissolved (mg/L as Mn)	4	1.7	.12	.16	.54
Sulfate, dissolved (mg/L as SO_4)	4	300	56	82.5	130.3
Chloride, dissolved (mg/L as Cl)	4	2.2	1.1	1.7	1.7
Oxygen, dissolved (mg/L)	3	9.7	8.4	9.5	9.2
Silica, dissolved (mg/L as SiO_2)	4	7.4	3.7	4.4	5.0
Nitrogen, NO_2 + NO_3, dissolved (mg/L as N)	4	.59	.34	.47	.47

Table 7.—Summary of surface-water quality at gaged and ungaged sites in the study area—Continued.
[Numbers following the station location refer to location on figure 2]

	NUMBER OF SAMPLES	MAXIMUM	MINIMUM	MEDIAN	MEAN
SOUTH FORK NEAR WILSON, MARYLAND (Site 34)					
pH	17	7.1	4.2	6.5	--
Specific conductance (µmhos)	16	959	125	452.5	442.1
Alkalinity field (mg/L as $CaCO_3$)	8	28	0	17.1	15.1
Acidity (mg/L as $CaCO_3$)	12	20	0	5	7.9
Solids, sum of constituents (dissolved)	15	683	65	373	296.4
Turbidity (Nephelometric Turbidity Units)	10	45	.6	2.0	10.1
Calcium, dissolved (mg/L as Ca)	15	170	13	81	70.5
Magnesium, dissolved (mg/l as Mg)	15	20	2.1	9.5	8.5
Sodium, dissolved (mg/L as Na)	15	25	.5	4.6	6.8
Potassium, dissolved (mg/l as K)	15	4.2	.9	2.4	2.4
Iron, dissolved (mg/L as Fe)	17	0.70	.00	0.03	0.12
Aluminum, dissolved (µg/L as Al)	5	1,000	0.00	50	236
Manganese, dissolved (mg/L as Mn)	17	2.4	.04	.62	.71
Sulfate, dissolved (mg/L as SO_4)	17	470	40	250	191.2
Chloride, dissolved (mg/L as Cl)	15	4.9	1.2	2.6	2.6
Oxygen, dissolved (mg/L)	13	12.7	7.9	9.5	9.8
Silica, dissolved (mg/L as SiO_2)	15	7.5	3.1	4.5	4.6
Nitrogen, NO_2 + NO_3, dissolved (mg/L as N)	11	.92	.20	.39	.45
NORTH FORK AT MOON RIDGE, MARYLAND (Site 35)					
pH	5	6.8	3.4	3.9	--
Specific conductance (µmhos)	5	122	46	83	80
Alkalinity field (mg/L as $CaCO_3$)	0	--	--	--	--
Acidity (mg/L as $CaCO_3$)	3	25	15	15	18.3
Solids, sum of constituents (dissolved)	4	72	39	55	55
Turbidity (Nephelometric Turbidity Units)	0	--	--	--	--
Calcium, dissolved (mg/L as Ca)	4	9.4	6.4	7.0	7.4
Magnesium, dissolved (mg/L as Mg)	4	3.1	1.9	2.3	2.4
Sodium, dissolved (mg/L as Na)	4	0.9	0.4	0.5	0.6
Potassium, dissolved (mg/L as K)	4	1.4	.5	.8	.9
Iron, dissolved (mg/L as Fe)	5	.16	.00	.53	.66
Aluminum, dissolved (µg/L as Al)	0	--	--	--	--
Manganese, dissolved (mg/L as Mn)	5	1.3	.48	.64	.73
Sulfate, dissolved (mg/L as SO_4)	6	280	21	34.5	73.5
Chloride, dissolved (mg/L as Cl)	5	2.6	0.7	1	1.3
Oxygen, dissolved (mg/L)	3	11	7.0	9.2	9.1
Silica, dissolved (mg/L as SiO_2)	4	5.6	4.1	4.7	4.8
Nitrogen, NO_2 + NO_3, dissolved (mg/L as N)	5	.98	.11	.31	.42
NORTH FORK NEAR WILSON, MARYLAND (Site 36)					
pH	18	6.9	3.8	5.1	--
Specific conductance (µmhos)	17	547	53	139	160
Alkalinity field (mg/L as $CaCO_3$)	8	8	1	2.6	3.7
Acidity (mg/L as $CaCO_3$)	14	60	0	5	12.5
Solids, sum of constituents (dissolved)	15	332	37	83	102.3
Turbidity (Nephelometric Turbidity Units)	10	8.6	.8	3.1	3.7
Calcium, dissolved (mg/L as Ca)	15	68	5.4	17	19.5
Magnesium, dissolved (mg/L as Mg)	15	15	.8	3.8	4.6
Sodium, dissolved (mg/L as Na)	15	1.4	.6	0.9	1.0
Potassium, dissolved (mg/L as K)	15	2.1	.6	.9	1.0
Iron, dissolved (mg/L as Fe)	17	12	.11	.34	1.25
Aluminum, dissolved (µg/L as Al)	5	750	30	50	200
Manganese, dissolved (mg/L as Mn)	17	1.6	.28	.46	0.53
Sulfate, dissolved (mg/L as SO_4)	17	220	20	54	61.5
Chloride, dissolved (mg/L as Cl)	15	3.7	0.7	1.3	1.4
Oxygen, dissolved (mg/L)	12	12.6	7.9	9.5	9.9
Silica, dissolved (mg/L as SiO_2)	15	7.9	3.6	4.7	4.8
Nitrogen, NO_2 + NO_3, dissolved (mg/L as N)	13	0.97	0.2	.45	.49

Table 7.—Summary of surface-water quality at gaged and ungaged sites in the study area—Continued. [Numbers following the station location refer to location on figure 2]

	NUMBER OF SAMPLES	MAXIMUM	MINIMUM	MEDIAN	MEAN
SAND RUN AT WILSON, MARYLAND (Site 42)					
pH	7	7.8	4.2	6.3	--
Specific conductance (µmhos)	7	535	140	345	326
Alkalinity field (mg/L as $CaCO_3$)	3	6	0	1	2.3
Acidity (mg/L as $CaCO_3$)	4	30	5	10	13.8
Solids, sum of constituents (dissolved)	7	372	74	213	205.7
Turbidity (Nephelometric Turbidity Units)	0	--	--	--	--
Calcium, dissolved (mg/L as Ca)	7	89	13	46	44.1
Magnesium, dissolved (mg/l as Mg)	7	12	2.6	7.3	6.8
Sodium, dissolved (mg/L as Na)	7	17	.6	4.5	5.8
Potassium, dissolved (mg/l as K)	7	2.7	.8	1.7	1.6
Iron, dissolved (mg/L as Fe)	7	0.49	.01	0.14	0.21
Aluminum, dissolved (µg/L as Al)	0	--	--	--	--
Manganese, dissolved (mg/L as Mn)	7	.59	.32	.46	.46
Sulfate, dissolved (mg/L as SO_4)	7	240	45	130	131
Chloride, dissolved (mg/L as Cl)	7	2.8	1.2	1.5	1.7
Oxygen, dissolved (mg/L)	6	11.6	7.3	9.3	9.4
Silica, dissolved (mg/L as SiO_2)	7	5.7	3.7	4.6	4.8
Nitrogen, NO_2 + NO_3, dissolved (mg/L as N)	6	.58	.23	.45	.43

stallation of an anhydrous-ammonia treatment system brought the quality of discharge from this site under satisfactory control.

Samples for laboratory analyses were collected periodically at a number of sites. Field measurements were also made at these sites, and at some additional sites. The results are tabulated in appendix A; table 7 presents ranges and average values for some of the more important parameters. Multiple-parameter monitoring instruments at the three gaging stations provided hourly measurements of temperature and specific conductance. The temperature and specific conductance variations are shown in figure 18, which shows daily mean values. The conductivity values show much variation, but seem to peak in August. The relationship of conductivity and discharge varies from stream to stream (fig. 19). Conductivity appears to be least affected by discharge in the North Fork and most affected in Laurel Run. The apparent outlier in the North Fork data is likely due to acid mine drainage from the abandoned Buffalo Coal Company mine in the Lower Bakerstown seam (site FA 35). This site usually ceased flowing during periods of low flow in the North Fork. However, on the day of this particular measurement (Jan. 15, 1982), discharge from the abandoned mine may have constituted a more significant portion of the North Fork discharge perhaps because of subfreezing temperatures at that time. The abandoned mine drainage into Laurel Run also seems to affect the receiving stream, having greater effects during low flows (these drainage points do not cease flowing during dry periods) as suggested by what seems to be a break in slope in the Laurel Run data (fig. 19). Specific conductance seems to have a weaker relationship to discharge in the South Fork. This may be due to the effects of additions of treated AMD and modifications of streamflow, which cannot be accounted for quantitatively.

Laurel Run has the lowest pH values and the narrowest range despite large variations in discharge (fig. 20); it also has the highest values of acidity. The pH of Laurel Run is kept low by the addition of AMD from the abandoned Kempton Mine (GA 3 and GA 6). The South Fork pH measurements cover an approximately equal, although higher range. That range is extended by a single low measurement (4.2 on Sept. 17, 1981). This was the result of the release of mine drainage from the AMD treatment plant located upstream of the sampling site, which was out of operation that day; otherwise, the input of treated water maintained the pH above six units, regardless of discharge. The North Fork has the broadest range in pH, which may be influenced by discharges from the abandoned Buffalo Coal Mine (FA 35) at a point located on the west side of Table Rock Road at the powerline crossing. Water discharging from the abandoned mine is of low pH and high acidity; however, it ceases to flow during extended dry periods.

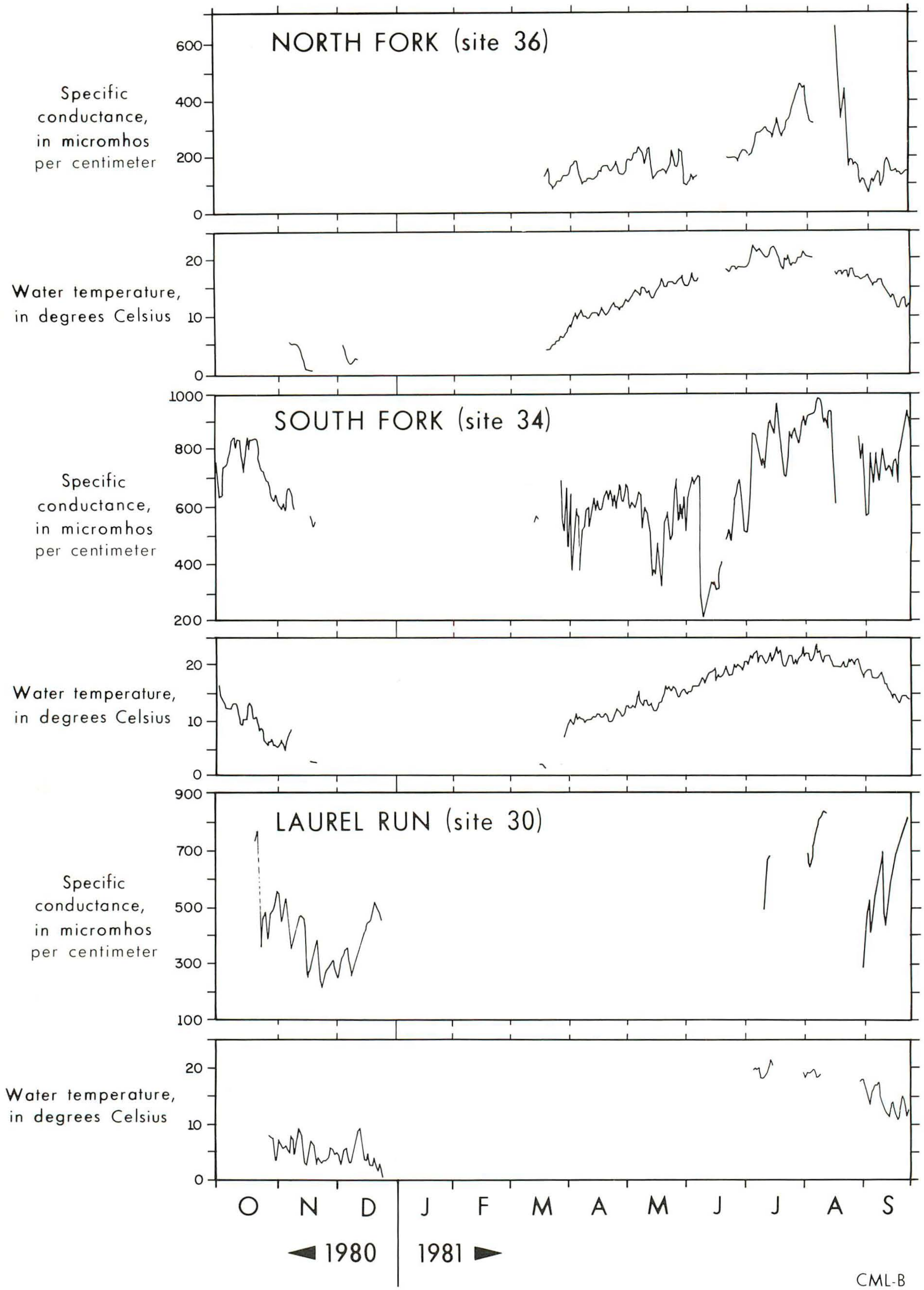


Figure 18.—Temperature and specific conductance of North Fork, South Fork, and Laurel Run.

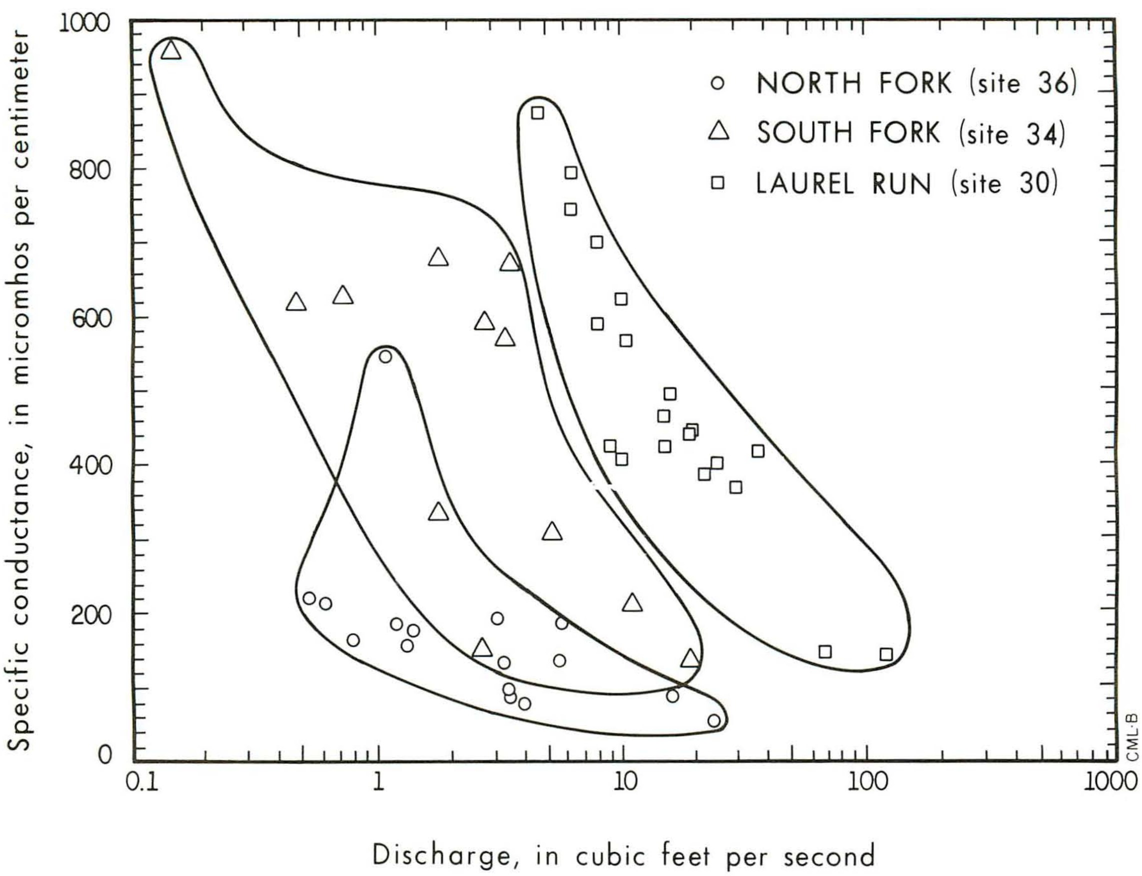


Figure 19.—Relationships of specific conductance and discharge in North Fork, South Fork, and Laurel Run.

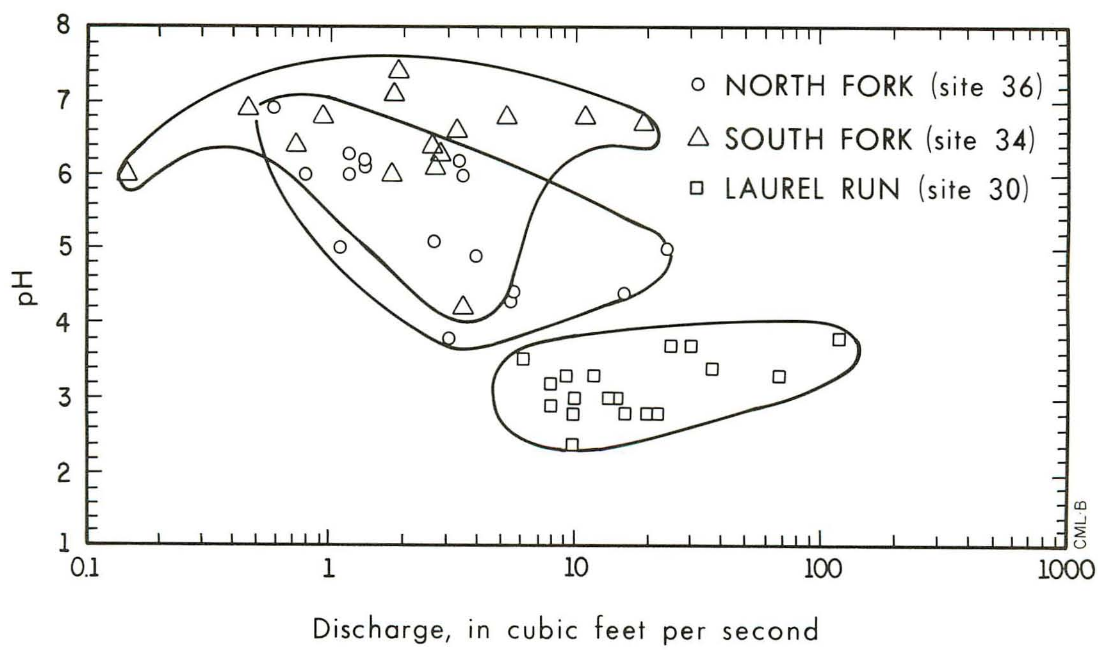


Figure 20.—Relationship of pH and discharge in North Fork, South Fork, and Laurel Run.

During such periods, a greater portion of the streamflow may be derived from less mineralized water from shallow ground-water flow systems, thereby accounting for the higher pH values.

The quality of water discharged to Maryland streams is regulated by the Maryland Department of Health and Mental Hygiene. Permit requirements vary, depending on site-specific conditions, but the pH of the receiving stream, in any case, must be between 6.5 and 8.5 (Maryland Department of Health and Mental Hygiene, Code of Maryland Regulations 10.50.01). The pH in the South Fork was maintained above 6 (except for a period when the AMD treatment plant was not operating). About 70 percent of the pH measurements in the North Fork were less than 6, and all of the measurements in Laurel Run were well below 6.

Dissolved sulfate is another indicator of acid mine drainage. The relationships between discharges and dissolved sulfate concentrations measured at the three gaging stations (fig. 21) are similar to the discharge-specific conductance relationships (fig. 19). Large quantities of sulfates in the North Fork and Laurel Run are due mainly to water draining from abandoned underground mines. The high sulfate concentrations in the South Fork probably are the result of leaching of precipitation through coal piles and coal waste along coal-transfer facilities leading to the coal-treatment plant, and from AMD. The discharge-dissolved sulfate relationship in the South Fork is not well defined probably because of the combined effects of discharge of treated water and withdrawal from the makeup water pond.

Less AMD will probably be discharged into streams without treatment by present operations than by past operations. Spoil from active subsurface mines is being distributed in abandoned strip mines, graded, and revegetated. Thus, water quality may improve, particularly with regard to suspended material, and sediment production may decrease as these areas are restored.

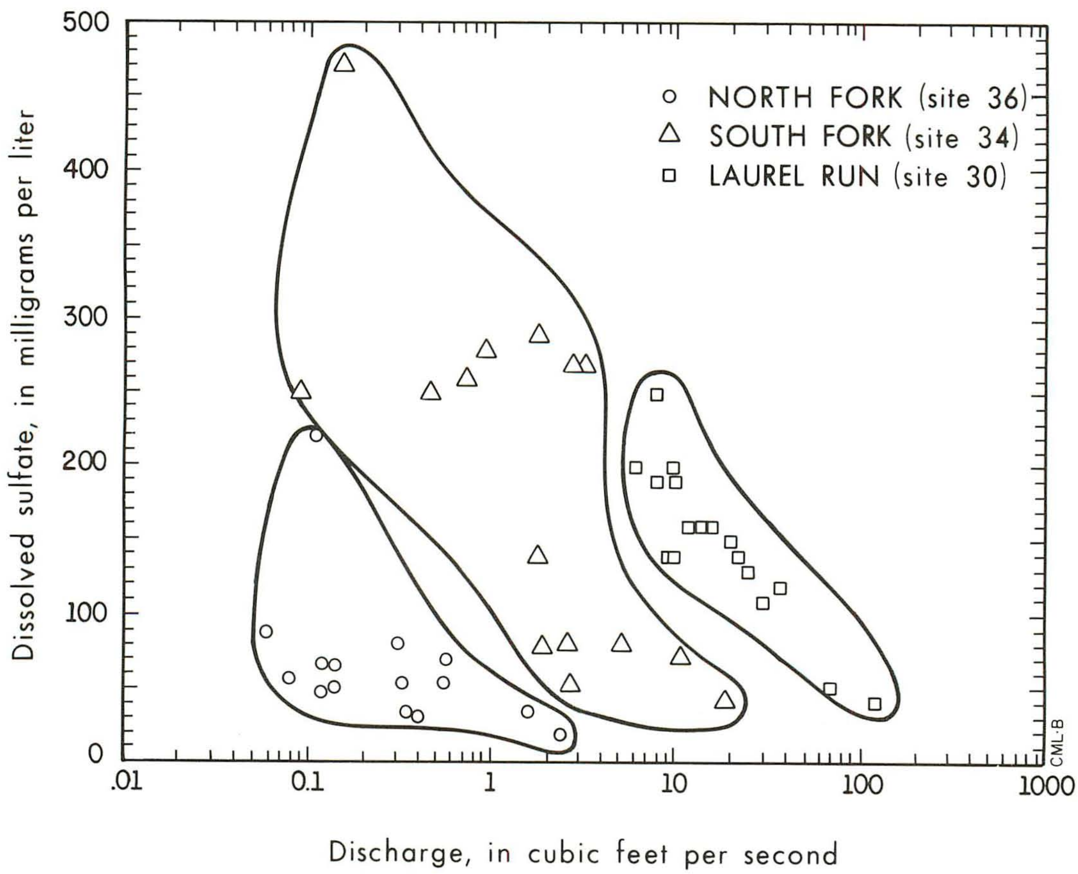


Figure 21.—Relationship of dissolved sulfate and discharge in North Fork, South Fork, and Laurel Run.

GROUND WATER

Observation-Well Network

Three clusters of wells were drilled in the study area to provide geologic and hydrologic data. Four wells were drilled at sites 1 and 2 and five wells were drilled at site 3. The sites were chosen to provide data across the syncline (within constraints imposed by property ownership and projected early mining). The three clusters of wells, the stream-gaging stations, and the precipitation gage (fig. 2) are located within the boundaries of the A Mine.

Each well in a cluster is open to a different zone (fig. 22). At each cluster, zone 1 is open just below the Upper Freeport coal; zone 2 is open above the Upper Freeport coal; zone 3 is open between the Brush Creek and Lower Bakerstown coal horizons, and zone 4 is open above the Harlem coal. Zone 5 at site 3 is open near land surface (from 22 to 85 ft). With the exception of the shallow zone at site 3, these zones are fairly extensive sandstone units. Four-inch-diameter casing (fig. 23) allows room for water-level recording equipment and for a testing and sampling pump. Several wells drilled for Mettiki, domestic wells, underground mine-discharge sites, and springs are included in the ground-water observation network (table 8).

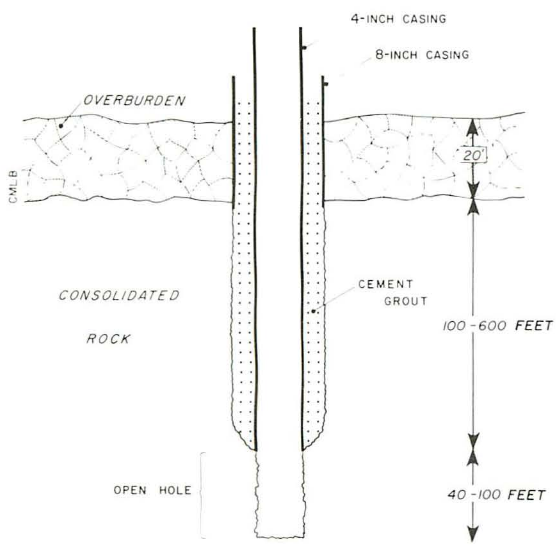


Figure 23.—Typical observation-well construction.

The 13 wells of the three clusters were drilled using air-rotary and, for some of the wells, diamond-bit coring drills. Descriptions of the cuttings and cores are included in appendix B. The cores, which were of the deeper segments of the wells, were mostly broken and, in places, crumbly. Much of this, especially involving shaly material, may have resulted from coring rather than the presence of natural fractures, because iron-staining or weathering was not evident on any of the broken core surfaces.

Geophysical logs were obtained for most of these wells and some of Mettiki's wells (table 9 and appendix B). The geophysical logs provide some information regarding the properties and extent of the ground-water system.

Water Levels

Water-level measurements began on Mettiki's observation wells in June 1978, and continuous recorders were installed on the 13 test wells between May and July 1980. Water levels in each well rose higher than the top of the open-hole zone. Well FA 36 flowed initially, but ceased by May 1981. Well FA 31 began to flow at about 780 ft below land surface and, at 1,131 ft below land surface, water rose inside the drill stem to about 8 ft above land surface. Water was simultaneously overflowing the top of the casing, indicating that the actual head was greater than 8 ft above land surface. The well was subsequently plugged back to 606 ft below land surface and stopped flowing.

Most of the springs (table 8) inventoried within the study area seem to be perched at the level of the Barton coal. One spring, FA 10, may be perched at the level of the Lower Bakerstown coal.

Ground water is discharged to the surface at three additional sites. Site FA 35 drains the abandoned Buffalo Coal Company Mine No. 1 (Lower Bakerstown coal); sites GA 3 and GA 6 drain the abandoned Kempton Mine (Upper Freeport coal).

At sites 1 and 2, the water level of the shallow zone is near or below the level of the nearby South Fork. If this water-bearing zone is the unconfined aquifer, it indicates that the South Fork is perched along a part of its length, and infiltration may occur along some reaches.

Water levels varied in each well at each site (fig. 24). Furthermore, the positions of the water levels of each zone relative to each other varied from site to site. The period of record (June 1980 to September 1981) is insufficient to characterize long-term conditions, but some important features can be noted.

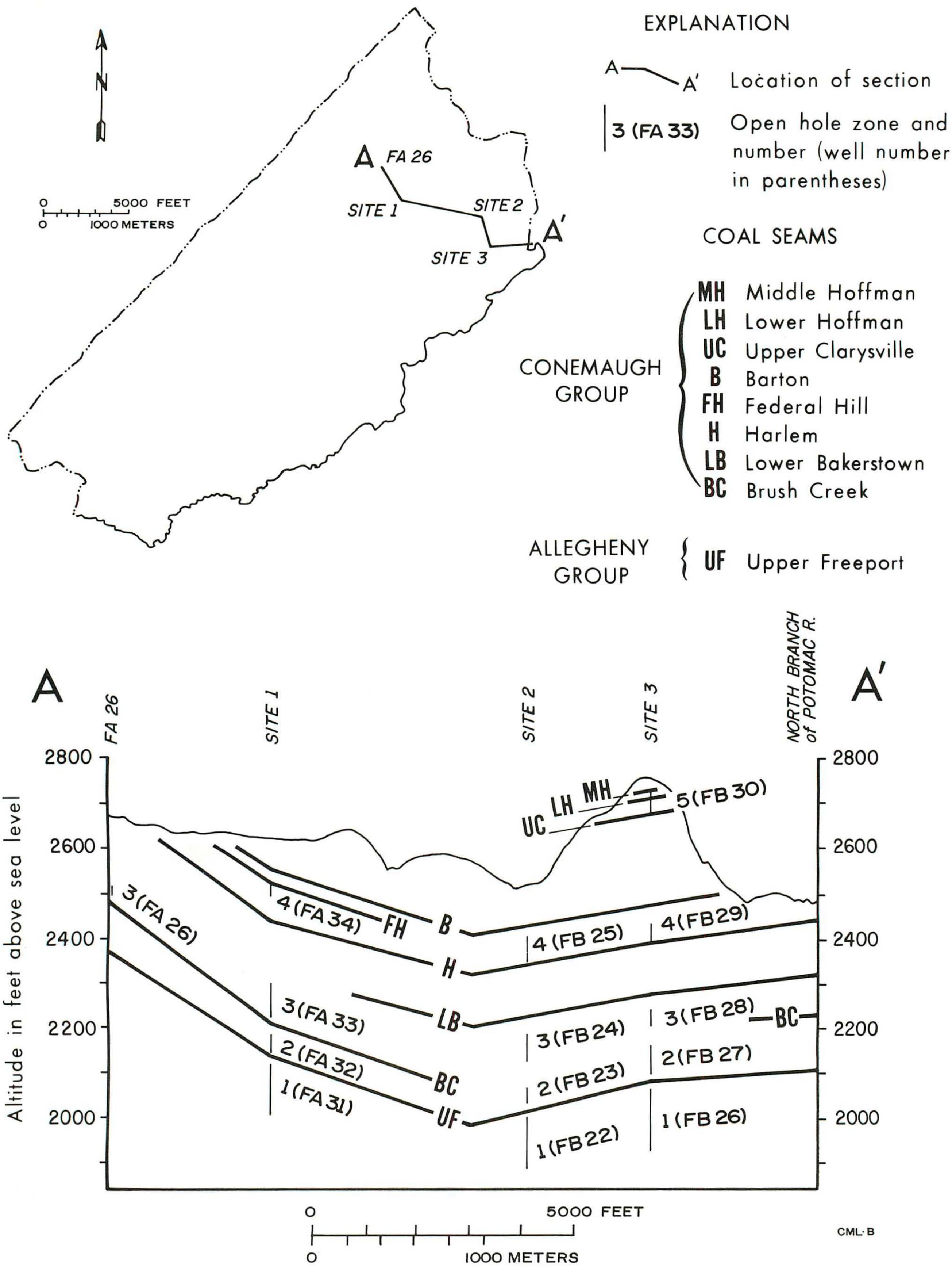


Figure 22.—Open-hole zones of wells and identification of coals.

Table 8.—Records of wells, underground mine-discharge sites, and springs in the study area, southwest Garrett County, Maryland.

Well No.	Owner	Altitude of land surface (ft)	Depth of well (ft)	Depth cased (ft)	Casing diameter (in)	Aquifer	Water level Depth (ft)	Water level Date measured	Drawdown (ft)	Discharge Rate (gal/min)	Discharge Date measured	Discharge Hours pumped	Specific capacity [(gal/min)/ft]	Use of well[1]
FA 20	Cooper, Charles	2,750	78	22	5	Conemaugh	28	6/17/73	12	8.0	6/17/73	2.0	0.7	H
FA 24	Mettiki Coal Co.	2,610	229	30	8	do.	170	11/23/77	59	30	11/23/77	.5	.5	N
FA 25	do.	2,673	315	304	6	do.	301	6/23/78	--	--	--	--	--	O
FA 26	do.	2,673	170	150	6	do.	16	6/23/78	--	--	--	--	--	O
FA 27	do.	2,860	215	190	6	do.	169	6/23/78	--	--	--	--	--	O
FA 28	do.	2,890	341	317	6	do.	105.50	6/23/78	--	--	--	--	--	O
FA 29	do.	2,890	226	203	6	do.	130.75	6/23/78	--	--	--	--	--	O
FA 30	do.	2,730	447	417	6	do.	440	5/20/78	7	50	5/20/78	--	7.1	N
FA 31	U.S. Geological Survey	2,618	606	470	4	Allegheny	11.54	10/09/80	107	2.0	3/11/81	.2	.02	O
FA 32	do.	2,618	473	430	4	Conemaugh	18.69	10/09/80	108	3.6	3/12/81	.4	--	O
FA 33	do.	2,618	391	318	4	do.	17.94	10/09/80	93	2.0	5/06/81	1.5	--	O
FA 34	do.	2,618	115	96	4	do.	16.15	10/09/80	2	6.0	5/07/81	2.0	3.6	O
FA 36	Mettiki Coal Co.	2,650	210	46	8	do.	-2	6/20/78	--	200	6/20/78	.5	--	O
FA 37	do.	2,780	253	40	8	do.	50	1/17/79	203	100	1/17/79	.5	.5	N
FA 38	Glofelty, Curtis	2,680	118	39	6	do.	31	10/10/79	87	7.0	10/10/79	1.0	.1	H
FB 22	U.S. Geological Survey	2,530	640	517	4	Allegheny	78.18	10/09/80	65	3.0	4/21/81	.3	.05	O
FB 23	do.	2,530	495	460	4	Conemaugh	19.70	10/09/80	54	2.0	4/22/81	.5	.04	O
FB 24	do.	2,530	400	340	4	do.	20.05	10/09/80	117	4.0	4/23/81	.4	.03	O
FB 25	do.	2,530	180	120	4	do.	29.07	10/09/80	5	7.5	4/24/81	1.5	1.4	O
FB 26	do.	2,755	832	687	4	Allegheny	269.33	10/09/80	--	--	--	--	--	O
FB 27	do.	2,755	656	590	4	Conemaugh	4.60	10/09/80	167	4.0	5/04/81	.6	.02	O
FB 28	do.	2,755	556	517	4	do.	216.09	10/09/80	--	--	--	--	--	O
FB 29	do.	2,755	360	316	4	do.	252.69	10/09/80	--	--	--	--	--	O
FB 30	do.	2,755	85	82	4	do.	32.47	10/09/80	8	6.3	5/05/81	2.3	.8	O

[1] H, domestic; N, industrial; O, observation.

UNDERGROUND MINE-DISCHARGE SITES

Site No.	Altitude of land surface (ft)	Discharge Rate (gal/min)	Discharge Date measured	Coal seam drained
FA 35	2,630	58	6/30/81	Lower Bakerstown.
GA 3	2,640	690	10/29/81	Upper Freeport.
GA 6	2,650	1,659	8/25/70	Do.

SPRINGS

Site No.	Owner	Discharge Rate (gal/min)	Discharge Date measured	Altitude of land surface (ft)	Aquifer	Improvements	Use of water
GA 1	Town of Kempton	750	7/00/50	2,860	Conemaugh	Spring house	Public supply.
GA 2	Lipsco, Berlinda	--	--	2,690	do.	Tile and rock basin	--
GA 4	Radeheaver, Paul	40	10/29/81	2,660	do.	Concrete basin	Domestic.
GA 5	--	5	10/29/81	2,660	do.	Pipe	Unused.

Table 9.—Geophysical logs of selected wells in the study area.

Well No.	SP[1]-Multi-point electric	Caliper	Gamma	Neutron	Gamma-gamma	Temper-ature	Brine tracer	Fluid resistivity	Single point resistance	Acoustic	Focused electric
FA 25	-	X	X	-	-	-	-	-	X	-	-
FA 26	-	X	X	-	-	-	-	-	X	-	-
FA 27	-	X	X	-	-	-	-	-	X	-	-
FA 28	-	X	X	-	-	-	-	-	X	-	-
FA 29	-	X	X	-	-	-	-	-	X	-	-
FA 31	X	X	X	X	X	X	X	X	X	-	-
FA 32	X	X	X	-	-	-	-	-	-	-	-
FA 33	X	X	X	-	-	-	-	-	-	-	-
FA 34	X	X	X	-	-	-	-	-	-	-	-
FB 22	X	X	X	-	-	-	-	-	X	-	-
FB 23	X	X	-	-	-	-	-	-	X	-	-
FB 24	X	X	-	-	-	-	-	-	X	-	-
FB 25	X	X	-	-	-	-	-	-	X	-	-
FB 26	X	X	X	X	X	X	X	X	-	X	X

[1] Spontaneous potential.

A significant event occurred at site 1 beginning at the end of March 1981, when water levels in all four wells dropped substantially. In January, a side heading in the Upper Freeport coal was begun by Mettiki in a northeasterly direction from the main heading. The purpose of the cut was to allow realinement of the main heading. By July 1, this side heading (fig. 25) was within about 300 ft of the well cluster, and progress was suspended. The water levels ceased to drop steeply at the end of June, and two wells (open to zones 1 and 3) even showed rises. Much of the record for this period was lost for zones 2 and 3, but measured values showed that the water level in well FA 32 (zone 2) had dropped to 392 ft below land surface (Aug. 12), and the water level in well FA 33 reached 185 ft below land surface (July 22). The zone most affected was the one above the Upper Freeport coal. The zone below the coal was affected to a much lesser extent, attesting to the efficacy of the underclay as a confining bed. Excluding this zone, the declines are inversely proportional to the logarithm of the distance of the zone above the coal (fig. 26), essentially a distance-drawdown relation.

Neither of the other two clusters has shown such effects; however, at site 3 some significant declines occurred as a result of a different factor. Wells FB 28 and FB 30 dropped significantly in May 1981. At this site, well FB 27 was pumped at 4 gal/min on May 4, and well FB 30 was pumped at 4 and 8 gal/min on May 5. The other three wells at this site were not pumped because of their deep static levels. Well FB 27 recovered slowly to its original level. Well FB 30 was drawn down less than 8 ft and recovered relatively quickly (1.8 ft of residual drawdown after 10 minutes). During the pumping tests, water levels in the other wells were not observed to change. Within a few days, a test hole was cored for MAPCO, Inc., within 300 ft of the cluster, to a depth just below the Lower Bakerstown coal. This hole penetrated zones 4 and 5, and a portion of zone 3. It is possible that the observed change in water levels (after recovery from pumping) is due to flow of water through the test hole from zones 3 and 5 into zone 4 (and perhaps another zone not measured), bypassing several confining layers.

Another feature of the hydrographs is the continuous water-level decline in zone 1 (wells FA 31, FB 22, and FB 26). At sites 2 and 3, the slopes of the water levels are nearly the same. No pumping is known to occur from this zone in the area. The decline may be due to diversion of recharge to the zone, perhaps by dewatering of a coal mine in West Virginia, or to reductions in pressure due to Mettiki dewatering.

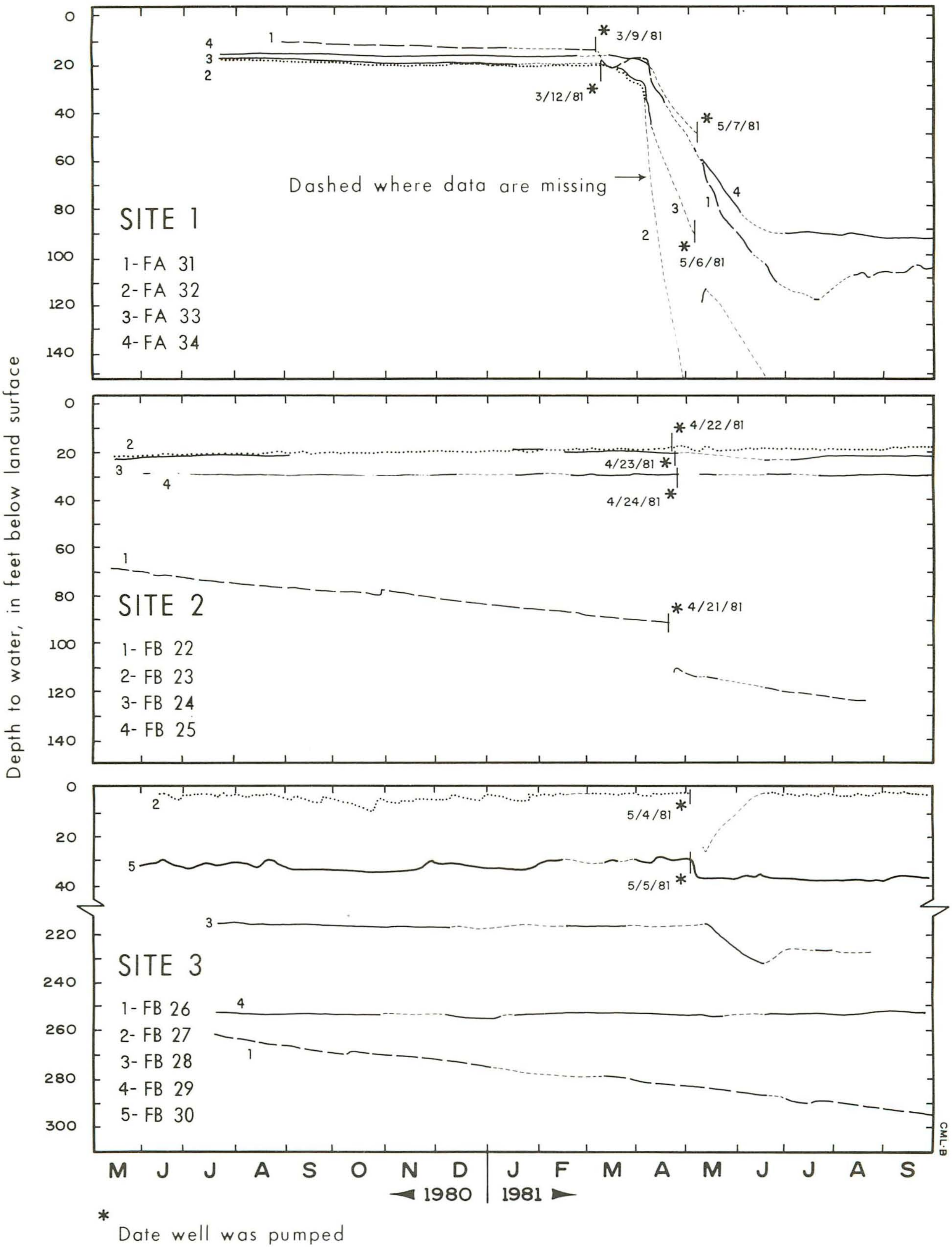


Figure 24.—Observation wells at sites 1, 2, and 3.

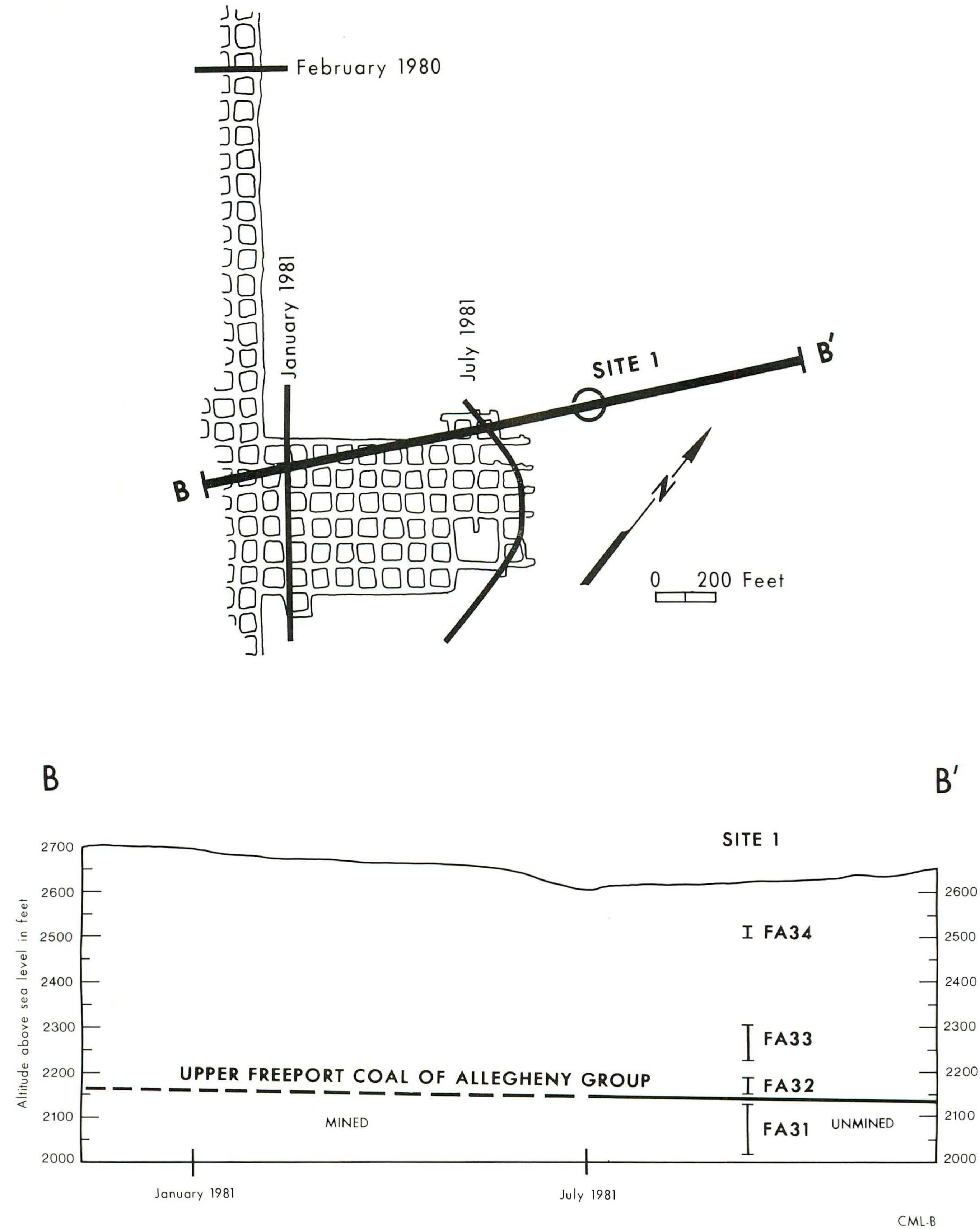


Figure 25.—Mining progress in the vicinity of site 1.

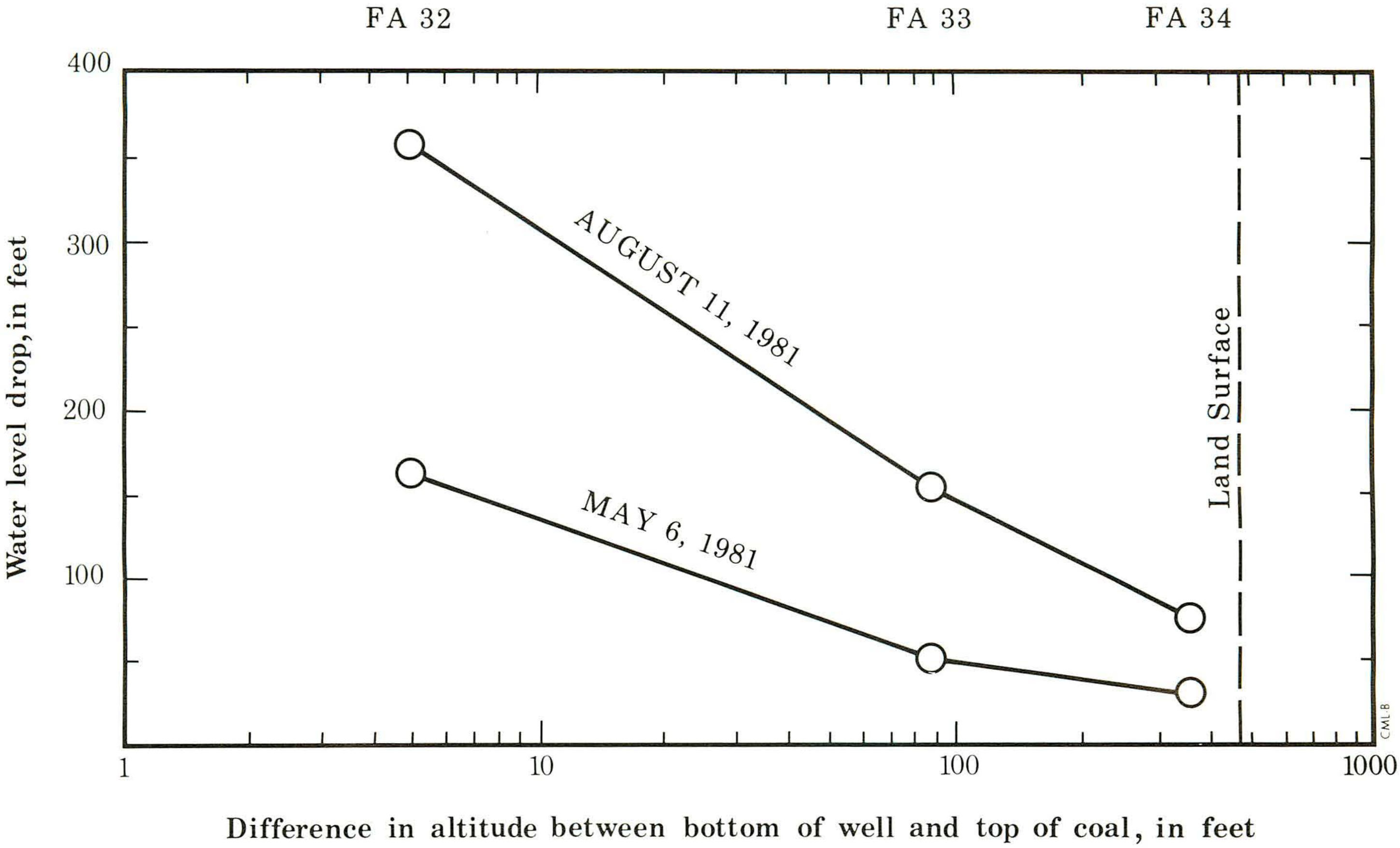


Figure 26.—Relationship of the amount of water-level decline since March 1981 to the difference in altitude between the well bottom and the Upper Freeport coal of the Allegheny Group.

Aquifer Properties

Well FA 31, at site 1, was drilled to 1,131 ft below land surface in order to locate the base of fresh ground water. The fluid resistivity log shows a sharp decrease in resistivity (from about 33 ohm-meters) at a depth of 924 ft. At about 1,020-ft depth, the resistivity stabilized at about 3 ohm-meters. This well began to flow when its depth reached about 780 ft below land surface and continued to flow until the lower portion was grouted. A brine tracer log for the interval 860 to 900 ft indicates an upward flow of about 2 ft/min (approximately 1 gal/min). Brackish water in the borehole was apparently shifted upward with respect to the undisturbed occurrence within the rocks by this vertical flow. The spontaneous potential (SP) log indicates that the brackish water within the formation occurred at depths below about 1,020 ft and became diluted with fresher water up to about 940 ft. The SP and multipoint resistivity logs also indicated freshwater coming into the borehole at about 770 ft and 670 to 690 ft. Brackish water was not found in any other wells.

Water-bearing zones in the study area are not arranged in simple, continuous layers. To appreciate the aquifer geometry, one must consider the environments of deposition as discussed in the section on Geology. Features such as sand-rich or clay-rich zones are indicated on the gamma logs; however, these logs do not reveal that the sandstone bodies are very well consolidated with a siliceous cement. The low bulk porosity of the rocks in the study area is evident from examination of cores and neutron logs; the latter indicate that the sandstone bodies have bulk porosities of less than 6 percent. Caliper and acoustical logs indicate some significant fractures which increase permeability. Despite their well-cemented nature, the sandstones may be better aquifers than the shales owing to greater fracture density, a consequence of the less brittle nature of the shales. There is some degree of hydraulic connection in all three dimensions. However, the underclays may be effective confining beds where present, particularly those that underlie the Upper Freeport and Lower Bakerstown coals. Some of the shales and mudstones may also restrict vertical movement of water. The open-hole zones, then, may not fully penetrate discrete aquifers.

An estimate of porosity can be made from the resistivity logs where formation water is brackish, using the relationship of the formation factor (resistivity measured by the 64-in. normal logging tool, divided by resistivity of the formation water) and porosity (Lynch, 1962, p. 201):

$$\phi = 2.15 \sqrt{0.62/F}$$

where

ϕ = porosity, and

F = formation factor.

For a depth of 1,040 ft in FA 31,

$$\phi = 2.15 \sqrt{0.62/412} = 0.049 = 5 \text{ percent.}$$

This equation was developed for estimating primary porosity of shale-free sandstone rather than fracture porosity; however, it does seem to give results which are in reasonable agreement with the neutron log.

Aquifer tests were performed on all wells at sites 1 and 2, and on wells FB 27 and FB 30 at site 3. The static levels in the other wells at site 3 were too deep to allow testing to be done with available equipment. Pumping was done with a low capacity submersible pump that could fit inside the 4-in. casing and was able to pump from depths exceeding 200 ft.

Examples of drawdown and recovery data for the test wells are presented on logarithmic plots in figure 27. Drawdown was only observed in the pumping well because the pumping rate was too low to affect the other wells. Drawdown for well FB 25, which is open from 120 to 180 ft, is shown in figure 27a. The pumping rate, 7.5 gal/min, did not stress the aquifer very much and the water level began to stabilize very quickly. The deviation from the Theis type curve is probably due to delayed yield from storage, under unconfined conditions. Figure 27b shows the time-drawdown data for well FA 33, which is open from 318 to 391 ft. This was a much lower-yielding well, and the linear nature of the graph indicates that most of the water was coming from borehole storage. Figure 27c shows recovery in well FA 31, which is open from 489 to 606 ft, and also was a low yielding well. Deviations from the Theis type curve may also be caused by the fractured, heterogeneous nature of the aquifer and variations in the pumping rate.

Approximation of hydraulic conductivity (K) or transmissivity (T) using various analytical methods (Bouwer and Rice slug test, 1976; Ogden's one-drawdown estimate of T, 1965; semilogarithmic plotting) suggest that transmissivities of the deeper zones are less than about 25 ft^2/d, and, of the shallower zones, a few hundred feet per day (table 10).

The method of Bouwer and Rice is demonstrated below. (Use of slug-test calculations seemed justified because of the low pumping rate, short duration of pumping, and tightness of the formation). Hydraulic conductivity, K, is calculated as:

$$K = \frac{r_c^2 \ln (R_e/r_w)}{2L} \quad \frac{1}{t} \quad \frac{y_o}{y_t}$$

where

r_c = inside radius of casing;

R_e = effective radius over which y is dissipated;

r_w = radius of open hole;

L = length of open hole;

t = time required for water-level rise;

y_o = distance between water level and static level at t = 0; and

y_t = distance between water level and static level at time t.

R_e is evaluated by the expression:

$$\ln \frac{R_e}{r_w} = \left[\frac{1.1}{\ln (H/r_w)} + \frac{A + B \ln [(D-H)/r_w]}{L/r_w} \right]^{-1}$$

where

H = distance from top of aquifer to bottom of well;

D = thickness of the aquifer; and

A,B = dimensionless coefficients (from graph in Bouwer and Rice, 1976, p. 426).

For a fully penetrating well (H = D), a modified form of the equation is used:

$$\ln \frac{R_e}{r_w} = \left(\frac{1.1}{\ln (H/r_w)} + \frac{C}{L/r_w} \right)^{-1}$$

where

C = another dimensionless coefficient, obtained from the same graph.

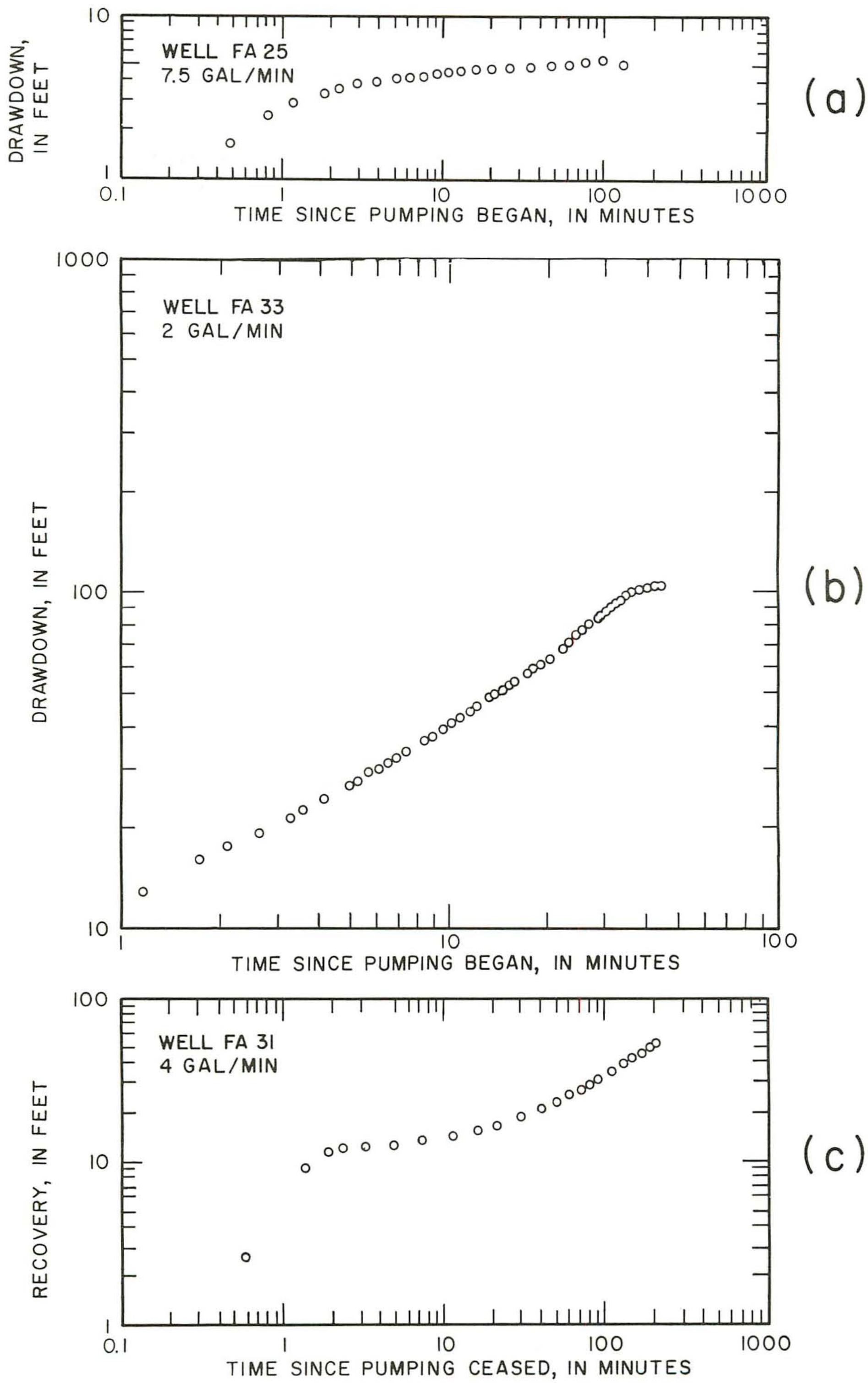


Figure 27.—Examples of drawdown and recovery data for selected wells.

Table 10.—Characteristics of the hydrologic units tested.

Site No.	Well No.	Zone	Assumed thickness (ft)	Assumed storage coefficient S[1]	Hydraulic conductivity[2] (ft/d)	Transmissivity (feet squared per day)		
						Hydraulic conductivity X thickness	Time-drawdown[3]	Single drawdown[4]
1	FA 31	1	76	0.00008	0.3	22	2	25
	FA 32	2	43	.00004	.5	23	.7	2
	FA 33	3	66	.00007	.2	11	3	3
	FA 34	4	64	.00006	9	550	570	1,100
2	FB 22	1	120	.0001	.05	6	3	6
	FB 23	2	48	.00005	.3	15	8	10
	FB 24	3	83	.00008	.2	13	11	12
	FB 25	4	61	.00006	7	427	241	320
3	FB 27	2	61	.00006	.05	3	9	6
	FB 30	5	78	.00008	7	530	280	380

1 S, is assumed thickness X 10^{-6} (Lohman, 1979, p. 8).
2 Bouwer and Rice (1976) slug test.
3 Cooper and Jacob (1946).
4 Ogden (1965).

Data from well FB 25, pumped for a short period on April 24, 1981, yield:

$$\ln \frac{R_e}{r_w} = \left(\frac{1.1}{\ln (61 \text{ ft}/0.125 \text{ ft})} + \frac{10.5}{60 \text{ ft}/0.125 \text{ ft}}\right)^{-1}$$

$$= 5.0107$$

$$K = \frac{(0.17 \text{ ft})^2 \; (5.0107)}{2\,(60 \text{ ft})}\left(\frac{1}{0.44 \text{ min}}\right) \ln \frac{3.81 \text{ ft}}{0.71 \text{ ft}}$$

$= 4.6 \times 10^{-3}$ ft/min or 6.635 ft/d, rounded to 7 ft/d.

Transmissivity (T) is obtained by multiplying K by the assumed thickness of the aquifer:

$$T = (7 \text{ ft/d})\,(61 \text{ ft}) = 427 \text{ ft}^2/\text{d}.$$

Aquifer thicknesses, especially for the deeper wells, are not known with certainty and are one source of disagreement for transmissivities calculated by various methods. Thicknesses used for the above analyses were estimated from lithology, but the aquifer boundaries were difficult to distinguish.

Hydraulic conductivities calculated by this method (fig. 28) vary with the depth of the open-hole zone (plotted as the midpoint of the zone). The equation for the line, obtained by a least-squares regression, is:

$$\log K = 1.144 - 0.004d$$

or

$$K = 28e^{-0.009d}$$

where

K = hydraulic conductivity; and

d = midpoint of the open-hole zone.

Such a relationship is expected because of the general tendency for fractures to decrease in abundance and openness as depth increases. A relationship of the same form was noted by Stoner (1983, p. 130) in a geologically similar area and by other workers in fracture-controlled permeability terrains. A consequence of this relationship is that most of the ground-water circulation occurs within a few hundred feet of land surface.

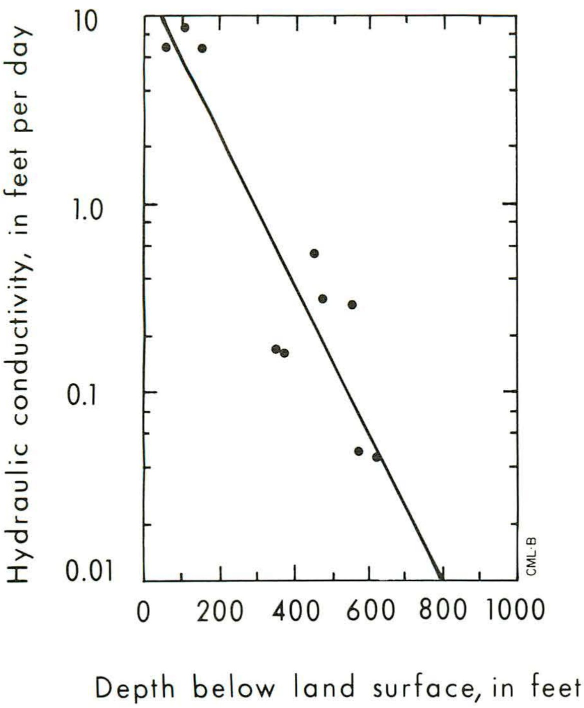


Figure 28.—Variation of hydraulic conductivity with depth.

A sample calculation for the method of Ogden (1965) is shown below:

$$uW(u) = \frac{1.87r^2 Ss}{114.6\ Qt}$$

where

$$u = \frac{1.87r^2 S}{Tt}$$

(based on the Theis nonequilibrium method);

W(u) = the well function of Theis;

r = radius of the pumped well;

S = storage coefficient;

s = drawdown;

Q = discharge; and

t = time since pumping began.

Because S was not determined by the pumping test, it was estimated as:

S = aquifer thickness x 10^{-6} (Lohman, 1979, p. 53).

The value u is obtained graphically (Ogden, 1965, p. 52) from uW(u) and used to calculate transmissivity (T):

$$T = \frac{1.87r^2 S}{ut}$$

Using the data from FB 25:

$$S = (61)(10^{-6}) = 0.00006$$

$$uW(u) = \frac{(1.87\ \text{gal/ft}^3)(0.125\ \text{ft})^2}{(114.6\ \text{min/d})(7.5\ \text{gal/min})} \cdot \frac{(0.00006)(5\ \text{ft})}{(132.42\ \text{min} \cdot 1\text{d}/1{,}440\ \text{min})}$$

$$= 1.1 \times 10^{-7}$$

From Ogden's graph:

$$u = 8 \times 10^{-9}$$

and solving for T:

$$T = \frac{(1.87\ \text{gal/ft}^3)(0.125\ \text{ft})^2\ (0.00006)}{(8)(10^{-9})(132.42\ \text{min} \cdot 1\text{d}/1{,}440\ \text{min})}$$

$$= 2{,}383\ \text{(gal/d)/ft, or } 319\ \text{ft}^2/\text{d},$$

which is in fair agreement with the T calculated by the method of Bouwer and Rice (1976).

Because aquifer tests involving small pumpage stress only a small portion of the aquifer, it may be desirable to estimate areal transmissivities.

If streamflow is measured, areal transmissivity can be estimated without measuring ground-water levels in a well because the base-flow and water-level recession slopes are equal (Rorabaugh, 1963, p. 434). The basic equation (Rorabaugh, 1960, eq. 5) is:

$$T/S = \frac{0.933\ a^2 \log (h_1/h_2)}{(t_2 - t_1)}$$

where

T/S = the aquifer diffusivity (transmissivity divided by storage coefficient);

a = distance from the stream to the divide (which may be computed as one-half times the basin area divided by total stream length);

h_1, h_2 = ground-water levels at early and late times during recession, denoted t_1 and t_2.

If a water-level decline of one log cycle is chosen, the factor log (h_1/h_2) is equal to 1. Because the quantity of base flow is a function of the ground-water levels, the base-flow decline over one log cycle may be used, and only the duration, $t_1 - t_2$, need be measured. The equation thus simplifies to:

$$\frac{T}{S} = \frac{0.933\ a^2}{(t_2 - t_1)}$$

and transmissivity can be calculated if storage (S) is estimated (table 11).

Paired values of S are shown: Pumping tests at the three well clusters suggest the lower values may be close, but other workers have used higher values. Trainer and Watkins (1975, p. 39) obtained a value of T/S of 29,000 ft²/d for fractured rocks having thin regolith in the Upper Potomac River basin, and used S = 0.005 to derive T = 140 ft²/d as an average value for that setting. The calculated diffusivity of the Laurel Run basin (30,000 ft²/d) is close to the average value obtained by Trainer and Watkins. The higher values of the other two may be due to shortened recession times as a consequence of undermining (Buffalo Coal Co. Mine No. 1). The lower assumed S values are more appropriate for the deeper zones; those zones are of much less significance in terms of ground-water circulation than the uppermost 100 ft. Interpretation of areal values is made difficult by the combination of natural heterogeneity and alterations to the natural system.

Ground-Water Flow System

The ground-water flow system had already been modified by earlier coal mining when this study began. Strip mining probably affected local infiltration and recharge rates. Underground mines, which act as large sinks, have altered ground-water flow directions and provided conduits for discharge to the surface at various locations.

Hollyday and McKenzie (1973, p. 13-14) state that the natural flow system in the Allegheny Plateau in Maryland is similar to that in western Pennsylvania as described by Carswell and Bennett (1963), and Poth (1963). This study is in basic agreement with these findings. The shallow part of the system that underlies the hills discharges to the local streams and, to some extent, leaks downward to the deeper portions of the flow system, which discharges into higher order streams which are at lower elevations. The shallow system may also be perched locally above strata of low permeability, such as clays or shales that are less fractured than the sandstones. These barriers cause the water to flow laterally until it can discharge at springs or seeps above the smaller valleys. Very shallow ephemeral systems may be important contributors to streamflow following periods of precipitation (the interflow component). These systems are local in extent and may discharge along the hillsides above stream level. They may be perched on impervious soil zones such as fragipans, or they may be concentrated by piping near the lower areas of the hillslopes.

Water-table conditions probably are represented by the water levels in the shallow wells installed at each cluster. Most of the water that recharges this system is from precipitation within the area, and locally from leakage of nearby streams. At site 1, near the middle of the South Fork, the water table is generally several feet above the level of the stream. At site 2, near the lower reach of the South Fork, the water table is generally near or several feet below the level of the stream. At site 3, on a hilltop, the water table is about 30 ft deep. The water level in zone 4 (the next shallowest well at site 3) is considerably lower than the level of the water table. This suggests perching of the water-table aquifer, with

Table 11.—Aquifer diffusivity and estimated transmissivity and storage of the North Fork, South Fork, and Laurel Run basins

Basin	Aquifer diffusivity (ft²/d)	Assumed storage coefficient	Estimated transmissivity (ft²/d)
South Fork	63,000	0.0001	6.3
Sand Run		.005	315
North Fork	145,000	.0001	15
Sand Run		.005	725
Laurel Run	30,000	.0001	3
		.005	150

some leakage downward. The dissected terrain results in a number of independent shallow subsystems.

The deeper ground-water flow system, which does not interact with the streams within the study area, is also a discontinuous system. Beds of much lower permeability, particularly the underclays of the Lower Bakerstown and Upper Freeport coals, separate some of the flow paths. These confining beds are not continuous and some leakage probably occurs across them.

Flow in the deepest freshwater zone probably originates outside of the study area and discharges to major stream valleys in the region. This deeper system may receive additional recharge through leakage from above. The base of the freshwater system is the interface with saline water (observed in well FA 31 at a depth of 940 ft), which has been mapped in West Virginia (Foster, 1980), adjacent to the study area. Figure 29 shows a possible interpretation of the deep freshwater flow system; the base is derived from the maps of Foster. This system may discharge to the North Branch Potomac River through upward leakage. Underground coal mines are additional sinks for this part of the flow system.

Figure 30 shows possible flow paths prior to April 1981 in the same section shown in figure 22. In the vicinity of site 1, there is a downward-flow component (above the level of the Upper Freeport coal), but at sites 2 and 3 there is an upward-flow component (except for downward leakage through the streambed of the South Fork near site 2 and from the perched water table at site 3). Bearing in mind that the section is not along a straight line, it appears that there are both downdip- and down-plunge-flow components.

Figure 31 is a section that is constructed along a straight line from the crest of Backbone Mountain, through site 1, to the North Branch Potomac River. From this figure, it might seem that the vertical-flow components of sites 2 and 3 could be generated by recharge on the mountain; however, the greater relief of the regional system (fig. 29) suggests that recharge in the Backbone Mountain area to the deeper zones may only cause mounding of the potentiometric surface within a regional slope.

Pumpage of water from the Mettiki mines has affected shallow and deep ground water as shown by water levels at site 1 (figs. 24 and 25). These effects are limited to within several hundred feet of the mine workings. The water table has been lowered in some areas to several tens of feet below stream level. This may result in a reversal of ground-water flow and a decrease in streamflow unless compensated for (for example, by discharge of treated mine and process water).

The removal of coal pillars from worked-out mines will create extensive fracturing as the voids collapse. When this does occur, permanent modifications to the ground-water flow system will result, and a new equilibrium will eventually become established after mine dewatering ceases.

Ground-Water Quality

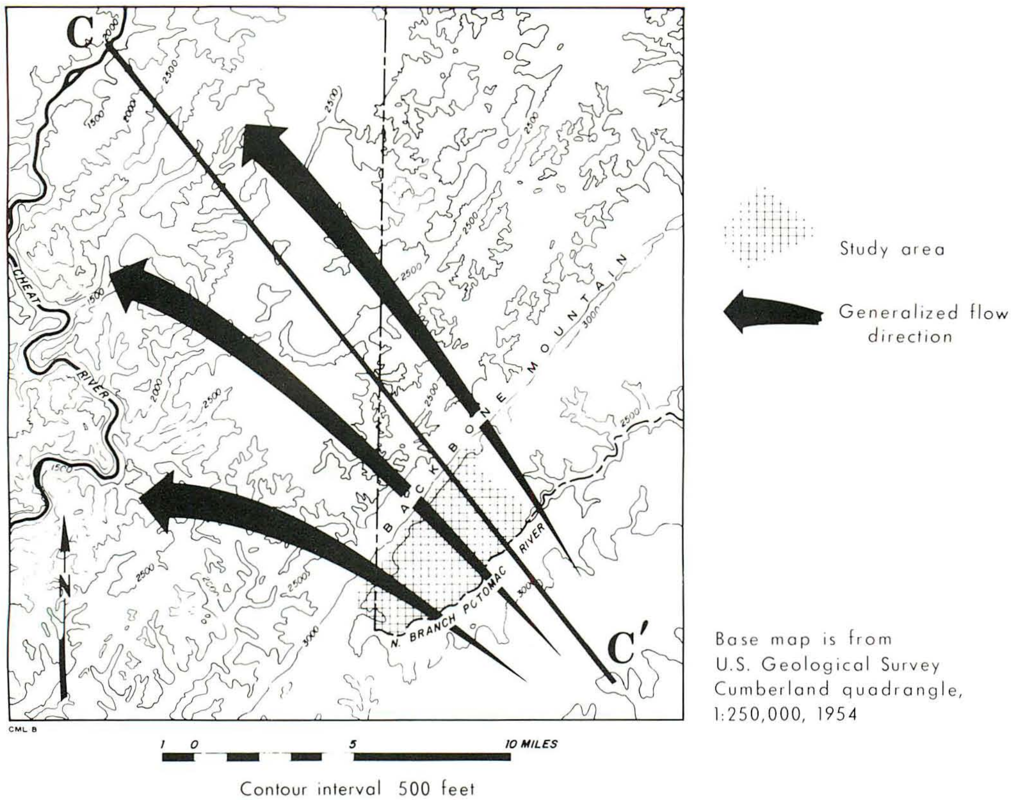
Samples of water from seven of the cluster wells were collected for laboratory water-quality analyses as the wells were pumped. Temperature, pH, and specific conductance of the samples were measured at the time of collection. Additional samples were collected from two underground-mine discharge sites, three springs, and one seepage point within the A Mine. The deeper wells yielded insufficient quantities of water to ensure that the samples represented formation water; pH values of some of these samples (as high as 11.6) are above the usual pH limits of normal environments (Krauskopf, 1967, p. 247) and suggest that the water sampled may have been contaminated by reaction with the cement grout at the bottom of the casing. All analyses are shown in table 12, with the caution that samples from some of the low-yielding wells may not be representative of formation water. Analyses reported by Mettiki (table 13) also included high pH values from low-yielding wells and may represent water that has reacted with grout. The pH of water from well FB 23, which is just above the Upper Freeport coal, is 7.0, and the pH of the sample collected inside the A mine is 7.6. This suggests that water from the deeper zones should not have very high pH values.

The potassium concentrations of several of the wells are nearly as high or higher than the sodium concentrations; this may be due to cation exchange in clay-rich zones and (or) weathering of potash-feldspar, muscovite, or illite minerals in the rocks.

Well FB 31 was sampled at depths of 870, 965, and 1,100 ft (table 12) by use of a down-hole sampler. The high sodium and chloride concentrations (1,800 mg/L and 2,900 mg/L) from 1,100 ft verify that the base of the freshwater zone was penetrated. The data suggest that two separate ground-water zones were sampled (salty water at 1,100 ft, and freshwater at 965 ft). A third zone of mixed water produced by upward flow in the borehole was sampled at 870 ft.

Field analyses of three springs show lower pH and specific conductance values than most of the wells (table 12). This may simply reflect shorter flow paths and briefer residence times of water in the ground, or perhaps the deeper water has passed through more reactive zones, particularly marine shales.

Table 12 also includes data from coal-mine drainage. One of the sites from the Kempton Mine (GA 3) was sampled during this study. The other, site GA 6, was sampled by Hollyday and McKenzie (1973). The analyses of the mine drainage water indicate that they are significant sources of acid water and contain large amounts of iron, sulfate, and other dissolved ions.



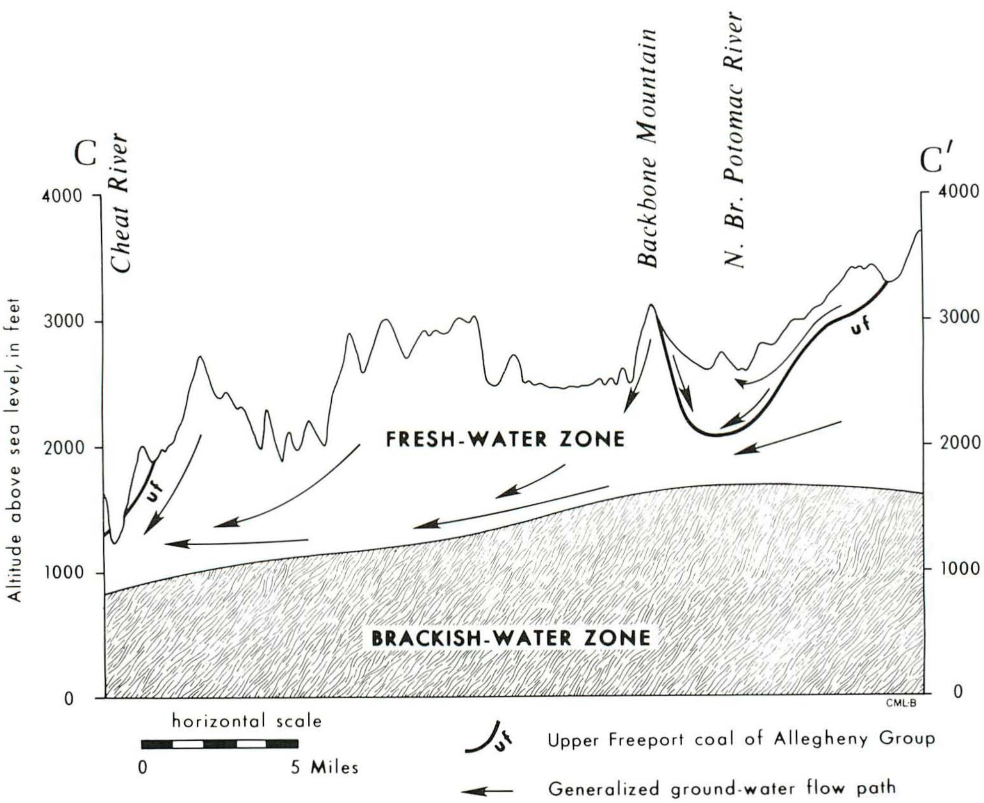


Figure 29.—Regional flow directions.

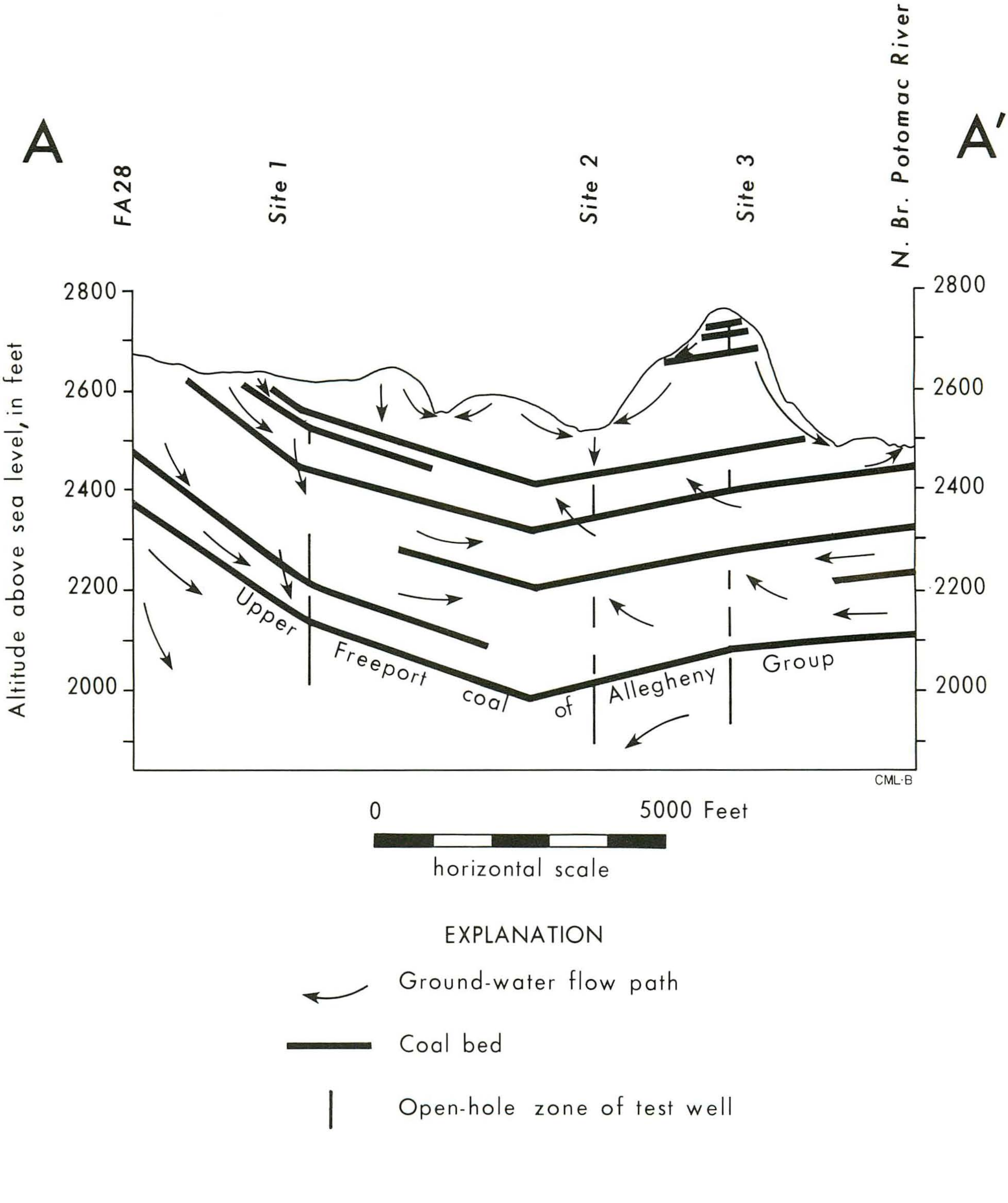


Figure 30.—Possible ground-water flow paths prior to April 1981. (Section is the same as shown in figure 22).

Table 12.—Chemical analyses of ground water.

Site No.	Type of site	Geologic unit	Date of sample	Depth to top of sample interval (ft)	Depth to bottom of sample interval (ft)	Specific conductance field (µmhos)	Specific conductance laboratory (µmhos)	pH Field	pH Laboratory	Temperature, water (°C)	Hardness, (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L as $CaCO_3$)	Acidity, total heated (mg/L as H)	Acidity (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)
FA 20	W	Conemaugh	78-08-03	22	78	25	--	6.8	--	--	12	3	--	--	3.3	0.8	0.3	0.5
FA 31	W	Pottsville	80-02-11	488	2/1,131	--	9,470	--	8.0	--	300	99	--	--	90	18	1,800	4.7
do.	W	do.	80-02-11	488	3/1,131	--	292	--	7.6	--	23	0	--	--	6.9	1.4	26	.5
do.	W	Allegheny	80-02-11	488	4/1,131	380	--	--	7.9	-·-	34	10	--	--	11	1.6	95	.7
do.	W	do.1/	81-03-10	470	606	420	286	10.4	11.0	9.8	64	0	--	--	24	1.0	10	7.9
FA 32	W	do.1/	81-03-12	430	473	2,600	2,910	11.6	11.8	10.0	710	--	--	--	280	1.7	13	41
FA 34	W	Conemaugh	81-05-07	96	115	141	161	7.0	7.6	14.8	82	8	--	--	24	5.4	.7	1.1
FA 35	D	do.	81-05-15	--	--	3,280	3,210	4.9	3.0	11.3	1,700	1,700	--	--	·470	120	5.5	12
do.	D	do.	81-06-30	--	--	--	3,110	--	4.0	--	1,600	1,600	9.0	447	440	110	6.5	13
FB 22	W	do.1/	81-04-21	517	640	490	363	10.6	10.8	11.6	33	0	--	--	13	.2	20	43
FB 23	W	Conemaugh	81-04-22	460	495	195	216	7.0	7.8	12.0	110	19	--	--	34	5.7	1.1	1.0
FB 25	W	do.	81-04-24	120	180	438	443	7.3	8.2	9.4	210	87	--	--	60	14	11	3.7
FB 30	W	do.	81-05-05	82	85	193	202	6.4	7.2	12.3	110	7	--	--	31	6.7	.4	1.6
GA 1	S	do.	81-10-29	--	--	86	--	6.9	--	11.0	--	--	--	--	--	--	--	--
GA 3	D	Allegheny	81-10-29	--	--	803	897	3.2	3.0	10.5	190	--	4.8	--	47	18	4.5	2.8
GA 4	S	Conemaugh	81-10-29	--	--	21	--	5.1	--	9.1	--	--	--	--	--	--	--	--
GA 5	S	do.	81-10-29	--	--	26	--	6.3	--	10.0	--	--	--	--	--	--	--	--
GA 6 5/	D	Allegheny	70-08-25	--	--	1,020	1,690	3.4	2.6	10.3	--	599	--	--	80	32	5.6	3.5
Mine drip	A	do.	81-12-18	--	--	350	332	--	7.6	8.0	160	62	--	--	48	9.6	2.7	2.2

1/ Probably affected by grout and not representative of formation water.
2/ Sampler at depth of 1,100 feet.
3/ Sampler at depth of 965 feet.
4/ Sampler at depth of 870 feet.
5/ Hollyday and McKenzie (1973).

(W, well; D, abandoned-mine discharge; S, spring; A, active-mine wall)

Table 12.—Chemical analyses of ground water—Continued.

Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Nitrogen, NO_2 + NO_3 total (mg/L as N)	Nitrogen, NO_2 + NO_3 dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Silica, dissolved (mg/L as SiO_2)	Iron, suspended recoverable (µg/L as Fe)	Iron, total (µg/L as Fe)	Iron, dissolved (µg/L as Fe)	Manganese, suspended recoverable (µg/L as Mn)	Manganese, total (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)	Solids, residue at 180 deg. C, dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Solids, volatile, dissolved (mg/L)	Site No.
8	1.5	0.1	0.0	--	--	0.00	--	4.6	--	80	--	--	10	--	25	17	--	FA 20
200	0.6	2,900	--	0.03	--	.050	--	10	2,000	4,200	2,200	20	130	110	--	4,950	--	FA 31
21	.1	42	--	--	--	--	--	4.5	310	330	20	10	20	10	--	131	--	do.
24	.1	150	--	--	--	--	--	7.5	320	450	130	0	10	20	--	280	--	do.
79	8.4	2.1	.3	--	0.11	--	<0.010	8.4	--	--	780	--	--	5	106	111	--	do.
740	29	1.6	<.1	--	.01	--	.010	9.5	--	--	170	--	--	10	1,360	821	--	FA 32
74	4.0	.5	.1	--	<.01	--	.040	7.5	0	1,400	1,400	0	90	100	102	89	--	FA 34
0	2,100	2.5	.1	--	.04	--	.020	31	60,000	290,000	230,000	0	5,700	6,000	3,360	2,980	--	FA 35
0	2,100	2.4	.2	--	.03	--	--	22	--	--	130,000	--	--	5,800	3,430	2,840	507	do.
98	12	1.3	.2	--	<.01	--	.020	10	--	--	2,300	--	--	30	163	161	--	FB 22
89	14	1.0	.2	--	.01	--	.020	6.3	--	--	40	--	--	120	120	117	--	FB 23
120	99	.6	.2	--	<.01	--	<.010	7.8	--	--	290	--	--	60	275	269	--	FB 25
98	7.2	1.1	.2	--	.02	--	.040	7.8	0	3,600	3,800	0	260	290	121	119	--	FB 30
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	GA 1
--	440	2.6	.4	--	<.01	--	.07	33	2,000	52,000	50,000	100	1,800	1,700	--	--	--	GA 3
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	GA 4
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	GA 5
--	--	2.2	.8	--	--	--	--	43	--	85,000	--	--	2,500	--	1,000	--	--	GA 6
97	68	.9	.2	.41	--	<.01	--	6.8	1,600	2,300	750	0	120	120	222	198	--	Mine drip

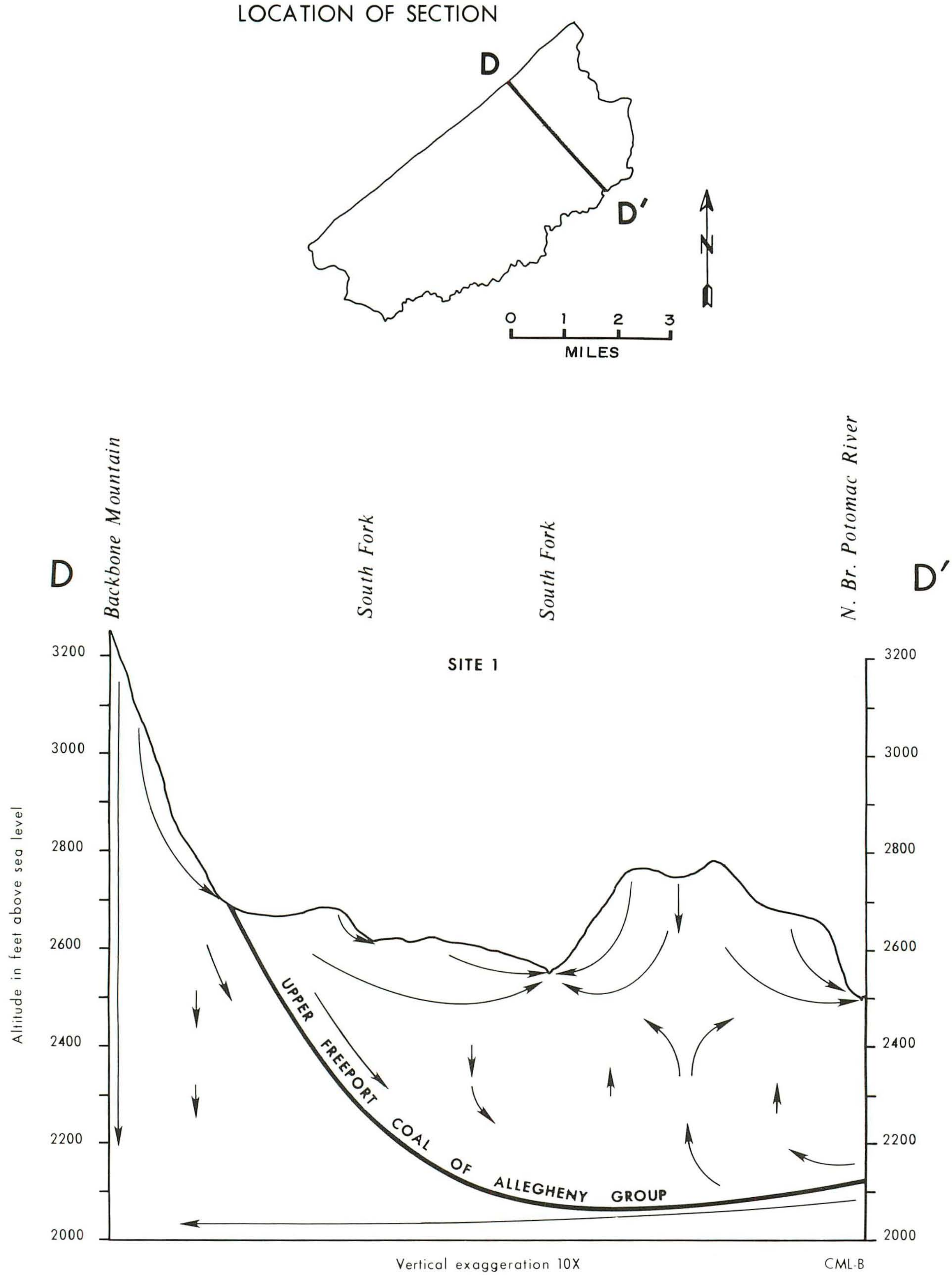


Figure 31.—Section from Backbone Mountain through site 1 to the North Branch Potomac River showing generalized ground-water flow.

Table 13.—Chemical analyses of water from Mettiki Coal Corporation observation wells, Garrett County, Md.

[Analyses reported by Mettiki Coal Corp., July 14, 1978. Samples collected and analyzed June 23, 1978.]

Well	Well depth (ft)	Geologic unit	Water level (ft)	pH	Hardness (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)	Sulfate (mg/L)
FA 25	315	Mahonning Sandstone	302	8.3	80	100	107
FA 26	170	Buffalo Sandstone	17	9.4	60	40	22
FA 27	215	Grafton Sandstone	170	11.0	520	380	81
FA 28	343	Mahonning Sandstone	107	9.8	60	40	26
FA 29	228	Saltsburg Sandstone	132	9.0	100	80	14

The trilinear diagram of figure 32 shows significant differences between water sampled from wells and water sampled from abandoned mine discharge points and from streams. The well samples presumably represent undisturbed conditions; they generally have fairly low total dissolved solids content (table 12) and, especially, relatively low sulfate. The abandoned mine drainage samples on the other hand, have high total dissolved solids, and dissolved sulfate dominates the anions—a result of the oxidation of sulfide minerals (pyrite) and the generation of acid. The North Fork and Laurel Run receive such acidic drainage, and their chemistries are affected all the way downstream.

The sample from well FB 25, the shallow well at site 2 (zone 4), plots between the well and stream samples in figure 32. This is evidence that the water from this well was a mixture of "undisturbed" ground water and recharge from leakage from the South Fork.

The mine-drip sample also plots between the well and stream samples in figure 32. This probably is not due to mixing of water, but, rather, to early stages of pyrite oxidation in the vicinity of the ventilated shaft.

The production of acid occurs as sulfide minerals (mostly pyrite, FeS_2) are exposed in the mine workings. The set of oxidation reactions, which requires exposure to oxygen to be initiated, is catalyzed by bacteria which can increase the rate-determining step (oxidation of ferrous iron by oxygen) by as much as six orders of magnitude (Singer and Stumm, 1970, p. 1,122). The reactions involved are:

(1) $$FeS_2 + \frac{7}{2} O_2 + H_2O \longrightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+.$$

(2) $$Fe^{2+} + \frac{5}{2} H_2O + \frac{1}{4} O_2 \longrightarrow Fe(OH)_3(s) + 2H^+.$$

(3) $$Fe^{2+} + \frac{1}{2} O_2 + H^+ \longrightarrow Fe^{3+} + \frac{1}{2} H_2O.$$

(4) $$FeS_2 + 14Fe^{3+} + 8H_2O \longrightarrow 15 Fe^{2+} + 2SO_4^{2-} + 16 H+.$$

These reactions, and the role of bacteria in them, are well described by Kleinmann and others (1981). The reaction cycle is self-reinforcing. At first the bacterial role is minor, but if the cycle proceeds far enough, bacterial action controls the rate of acid production. Limiting the oxidation of ferrous iron (reaction 3) by decreasing available oxygen (for example, flooding the mine) is not always feasible; Kleinmann and others (1981) discuss field tests involving use of bactericides to limit this oxidation step.

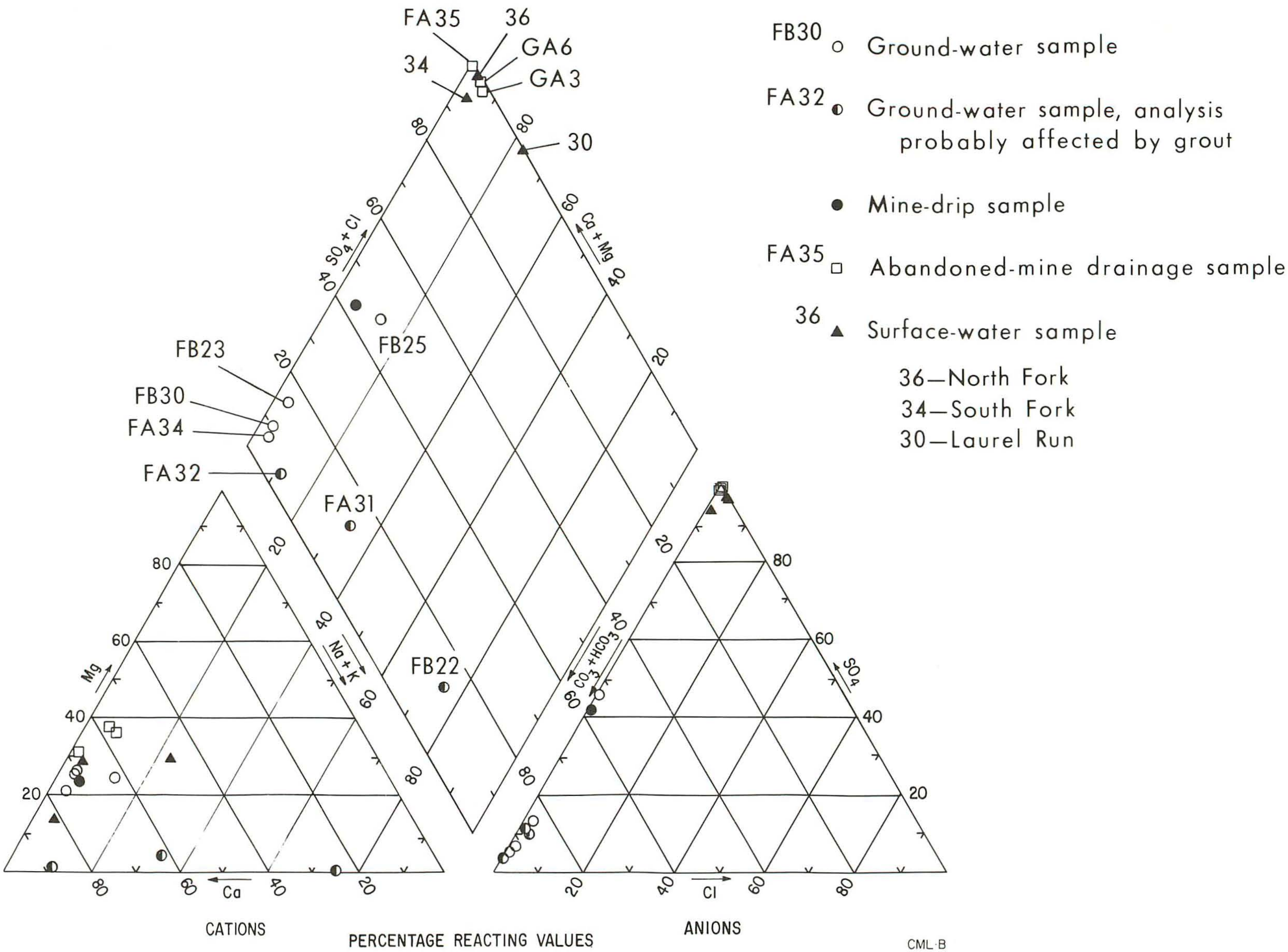


Figure 32.—Chemistry of ground and surface water in the study area.

HYDROLOGIC BUDGET

Components of the Budget

A general equation for water balance in a drainage basin is:

$$INPUT = OUTPUT$$

$$P + I = R + ET + E + \Delta S$$

where

P = precipitation;

I = water imported into the basin;

R = total runoff (discharge past the gage);

ET = evapotranspiration;

E = water exported outside the basin; and

ΔS = change in basin storage.

The terms for water imports and exports are important in the study area because of the extent of underground mines and interbasin transfers of mine pumpage. Evapotranspiration was estimated using the method of Thornthwaite and Mather (1957). Change in basin storage was calculated at the residual term and was found to be approximately equal to mine pumpage.

Evaluation of the Budget

Precipitation and total runoff were measured for water year 1981. Water imported into the study area through the abandoned Kempton Mine was estimated from discharge measurements at GA 3 and GA 6. Other interbasin transfers could not be quantified. Evapotranspiration was estimated as 23 in. For the three basins of the study area, an approximate evaluation of the hydrologic budget is:

$$52 \text{ in.} + 8 \text{ in.} = 41 \text{ in.} + 23 \text{ in.} + 0 \text{ in.} - 4 \text{ in.}$$

It is assumed that precipitation and evapotranspiration occurred uniformly throughout the area. For the three-basin area, an estimated 4 in. has been lost from storage for the 1-year period (fig. 33). This loss represents water pumped out of the active mines. Large water-level declines did not spread far from the undermined areas because of low transmissivity of the formations. Storage losses were therefore concentrated in the vicinity of mine workings.

FUTURE WORK

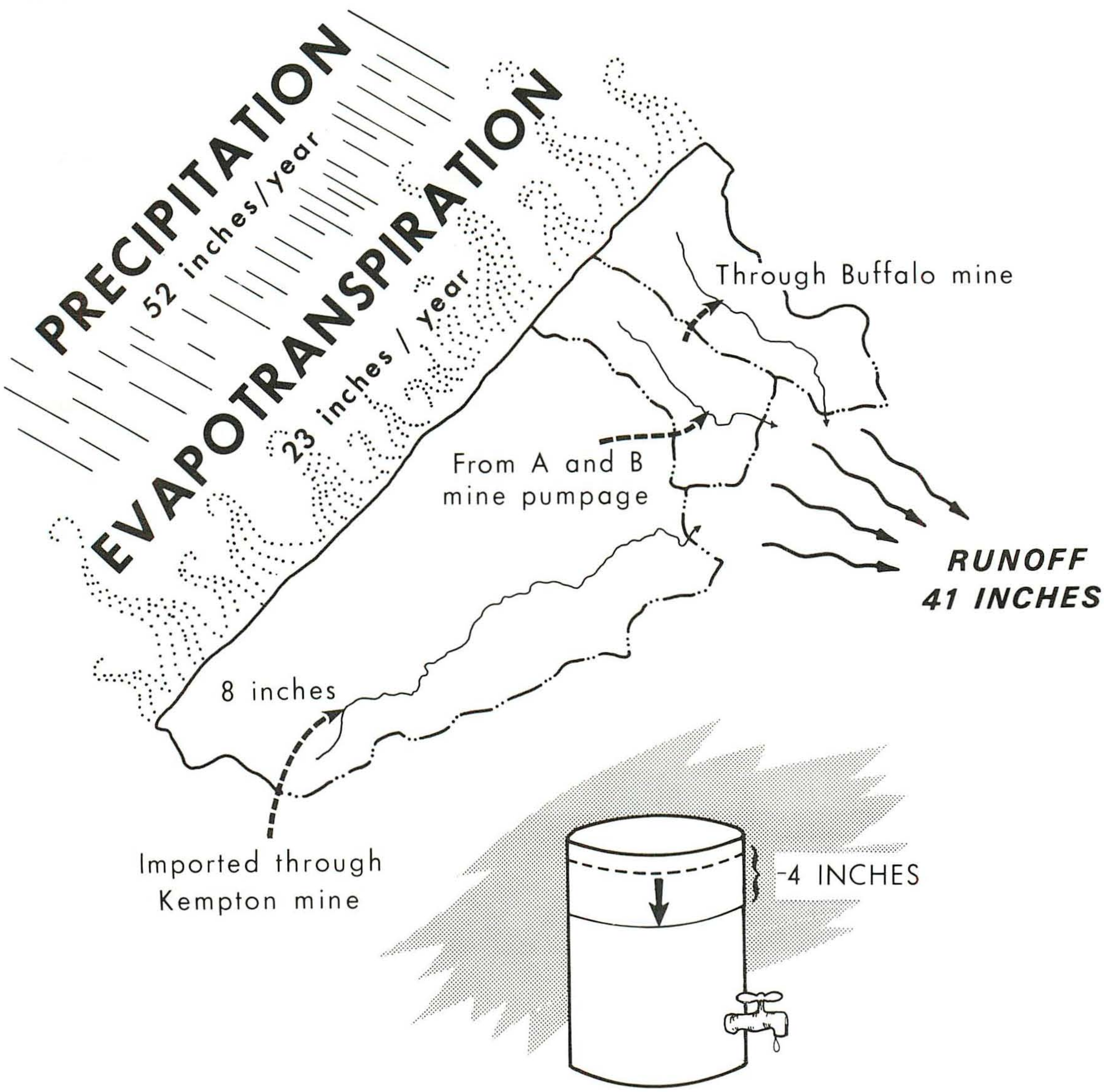
Mining in the area is scheduled to continue for a number of years after the present study is completed. A follow-up study will evaluate changes in conditions that have occurred since the present study and will be done in several phases. At the conclusion of each phase, specific needs for succeeding phases will be evaluated. The work will continue throughout the mining operation and recovery period. Future work will aid in describing the hydrologic systems in the coal basins of Maryland, and documenting and interpreting the impacts of underground coal mining on the hydrologic system.

Some possible consequences of underground coal mining are shown in figure 34. The continuing study will attempt to quantify these effects using the approach discussed below. The existing data-collection network will be utilized although some of the wells will be destroyed when mining extends beneath them. Maintenance of water-level, stream-stage, and stream water-quality recorders will continue, if possible, at all current data-collection sites.

Mine-pumpage and treated-water discharge records will be kept to assist in hydrologic analyses. This will help to evaluate the effects of interbasin water transfers, surface-water-quality assessments, and ground-water storage changes.

Well hydrographs will be inspected for trends in water-level changes and especially for large declines as mining approaches. When such changes do occur, the relative declines will be compared to those already noted at site 1, both with respect to magnitude of decline and distance to the mine heading. Water-level recoveries and fluctuations will also be examined with respect to mine-dewatering pumpage records.

Possible changes in aquifer characteristics will be investigated through the use of slug tests and, in the shallower wells, pumping tests. These tests should help to determine the degree of fracturing in the different zones above the Upper Freeport coal. Caliper logs for the open-hole segments may also help determine the extent of fracturing. Areal transmissivities will be



CML-B

Figure 33.—Approximate hydrologic budget for water year 1981. (October 1980–September 1981). Dashed arrows indicate inter-basin transfers through abandoned mines or active mining operations.

recalculated and compared with the values already obtained.

Streamflow measurements will be compared with earlier data. Baseline characteristics cannot be estimated with much accuracy due to the short period of record; however, changes in tributary contributions may be identified along with contributions from mine drainage (and withdrawals for use in coal preparation and reclamation). As the drainage basins are undermined, low flows may decrease due to induced streambed leakage.

Sampling will continue on a regular basis, although fewer parameters will be analyzed in the laboratory. Water temperature and specific conductance will be monitored continuously at the three gaging stations. Additional samples will be obtained from seepage into the mines. Changes in the quality of effluent from the abandoned mines may have an impact on downstream water quality. The abandoned Buffalo Coal Company Mine, which discharges to the North Fork, is receiving sludge from Mettiki's acid mine drainage treatment (limestone neutralization) facilities. This may have the effect of raising the pH and dissolved-solids content. Future acid mine drainage abatement efforts, particularly regarding drainage from the abandoned Kempton Mine, will be investigated for effects in the study area.

Seepage investigations will be undertaken to identify additional areas of streambed seepage losses as greater areas are undermined. Tributary contributions to streamflow and water quality will be included in the investigations. These data will assist low-flow characterization and will be helpful in describing stream/aquifer relations. Headwater and mouth areas will be investigated for differences in consequences due to mining.

The hydrologic budget will be estimated and compared to the data presented in this report. Changes are expected due to withdrawals from ground-water storage (mine dewatering) and induced streambed leakage (as greater areas of the drainage basins are undermined). Fracturing above areas that have been mined (pillars taken) may allow greater recharge to the deeper zones, and lowered water tables (where present) may reduce evapotranspiration.

Analysis of these data may indicate that use of digital-simulation modeling is appropriate. Such a model could be very helpful in describing the ground-water flow system, quantifying aquifer interactions, and evaluating the hydrologic budget. If it appears that such a model can be developed for this setting, a separate project will be proposed to undertake its design and calibration. Stoner (1983) used a two-dimensional cross-sectional model to help describe the hydrologic system in a similar area in southwestern Pennsylvania, and to predict hydrological consequences of mine dewatering. Because of some differences between study areas (more steeply dipping strata in southwestern Garrett County), it might be necessary to utilize a three-dimensional model. Additional models to evaluate potential impacts on water quality and streamflow may also be developed. Saulnier and Goddard (1982) discuss the application of several such models.

Streamflows and surface-water-quality data will be published annually as part of the U.S. Geological Survey's Water-Data Report series. Reports assessing impacts on the hydrologic system and presenting additional data are anticipated for publication during the several phases of the follow-up study.

SUMMARY

A large underground coal mine recently began operation in southwestern Garrett County, Md. The present study was undertaken to describe the hydrogeologic system of the area to be mined and to document changes in the hydrologic regime as a result of mining. Mining encompasses three main drainage basins, all of which are tributary to the North Branch Potomac River. Mining of the Upper Freeport coal of the Allegheny Group (Pennsylvanian) began in the direction of dip, on the northwest limb of a northeast-plunging syncline.

Gaging stations were constructed on the three main streams—the North and South Forks of Sand Run, and Laurel Run. Water-quality monitors were also installed at these stations. Additional stream sites were chosen for periodic measurements of flow and water quality. Thirteen wells were drilled in three clusters, and water-level recorders were installed on each well. Water levels were measured periodically in six additional wells. Precipitation and mine-water discharge records were provided by the mine company.

Ground water in the study area occurs in three flow systems: shallow, intermediate, and deep. All are controlled by fracture permeability. Hydraulic conductivity of the shallow flow system is about two orders of magnitude greater than that of the deeper systems. The base of the fresh ground-water system was observed in well FA 31 at a depth of about 940 ft. The deep flow system, under considerable head, is probably part of a regional system whose recharge area may be approx-

Figure 34.—Some possible consequences of underground coal mining on the hydrologic system. The block corresponds approximately to the basin of the South Fork of Sand Run. →

BEFORE MINING — (1) A few fracture zones already exist, due to natural stresses.
(2) The regional flow system is effectively separated from shallower systems by underclay.

DURING MINING — (3) Water table is lowered in vicinity of active mining.
(4) Ground water flows into mine as a result of lowered pressure due to dewatering.
(5) Streamflow and water quality are affected by withdrawals for coal treatment and additions of treated mine pumpage.
(6) Undermined stream reaches lose water by leakage through the stream bed.

AFTER MINING — (7) Land surface subsides as overburden collapses into mine.
(8) Mine becomes an effective ground-water conduit.
(9) Fractures develop as overburden collapses into mine.
(10) Vertical flow is made easier by fracturing.
(11) Fractures increase transmissivity and storage.
(12) Baseflow increases, fed by increased upward leakage.

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imately 10 mi south-southeast of the study area and may discharge to the Cheat River valley about 10 mi west of the study area.

Earlier episodes of mining within the study area have had significant effects on the hydrologic system, most noticeably on stream-water quality. Three acid mine-drainage sites were identified in the study. Abandoned surface-mine areas are being used for disposal of mine spoil from current mining.

Effects of current mining, which mainly resulted from mine dewatering, also were assessed during the study period. Water levels within several hundred feet of the A Mine dropped significantly; the greatest drop was more than 370 ft in well FA 32, which is open above the Upper Freeport coal. The smallest decline at that site was in the shallowest well, FA 34 (about 77 ft). The water-level decline in FA 31, open below the coal, was only slightly greater than that in the shallow well, indicating the degree to which the underclay inhibits ground-water flow.

Sections of Laurel Run were found to be losing reaches. Measured losses were 0.4 and 0.8 $(ft^3/s)/mi$. No losses were measured in an earlier seepage run made before undermining reached these areas. Discharges of treated mine pumpage into two streams contributed significantly to their flow. The periods of discharge into the streams were irregular; the rate of discharge was generally about 3 ft^3/s. Flow past the gage on the South Fork was also affected by water withdrawals. Supply water for the coal-treatment plant was withdrawn from a pond constructed between the AMD treatment facility discharge point and the stream gage. The impact of withdrawal was to diminish streamflow past the gage.

Interbasin transfers affected streamflow. Laurel Run had the highest annual mean discharge per square mile (3.16 ft^3/s). This may be due to the addition of drainage of water from outside the Laurel Run basin through the abandoned Kempton Mine.

Surface-water quality was affected by discharge of treated mine pumpage. Treatment of this water raised its pH and removed dissolved iron, but increased the total dissolved solids content. When the AMD treatment facility was temporarily inoperative, pH of water sampled at the gage dropped to 4.2, and conductivity dropped from about 870 to about 650μmhos/cm.

Ground-water samples were obtained from eight observation wells. Most samples from deeper wells showed pH values as high as 11.6. These values may not be representative of formation water, but may indicate a reaction of the well water with cement grout. High dissolved sulfate content in one of the shallow wells (FB 25) indicates that the aquifer may be obtaining recharge from the South Fork, which has a high sulfate content resulting from the discharge of treated acid mine drainage into the stream.

A program for continued data collection was set up to monitor the hydrologic system as mining progresses.

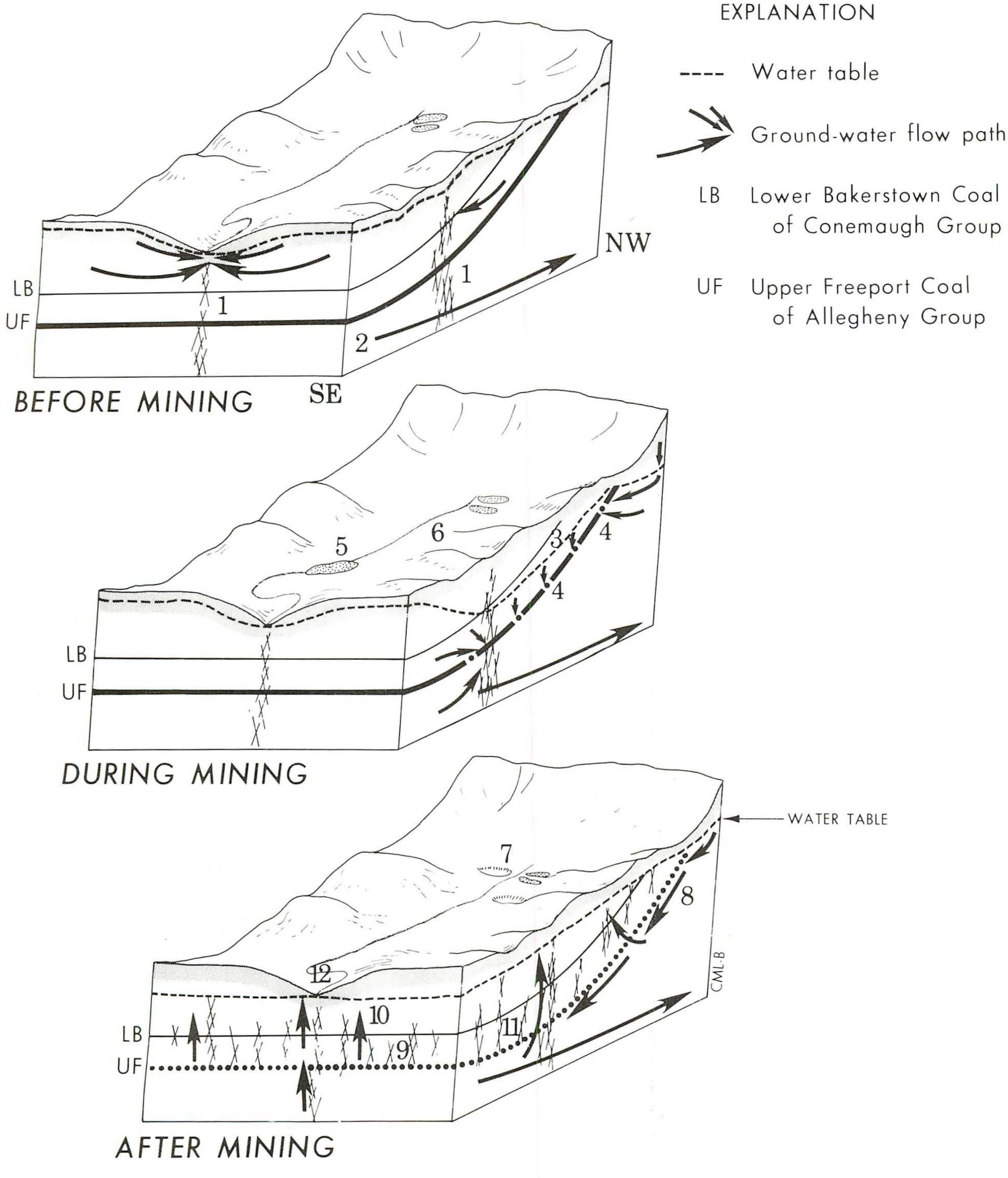

Figure 34.—Some possible consequences of underground coal mining on the hydrologic system.

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APPENDIXES

APPENDIX A

Surface-Water-Quality Records

LAUREL RUN NEAR RED OAK, MARYLAND (01594923)

DATE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	PH FIELD	PH LAB	TEMPER-ATURE, AIR (DEG C)	TEMPER-ATURE (DEG C)	TUR-BID-ITY (NTU)	OXYGEN, DIS-SOLVED (MG/L)	HARD-NESS (MG/L AS CACO3)
JULY, 1980										
22...	1230	9.6	700	3.1	3.0	--	21.0	6.0	--	120
NOV										
06...	1030	7.1	541	3.1	3.2	--	2.2	--	--	110
FEB, 1981										
19...	1330	38	297	3.0	3.4	11.0	5.4	--	10.3	59
MAY										
14...	1315	11	604	2.8	3.1	22.0	16.6	--	8.8	120
JULY										
01...	1300	5.2	731	2.6	3.0	--	14.2	--	--	150
AUG										
05...	1415	4.1	915	3.1	2.9	23.0	22.4	--	23.0	170

DATE	HARD-NESS, NONCAR-BONATE (MG/L CACO3)	ACIDITY (MG/L AS H)	ACIDITY (MG/L AS CACO3)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)	SODIUM, DIS-SOLVED (MG/L AS NA)	POTAS-SIUM, DIS-SOLVED (MG/L AS K)	SULFATE DIS-SOLVED (MG/L AS SO4)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL)	FLUO-RIDE, DIS-SOLVED (MG/L AS F)
JULY, 1980										
22...	115	2.1	104	28	11	2.7	1.8	200	1.8	0.20
NOV										
06...	104	2.0	99	24	11	3.0	1.7	190	1.4	.10
FEB, 1981										
19...	59	1.5	74	14	5.9	1.4	1.1	91	.8	.10
MAY										
14...	124	2.1	104	30	12	3.1	1.9	220	2.0	.20
JULY										
01...	145	--	--	35	14	3.4	2.1	200	1.8	.20
AUG										
05...	173	3.2	159	41	17	5.0	2.6	290	2.0	.30

DATE	SILICA, DIS-SOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED (MG/L)	SOLIDS, DIS-SOLVED (TONS PER DAY)	SOLIDS, RESIDUE AT 105 DEG. C, SUS-PENDED (MG/L)	SOLIDS, VOLA-TILE, DIS-SOLVED (MG/L)	NITRO-GEN, NITRATE TOTAL (MG/L AS N)	NITRO-GEN, NITRATE DIS-SOLVED (MG/L AS N)	NITRO-GEN, NO2+NO3 TOTAL (MG/L AS N)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N)
JULY, 1980										
22...	17	357	276	9.3	4	--	0.13	0.17	0.13	0.17
NOV										
06...	18	305	263	5.8	12	85	--	--	--	.26
FEB, 1981										
19...	11	166	133	17.0	17	46	--	--	--	1.1
MAY										
14...	20	365	300	11.1	12	104	--	--	--	.28
JULY										
^1...	21	452	291	6.3	14	149	--	--	--	.12
AUG										
05...	25	533	393	6.0	10	159	--	--	--	.04

DATE	NITRO-GEN, TOTAL (MG/L AS N)	NITRO-GEN DIS-SOLVED (MG/L AS N)	PHOS-PHORUS, TOTAL (MG/L AS P)	PHOS-PHORUS, DIS-SOLVED (MG/L AS P)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE)	IRON, DIS-SOLVED (UG/L AS FE)	MANGA-NESE, TOTAL RECOV-ERABLE (UG/L AS MN)	MANGA-NESE, SUS-PENDED RECOV. (UG/L AS MN)	MANGA-NESE, DIS-SOLVED (UG/L AS MN)
JULY, 1980									
22...	0.40	0.44	<0.01	<0.01	11000	11000	1100	0	1200
NOV									
06...	--	--	--	--	--	12000	--	--	1100
FEB, 1981									
19...	--	--	--	--	--	7200	--	--	570
MAY									
14...	--	--	--	--	--	10000	--	--	1200
JULY									
01...	--	--	--	--	--	12000	--	--	1400
AUG									
05...	--	--	--	--	--	8900	--	--	1600

CHESTNUT RIDGE RUN NEAR RED OAK, MARYLAND (01594926)

DATE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	PH FIELD	PH LAB	TEMPER-ATURE, AIR (DEG C)	TEMPER-ATURE (DEG C)	TUR-BID-ITY (NTU)	OXYGEN, DIS-SOLVED (MG/L)	HARD-NESS (MG/L AS CACO3)	HARD-NESS, NONCAR-BONATE (MG/L CACO3)
JULY, 1980											
22...	1400	--	130	6.9	6.5	22.0	21.0	8.1	--	46	38
NOV											
06...	0930	1.7	168	5.9	6.3	3.0	4.0	--	--	69	63
FEB, 1981											
19...	1230	14	78	4.6	5.0	11.0	2.6	--	12.0	32	31
MAY											
14...	1215	2.2	157	5.8	6.6	25.0	14.7	--	9.3	60	35
JULY											
01...	1215	2.0	178	5.7	5.8	--	15.2	--	--	72	66
AUG											
05...	1330	.88	540	5.3	4.7	23.0	21.5	--	7.6	240	242
13...	1325	.85	--	4.0	--	26.0	20.0	--	11.8	--	--

DATE	ACIDITY (MG/L AS H)	ACIDITY (MG/L AS CACO3)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)	SODIUM, DIS-SOLVED (MG/L AS NA)	POTAS-SIUM, DIS-SOLVED (MG/L AS K)	ALKA-LINITY FIELD (MG/L AS CACO3)	ALKA-LINITY LAB (MG/L AS CACO3)	CARBON DIOXIDE DIS-SOLVED (MG/L AS CO2)	SULFATE DIS-SOLVED (MG/L AS SO4)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL)
JULY, 1980											
22...	0.1	5.0	13	3.2	1.3	1.2	8.0	--	2.0	38	1.3
NOV											
06...	.1	5.0	20	4.7	2.3	1.5	--	6.0	15	62	2.0
FEB, 1981											
19...	.2	9.9	8.5	2.6	.8	.8	--	1.0	49	26	2.8
MAY											
14...	.1	5.0	17	4.2	2.5	1.3	--	25	77	51	2.0
JULY											
01...	.1	5.0	21	4.8	2.0	1.3	--	6.0	23	73	1.6
AUG											
05...	.1	5.0	73	15	7.3	3.6	--	2.0	19	250	3.5
13...	--	--	--	--	--	--	--	--	--	--	--

DATE	FLUO-RIDE, DIS-SOLVED (MG/L AS F)	SILICA, DIS-SOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED (MG/L)	SOLIDS, DIS-SOLVED (TONS PER DAY)	SOLIDS, RESIDUE AT 105 DEG. C, SUS-PENDED (MG/L)	SOLIDS, VOLA-TILE, DIS-SOLVED (MG/L)	NITRO-GEN, NITRATE TOTAL (MG/L AS N)	NITRO-GEN, NITRATE DIS-SOLVED (MG/L AS N)	NITRO-GEN, NO2+NO3 TOTAL (MG/L AS N)
JULY, 1980										
22...	0.10	5.6	70	70	--	13	--	0.38	0.30	0.38
NOV										
06...	.20	4.8	116	102	.53	4	17	--	--	--
FEB, 1981										
19...	<.10	4.2	56	47	2.1	8	9	--	--	--
MAY										
14...	<.10	4.3	108	98	.64	6	20	--	--	--
JULY										
01...	<.10	5.0	126	113	.68	12	23	--	--	--
AUG										
05...	.10	6.9	394	362	.94	15	26	--	--	--
13...	--	--	--	--	--	--	--	--	--	--

DATE	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N)	NITRO-GEN DIS-SOLVED (MG/L AS N)	PHOS-PHORUS, TOTAL (MG/L AS P)	PHOS-PHORUS, DIS-SOLVED (MG/L AS P)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE)	IRON, DIS-SOLVED (UG/L AS FE)	MANGA-NESE, TOTAL RECOV-ERABLE (UG/L AS MN)	MANGA-NESE, SUS-PENDED RECOV. (UG/L AS MN)	MANGA-NESE, DIS-SOLVED (UG/L AS MN)
JULY, 1980									
22...	0.30	0.54	0.010	<0.010	1400	160	450	0	460
NOV									
06...	.58	--	--	--	--	160	--	--	310
FEB, 1981									
19...	1.3	--	--	--	--	130	--	--	500
MAY									
14...	.80	--	--	--	--	90	--	--	360
JULY									
01...	.56	--	--	--	--	220	--	--	510
AUG									
05...	.40	--	--	--	--	220	--	--	1400
13...	--	--	--	--	--	--	--	--	--

DUTCH RUN AT RED OAK, MARYLAND (01594929)

DATE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	PH FIELD	PH LAB	TEMPER-ATURE, AIR (DEG C)	TEMPER-ATURE (DEG C)	OXYGEN, DIS-SOLVED (MG/L)	HARD-NESS (MG/L AS CACO3)	HARD-NESS, NONCAR-BONATE (MG/L CACO3)
NOV, 1980										
06...	1200	0.60	120	4.9	5.6	8.5	5.3	10.3	48	45
FEB, 1981										
19...	1130	9.4	98	4.5	4.6	9.0	1.6	5.4	35	--
MAY										
14...	1045	1.1	114	4.9	6.1	21.0	16.4	8.4	42	41
JULY										
01...	1015	.96	127	5.3	6.5	--	18.2	--	49	45
AUG										
05...	1230	.44	165	6.4	6.1	23.0	23.0	5.6	65	57
13...	--	.18	--	5.6	--	17.0	20.5	6.0	--	--

DATE	ACIDITY (MG/L AS H)	ACIDITY (MG/L AS CACO3)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)	SODIUM, DIS-SOLVED (MG/L AS NA)	POTAS-SIUM, DIS-SOLVED (MG/L AS K)	ALKA-LINITY LAB (MG/L AS CACO3)	CARBON DIOXIDE DIS-SOLVED (MG/L AS CO2)	SULFATE DIS-SOLVED (MG/L AS SO4)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL)
NOV, 1980										
06...	0.1	5.0	13	3.8	0.9	1.7	3.0	73	45	2.4
FEB, 1981										
19...	.2	9.9	9.4	2.9	.7	.8	--	--	36	1.4
MAY										
14...	.1	5.0	11	3.5	1.0	.8	1.0	24	43	1.4
JULY										
01...	--	--	13	3.9	.8	.9	4.0	39	36	1.4
AUG										
05...	.1	5.0	18	4.8	1.5	1.1	8.0	6.2	61	2.0
13...	--	--	--	--	--	--	--	--	--	--

DATE	FLUO-RIDE, DIS-SOLVED (MG/L AS F)	SILICA, DIS-SOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED (MG/L)	SOLIDS, DIS-SOLVED (TONS PER DAY)	SOLIDS, RESIDUE AT 105 DEG. C, SUS-PENDED (MG/L)	SOLIDS, VOLA-TILE, DIS-SOLVED (MG/L)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N)	IRON, DIS-SOLVED (UG/L AS FE)	MANGA-NESE, DIS-SOLVED (UG/L AS MN)
NOV, 1980										
06...	0.10	4.5	88	75	0.14	6	16	0.21	630	1200
FEB, 1981										
19...	<.10	4.7	66	--	1.7	8	6	.93	260	890
MAY										
14...	<.10	4.8	86	68	.26	18	18	.32	870	1200
JULY										
01...	.10	5.2	96	66	.25	14	25	.26	850	1300
AUG										
05...	<.10	5.1	113	101	.13	18	17	.14	1300	1200
13...	--	--	--	--	--	--	--	--	--	--

LAUREL RUN AT DOBBIN ROAD NEAR WILSON, MARYLAND (01594930)

DATE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	PH FIELD	PH LAB	TEMPER-ATURE, AIR (DEG C)	TEMPER-ATURE (DEG C)	TUR-BID-ITY (NTU)	OXYGEN, DIS-SOLVED (MG/L)	HARD-NESS (MG/L AS CACO3)	HARD-NESS, NONCAR-BONATE (MG/L CACO3)	ACIDITY (MG/L AS H)
APR, 1979												
18...	1030	30	370	3.7	--	12.0	5.0	--	11.4	73	73	--
JULY												
11...	1000	8.0	700	3.2	--	--	17.0	--	--	140	128	2.4
AUG												
15...	1000	15	463	3.0	--	--	16.0	--	--	97	96	1.4
21...	1500	12	510	3.3	--	21.0	18.5	--	7.6	97	--	1.7
OCT												
16...	0930	--	395	3.5	--	--	8.0	--	--	76	74	--
NOV												
15...	1245	25	400	3.7	--	3.0	2.5	--	12.3	78	78	.8
APR, 1980												
09...	1030	12	143	3.8	--	13.0	7.5	--	10.0	40	40	.4
JULY												
22...	1030	37	418	3.4	--	--	20.0	4.0	--	78	77	1.1
SEP												
10...	1415	9.9	622	2.4	--	18.5	17.5	--	8.4	--	--	1.7
OCT												
27...	1430	9.2	424	3.3	3.4	9.5	3.4	.40	11.2	110	110	1.4
NOV												
06...	1030	10	406	3.0	3.0	5.0	4.0	7.5	11.6	82	83	1.3
DEC												
16...	0900	22	385	2.8	3.3	.0	3.1	--	12.3	--	--	.2
JAN, 1981												
15...	1500	8.0	589	2.9	2.9	-2.0	.0	.40	12.3	120	--	3.0
FEB												
19...	0830	69	147	3.3	3.7	7.0	2.4	4.9	4.9	40	40	.8
APR												
09...	0930	20	448	2.8	3.9	13.0	10.9	18	9.8	110	113	1.4
MAY												
14...	0815	16	497	2.8	3.2	17.0	12.5	6.9	10.0	98	98	1.5
JUNE												
26...	1000	20	442	2.8	3.4	17.0	15.0	19	9.4	92	92	1.1
JULY												
01...	0900	10	568	2.8	3.2	--	15.5	3.8	--	120	115	1.8
AUG												
05...	0930	6.3	745	3.5	3.1	23.0	21.2	.40	8.0	160	163	2.0
SEP												
17...	1055	15	422	3.0	3.4	13.0	12.9	8.2	9.2	99	99	1.2

DATE	ACIDITY (MG/L AS CACO3)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)	SODIUM, DIS-SOLVED (MG/L AS NA)	POTAS-SIUM, DIS-SOLVED (MG/L AS K)	SULFATE DIS-SOLVED (MG/L AS SO4)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL)	FLUO-RIDE, DIS-SOLVED (MG/L AS F)	SILICA, DIS-SOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED (MG/L)	SOLIDS, DIS-SOLVED (TONS PER DAY)
APR, 1979												
18...	--	18	6.9	1.5	1.2	110	1.2	0.10	10	--	157	12.7
JULY												
11...	119	36	13	4.8	2.0	250	3.8	.20	19	404	353	8.7
AUG												
15...	70	25	8.4	1.8	1.6	160	2.6	.20	12	253	219	10.0
21...	84	24	9.0	2.2	1.4	160	--	.20	14	283	--	9.2
OCT												
16...	--	19	6.9	1.6	1.2	110	1.2	.20	11	179	159	--
NOV												
15...	40	19	7.4	2.1	1.3	130	1.1	.20	13	202	181	13.6
APR, 1980												
09...	20	11	3.0	.8	.9	42	.9	.10	5.3	94	66	3.0
JULY												
22...	55	20	6.8	1.9	1.4	120	1.6	.20	10	280	169	28.0
SEP												
10...	84	--	--	--	--	200	--	--	--	332	--	8.9
OCT												
27...	70	24	12	14	1.9	140	1.9	.10	17	252	219	6.3
NOV												
06...	65	20	7.9	2.4	1.7	140	1.2	.20	13	217	194	5.9
DEC												
16...	9.9	--	--	--	--	140	--	--	--	193	--	11.5
JAN, 1981												
15...	149	30	11	3.1	1.9	190	1.6	.30	20	339	280	7.3
FEB												
19...	40	9.8	3.7	1.0	.8	52	1.3	.10	7.3	96	80	17.9
APR												
09...	70	30	9.2	2.0	1.5	150	1.9	.20	17	258	225	13.9
MAY												
14...	74	24	9.3	2.6	1.6	160	1.8	.20	14	273	220	11.8
JUNE												
26...	55	23	8.4	2.0	1.5	130	1.4	.20	13	233	185	12.6
JULY												
01...	89	28	11	2.8	1.8	190	1.9	.20	16	317	257	8.6
AUG												
05...	99	42	14	4.6	2.5	200	2.2	.20	19	468	291	7.9
SEP												
17...	60	27	7.7	2.4	1.6	150	1.6	.10	11	261	209	10.6

DATE	SOLIDS, RESIDUE AT 105 DEG. C, SUS-PENDED (MG/L)	NITRO-GEN, NO2+NO3 TOTAL (MG/L AS N)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N)	NITRO-GEN,AM-MONIA + ORGANIC TOTAL (MG/L AS N)	NITRO-GEN,AM-MONIA + ORGANIC DIS. (MG/L AS N)	NITRO-GEN, TOTAL (MG/L AS N)	NITRO-GEN DIS-SOLVED (MG/L AS N)	PHOS-PHORUS, TOTAL (MG/L AS P)	ALUM-INUM, TOTAL RECOV-ERABLE (UG/L AS AL)	ALUM-INUM, DIS-SOLVED (UG/L AS AL)	ARSENIC TOTAL (UG/L AS AS)	ARSENIC DIS-SOLVED (UG/L AS AS)
APR, 1979												
18...	--	--	0.47	--	--	--	--	--	--	--	--	--
JULY												
11...	--	.08	--	--	--	--	--	<.010	--	6900	--	<1
AUG												
15...	--	.26	--	--	--	--	--	<.010	--	--	--	3
21...	--	--	--	--	--	--	--	--	--	--	--	--
OCT												
16...	--	.44	--	--	--	--	--	.000	--	--	--	--
NOV												
15...	--	--	.37	--	--	--	--	--	--	--	--	--
APR, 1980												
09...	--	--	.56	--	--	--	--	--	--	--	--	--
JULY												
22...	14	.17	.17	.22	.28	.39	.45	.020	--	--	--	--
SEP												
10...	--	--	--	--	--	--	--	--	--	--	--	--
OCT												
27...	15	.26	.26	.27	.18	.53	.44	.010	6000	5000	0	1
NOV												
06...	2	.32	.32	.08	.05	.40	.37	.000	--	--	--	--
DEC												
16...	--	--	--	--	--	--	--	--	--	--	--	--
JAN, 1981												
15...	14	.23	.27	.20	.19	.43	.46	<.010	6500	6500	1	1
FEB												
19...	21	1.1	1.1	.20	.10	1.3	1.2	.020	--	--	--	--
APR												
09...	21	.40	.29	.22	--	.62	--	<.010	5300	5100	1	1
MAY												
14...	8	.37	.36	.43	.31	.80	.67	<.010	--	--	--	--
JUNE												
26...	8	.37	.41	.10	.16	.47	.57	<.010	--	--	--	--
JULY												
01...	7	.27	.24	.47	.31	.74	.55	.010	--	--	--	--
AUG												
05...	14	.13	.16	.59	.51	.72	.67	.030	--	--	--	--
SEP												
17...	18	.29	.31	.38	.27	.67	.56	<.010	5300	1700	2	1

DATE	ARSENIC TOTAL IN BOT-TOM MA-TERIAL (UG/G AS AS)	BARIUM, TOTAL RECOV-ERABLE (UG/L AS BA)	BARIUM, DIS-SOLVED (UG/L AS BA)	BERYL-LIUM, DIS-SOLVED (UG/L AS BE)	BORON, TOTAL RECOV-ERABLE (UG/L AS B)	BORON, DIS-SOLVED (UG/L AS B)	CADMIUM TOTAL RECOV-ERABLE (UG/L AS CD)	CADMIUM DIS-SOLVED (UG/L AS CD)	CADMIUM RECOV. FM BOT-TOM MA-TERIAL (UG/G AS CD)	CHRO-MIUM, TOTAL RECOV-ERABLE (UG/L AS CR)	CHRO-MIUM, DIS-SOLVED (UG/L AS CR)	CHRO-MIUM, RECOV. FM BOT-TOM MA-TERIAL (UG/G)
APR, 1979												
18...	--	--	--	--	--	--	--	--	--	--	--	--
JULY												
11...	--	--	30	4	--	--	--	3	--	--	2	--
AUG												
15...	--	--	50	2	--	--	--	2	--	--	--	--
21...	0	--	--	--	--	--	--	--	<10	--	--	10
OCT												
16...	--	--	--	--	--	--	--	--	--	--	--	--
NOV												
15...	--	--	--	--	--	--	--	--	--	--	--	--
APR, 1980												
09...	--	--	--	--	--	--	--	--	--	--	--	--
JULY												
22...	--	--	--	--	--	--	--	--	--	--	--	--
SEP												
10...	--	--	--	--	--	--	--	--	--	--	--	--
OCT												
27...	--	200	70	--	0	0	0	0	--	10	<10	--
NOV												
06...	--	--	--	--	--	--	--	--	--	--	--	--
DEC												
16...	--	--	--	--	--	--	--	--	--	--	--	--
JAN, 1981												
15...	--	<50	40	--	10	10	0	3	--	10	10	--
FEB												
19...	--	--	--	--	--	--	--	--	--	--	--	--
APR												
09...	--	100	40	--	10	10	0	1	--	<10	<10	--
MAY												
14...	--	--	--	--	--	--	--	--	--	--	--	--
JUNE												
26...	--	--	--	--	--	--	--	--	--	--	--	--
JULY												
01...	--	--	--	--	--	--	--	--	--	--	--	--
AUG												
05...	--	--	--	--	--	--	--	--	--	--	--	--
SEP												
04...	--	--	--	--	--	--	--	--	--	--	--	--
17...	--	100	<50	--	<10	<10	10	1	--	20	10	--

DATE	COBALT, DIS- SOLVED (UG/L AS CO)	COBALT, RECOV. FM BOT- TOM MA- TERIAL (UG/G AS CO)	COPPER, TOTAL RECOV- ERABLE (UG/L AS CU)	COPPER, DIS- SOLVED (UG/L AS CU)	COPPER, RECOV. FM BOT- TOM MA- TERIAL (UG/G AS CU)	IRON, TOTAL RECOV- ERABLE (UG/L AS FE)	IRON, DIS- SOLVED (UG/L AS FE)	IRON, RECOV. FM BOT- TOM MA- TERIAL (UG/G AS FE)	LEAD, TOTAL RECOV- ERABLE (UG/L AS PB)	LEAD, DIS- SOLVED (UG/L AS PB)	LEAD, RECOV. FM BOT- TOM MA- TERIAL (UG/G AS PB)
APR, 1979											
18...	--	--	--	--	--	5600	5500	--	--	--	--
JULY											
11...	87	--	--	9	--	5400	5800	--	--	10	--
AUG											
15...	54	--	--	4	--	5000	5000	--	--	<2	--
21...	--	20	--	--	30	4200	4200	220000	--	--	20
OCT											
16...	--	--	--	--	--	6400	6300	--	--	--	--
NOV											
15...	--	--	--	--	--	6600	6600	--	--	--	--
APR, 1980											
09...	--	--	--	--	--	5700	1600	--	--	--	--
JULY											
22...	--	--	--	--	--	5200	4300	--	--	--	--
SEP											
10...	--	--	--	--	--	5300	4600	--	--	--	--
OCT											
27...	--	--	12	8	--	10000	--	--	0	7	--
NOV											
06...	--	--	--	--	--	5800	5600	--	--	--	--
DEC											
16...	--	--	--	--	--	7700	7900	--	--	--	--
JAN, 1981											
15...	--	--	30	6	--	10000	11000	--	0	0	--
FEB											
19...	--	--	--	--	--	4700	3100	--	--	--	--
APR											
09...	--	--	7	44	--	5900	6600	--	5	0	--
MAY											
14...	--	--	--	--	--	5000	5000	--	--	--	--
JUNE											
26...	--	--	--	--	--	4400	4400	--	--	--	--
JULY											
01...	--	--	--	--	--	4700	4600	--	--	--	--
AUG											
05...	--	--	--	--	--	5100	4300	--	--	--	--
SEP											
17...	--	--	10	3	--	4800	4600	--	<100	5	--

DATE	LITHIUM DIS- SOLVED (UG/L AS LI)	MANGA- NESE, TOTAL RECOV- ERABLE (UG/L AS MN)	MANGA- NESE, DIS- SOLVED (UG/L AS MN)	MANGA- NESE, RECOV. FM BOT- TOM MA- TERIAL (UG/G)	MERCURY TOTAL RECOV- ERABLE (UG/L AS HG)	MERCURY DIS- SOLVED (UG/L AS HG)	MERCURY RECOV. FM BOT- TOM MA- TERIAL (UG/G AS HG)	MOLYB- DENUM, DIS- SOLVED (UG/L AS MO)	NICKEL, TOTAL RECOV- ERABLE (UG/L AS NI)	NICKEL, DIS- SOLVED (UG/L AS NI)	SELE- NIUM, TOTAL (UG/L AS SE)
APR, 1979											
18...	--	760	790	--	--	--	--	--	--	--	--
JULY											
11...	40	1300	1300	--	--	<.5	--	<1	--	170	--
AUG											
15...	30	1200	1200	--	--	<.5	--	<1	--	85	--
21...	--	1000	1200	40	--	--	.00	--	--	--	--
OCT											
16...	--	840	860	--	--	--	--	--	--	--	--
NOV											
15...	--	810	770	--	--	--	--	--	--	--	--
APR, 1980											
09...	--	480	470	--	--	--	--	--	--	--	--
JULY											
22...	--	850	870	--	--	--	--	--	--	--	--
SEP											
10...	--	1200	1300	--	--	--	--	--	--	--	--
OCT											
27...	--	1100	970	--	<.1	<.1	--	--	100	94	0
NOV											
06...	--	800	800	--	--	--	--	--	--	--	--
DEC											
16...	--	890	870	--	--	--	--	--	--	--	--
JAN, 1981											
15...	--	980	1200	--	<.1	<.1	--	--	110	--	0
FEB											
19...	--	480	490	--	--	--	--	--	--	--	--
APR											
09...	--	990	1100	--	<.1	<.1	--	--	99	130	0
MAY											
14...	--	950	960	--	--	--	--	--	--	--	--
JUNE											
26...	--	950	970	--	--	--	--	--	--	--	--
JULY											
01...	--	1000	1000	--	--	--	--	--	--	--	--
AUG											
05...	--	1400	1400	--	--	--	--	--	--	--	--
SEP											
17...	--	800	880	--	<.1	<.1	--	--	83	83	<1

LAUREL RUN AT DOBBIN ROAD NEAR WILSON, MARYLAND (01594930) (CONTINUED)

DATE	SELE-NIUM, DIS-SOLVED (UG/L AS SE)	SELE-NIUM, TOTAL IN BOT-TOM MA-TERIAL (UG/G)	SILVER, TOTAL RECOV-ERABLE (UG/L AS AG)	SILVER, DIS-SOLVED (UG/L AS AG)	STRON-TIUM, DIS-SOLVED (UG/L AS SR)	ZINC, TOTAL RECOV-ERABLE (UG/L AS ZN)	ZINC, DIS-SOLVED (UG/L AS ZN)	ZINC, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS ZN)	CARBON, ORGANIC TOTAL (MG/L AS C)	CYANIDE TOTAL (MG/L AS CN)	PHENOLS TOTAL (UG/L)
APR, 1979											
18...	--	--	--	--	--	--	--	--	--	--	--
JULY											
11...	<1	--	--	<2	210	--	400	--	--	--	--
AUG											
15...	<1	--	--	--	120	--	240	--	--	--	--
21...	--	0	--	--	--	--	--	60	--	--	--
OCT											
16...	--	--	--	--	--	--	--	--	--	--	--
NOV											
15...	--	--	--	--	--	--	--	--	--	--	--
APR, 1980											
09...	--	--	--	--	--	--	--	--	3.7	--	--
JULY											
22...	--	--	--	--	--	--	--	--	--	--	--
SEP											
10...	--	--	--	--	--	--	--	--	--	--	--
OCT											
27...	0	--	0	0	--	270	240	--	--	--	--
NOV											
06...	--	--	--	--	--	--	--	--	1.9	.00	4
DEC											
16...	--	--	--	--	--	--	--	--	--	--	--
JAN, 1981											
15...	0	--	0	0	--	350	370	--	--	--	--
FEB											
19...	--	--	--	--	--	--	--	--	1.4	<.01	0
APR											
09...	0	--	1	0	--	300	350	--	1.2	--	--
MAY											
14...	--	--	--	--	--	--	--	--	1.4	<.01	0
JUNE											
26...	--	--	--	--	--	--	--	--	2.9	--	--
JULY											
01...	--	--	--	--	--	--	--	--	1.7	--	--
AUG											
05...	--	--	--	--	--	--	--	--	1.6	<.01	<1
SEP											
17...	<1	--	<1	<1	--	250	240	--	1.2	--	--

NORTH BRANCH POTOMAC RIVER AT WILSON, MARYLAND (01594931)

DATE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	PH FIELD	PH LAB	TEMPER-ATURE, AIR (DEG C)	TEMPER-ATURE (DEG C)	OXYGEN, DIS-SOLVED (MG/L)	HARD-NESS (MG/L AS CACO3)	HARD-NESS, NONCAR-BONATE (MG/L CACO3)	ACIDITY (MG/L AS H)
APR, 1979											
18...	1230	91	460	4.8	--	12.0	9.0	10.0	--	--	--
AUG											
21...	1145	36	710	3.9	--	20.5	19.0	7.7	--	--	.6
NOV											
15...	1430	62	390	4.6	--	2.0	3.0	12.2	--	--	.4
APR, 1980											
09...	1345	350	189	4.7	--	18.0	10.5	9.1	82	80	.1
SEP											
10...	1230	23	1070	3.5	--	16.5	19.3	8.5	--	--	.6
DEC											
16...	1145	65	588	3.7	4.3	.0	2.9	12.5	--	--	.3
AUG, 1981											
25...	0930	14	2000	4.4	4.7	15.0	17.5	8.6	--	--	.8

DATE	ACIDITY (MG/L AS CACO3)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)	SODIUM, DIS-SOLVED (MG/L AS NA)	POTAS-SIUM, DIS-SOLVED (MG/L AS K)	ALKA-LINITY FIELD (MG/L AS CACO3)	CARBON DIOXIDE DIS-SOLVED (MG/L AS CO2)	SULFATE DIS-SOLVED (MG/L AS SO4)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL)	FLUO-RIDE, DIS-SOLVED (MG/L AS F)	SILICA, DIS-SOLVED (MG/L AS SIO2)
APR, 1979											
18...	--	--	--	--	--	--	--	190	--	--	--
AUG											
21...	30	--	--	--	--	--	--	350	--	--	--
NOV											
15...	20	--	--	--	--	.0	.0	150	--	--	--
APR, 1980											
09...	5.0	28	3.0	1.1	.9	2.0	77	68	.9	.10	4.1
SEP											
10...	27	--	--	--	--	.0	.0	480	--	--	--
DEC											
16...	17	--	--	--	--	.0	.0	240	--	--	--
AUG, 1981											
25...	41	--	--	--	--	.0	.0	800	--	--	--

DATE	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED (MG/L)	SOLIDS, DIS-SOLVED (TONS PER DAY)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N)	ARSENIC TOTAL IN BOT-TOM MA-TERIAL (UG/G AS AS)	CADMIUM RECOV. FM BOT-TOM MA-TERIAL (UG/G AS CD)	CHRO-MIUM, RECOV. FM BOT-TOM MA-TERIAL (UG/G)	COBALT, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS CO)	COPPER, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS CU)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE)
APR, 1979										
18...	--	--	--	--	--	--	--	--	--	2100
AUG										
21...	532	--	51.7	--	<1	<10	20	<10	20	1400
NOV										
15...	240	--	40.2	--	--	--	--	--	--	3300
APR, 1980										
09...	137	108	129	.47	--	--	--	--	--	3800
SEP										
10...	823	--	51.1	--	--	--	--	--	--	1600
DEC										
16...	369	--	64.8	--	--	--	--	--	--	2800
AUG, 1981										
25...	1810	--	68.4	--	--	--	--	--	--	1200

DATE	IRON, DIS-SOLVED (UG/L AS FE)	IRON, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS FE)	LEAD, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS PB)	MANGA-NESE, TOTAL RECOV-ERABLE (UG/L AS MN)	MANGA-NESE, DIS-SOLVED (UG/L AS MN)	MANGA-NESE, RECOV. FM BOT-TOM MA-TERIAL (UG/G)	MERCURY RECOV. FM BOT-TOM MA-TERIAL (UG/G AS HG)	SELE-NIUM, TOTAL IN BOT-TOM MA-TERIAL (UG/G)	ZINC, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS ZN)	CARBON, ORGANIC TOTAL (MG/L AS C)
APR, 1979										
18...	1400	--	--	360	370	--	--	--	--	--
AUG										
21...	920	42000	10	620	630	150	<.01	<1	50	--
NOV										
15...	2000	--	--	480	500	--	--	--	--	--
APR, 1980										
09...	500	--	--	290	240	--	--	--	--	4.1
SEP										
10...	870	--	--	610	640	--	--	--	--	--
DEC										
16...	180	--	--	400	380	--	--	--	--	--
AUG, 1981										
25...	430	--	--	790	860	--	--	--	--	--

SOUTH FORK SAND RUN AT MOON RIDGE (01594932)

DATE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	PH FIELD	PH LAB	TEMPER-ATURE, AIR (DEG C)	TEMPER-ATURE (DEG C)	OXYGEN, DIS-SOLVED (MG/L)	HARD-NESS (MG/L AS CACO3)	HARD-NESS, NONCAR-BONATE (MG/L CACO3)
NOV, 1980										
05...	1230	0.59	315	6.9	7.4	5.0	5.7	9.7	93	60
FEB, 1981										
20...	1130	8.4	--	7.0	--	8.0	3.0	9.5	--	--
MAY										
14...	1415	.75	183	6.3	7.4	27.0	16.7	8.4	69	44
JUNE										
30...	1400	.99	206	6.7	7.0	--	17.0	--	90	68
AUG										
12...	1330	.12	678	6.8	6.7	23.0	19.8	--	230	222

DATE	ACIDITY (MG/L AS H)	ACIDITY (MG/L AS CACO3)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)	SODIUM, DIS-SOLVED (MG/L AS NA)	POTAS-SIUM, DIS-SOLVED (MG/L AS K)	CARBON DIOXIDE DIS-SOLVED (MG/L AS CO2)	SULFATE DIS-SOLVED (MG/L AS SO4)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL)	FLUO-RIDE, DIS-SOLVED (MG/L AS F)
NOV, 1980										
05...	0.0	0.0	29	4.9	28	2.0	8.0	100	2.2	0.10
FEB, 1981										
20...	--	--	--	--	--	--	--	--	--	--
MAY										
14...	.1	5.0	21	4.0	6.1	1.1	24	56	1.4	<.10
JUNE										
30...	--	--	28	4.8	3.1	1.3	8.5	65	1.1	<.10
AUG										
12...	--	--	71	14	48	3.0	4.0	300	1.9	.10

DATE	SILICA, DIS-SOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED (MG/L)	SOLIDS, DIS-SOLVED (TONS PER DAY)	SOLIDS, RESIDUE AT 105 DEG. C, SUS-PENDED (MG/L)	SOLIDS, VOLA-TILE, DIS-SOLVED (MG/L)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N)	IRON, DIS-SOLVED (UG/L AS FE)	MANGA-NESE, DIS-SOLVED (UG/L AS MN)
NOV, 1980									
05...	4.0	210	190	0.33	25	21	0.50	180	180
FEB, 1981									
20...	--	--	--	--	--	--	--	--	--
MAY									
14...	3.7	122	109	.25	14	26	.59	90	120
JUNE									
30...	4.7	146	121	.39	17	29	.43	60	140
AUG									
12...	7.4	463	455	--	8	24	.34	130	1700

SOUTH FORK SAND RUN NEAR WILSON, MARYLAND (01594934)

DATE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	PH FIELD	PH LAB	TEMPER-ATURE, AIR (DEG C)	TEMPER-ATURE (DEG C)	COLOR (PLAT-INUM-COBALT UNITS)	TUR-BID-ITY (NTU)	OXYGEN, DIS-SOLVED (MG/L)	HARD-NESS (MG/L AS CACO3)
JULY, 1979											
12...	1100	1.9	240	7.4	--	--	18.0	4	--	--	110
AUG											
14...	1315	2.6	272	6.4	--	--	18.0	10	--	--	100
OCT											
16...	1100	--	125	5.7	--	--	9.0	0	--	--	41
APR, 1980											
09...	1130	19	138	6.7	--	17.0	9.0	--	--	9.7	57
MAY											
07...	0930	2.7	150	6.1	--	14.0	13.5	--	--	9.4	60
SEP											
10...	0845	.93	--	6.8	--	11.0	15.2	--	--	9.5	--
OCT											
27...	1300	1.8	679	7.1	7.3	10.0	6.8	--	.60	9.9	280
NOV											
05...	1030	.48	620	6.9	7.4	6.0	6.3	--	5.3	9.2	260
DEC											
16...	1015	1.8	335	6.0	6.8	.0	2.3	--	--	12.2	--
JAN, 1981											
15...	1100	.09	570	6.5	7.2	-2.0	.0	--	2.2	12.2	250
FEB											
20...	0900	12	212	6.8	7.1	8.0	2.5	--	39	12.7	89
APR											
09...	1130	2.8	594	6.3	6.9	13.0	9.8	--	4.1	9.6	350
MAY											
14...	1530	.73	629	6.4	7.0	27.0	20.1	--	.55	7.9	280
JUNE											
26...	1230	5.2	309	6.8	6.6	26.0	19.5	--	45	8.7	140
30...	0945	3.4	570	6.6	6.4	26.0	18.9	--	1.6	8.4	290
AUG											
12...	0945	.15	959	6.0	7.0	20.0	21.3	--	.70	--	510
SEP											
17...	1315	3.5	671	4.2	4.7	14.0	17.0	--	1.7	8.1	350

DATE	HARD-NESS, NONCAR-BONATE (MG/L CACO3)	ACIDITY (MG/L AS H)	ACIDITY (MG/L AS CACO3)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)	SODIUM, DIS-SOLVED (MG/L AS NA)	POTAS-SIUM, DIS-SOLVED (MG/L AS K)	BICAR-BONATE FET-FLD (MG/L AS HCO3)	CAR-BONATE FET-FLD (MG/L AS CO3)	ALKA-LINITY FIELD (MG/L AS CACO3)	ALKA-LINITY LAB (MG/L AS CACO3)
JULY, 1979											
12...	82	--	--	36	4.7	1.0	1.5	34	0	28	--
AUG											
14...	80	--	--	35	4.1	.8	2.3	31	0	25	--
OCT											
16...	38	--	--	13	2.1	.5	.9	--	--	3.0	--
APR, 1980											
09...	30	.1	5.0	19	2.4	4.6	1.2	--	--	27	--
MAY											
07...	56	.1	5.0	19	3.0	3.4	1.0	--	--	4.0	--
SEP											
10...	--	.0	.0	--	--	--	--	--	--	34	--
OCT											
27...	248	--	--	97	9.5	25	4.2	--	--	--	34
NOV											
05...	233	.1	5.0	84	12	23	3.8	--	--	--	27
DEC											
16...	--	.0	.0	--	--	--	--	--	--	13	--
JAN, 1981											
15...	229	.2	9.9	81	11	7.0	2.7	--	--	--	19
FEB											
20...	80	--	--	29	4.1	4.6	1.2	--	--	--	9.0
APR											
09...	335	.4	20	120	12	5.7	2.4	--	--	--	15
MAY											
14...	260	.1	5.0	94	12	8.3	3.4	--	--	--	25
JUNE											
26...	118	.2	9.9	46	5.7	2.8	1.5	--	--	21	19
30...	271	.1	5.0	95	12	4.5	2.6	--	--	--	16
AUG											
12...	506	.3	15	170	20	6.8	3.7	--	--	--	2.0
SEP											
17...	354	.3	15	120	13	3.9	2.9	--	--	.0	2.0

DATE	CARBON DIOXIDE DIS- SOLVED (MG/L AS CO2)	SULFATE DIS- SOLVED (MG/L AS SO4)	CHLO- RIDE, DIS- SOLVED (MG/L AS CL)	FLUO- RIDE, DIS- SOLVED (MG/L AS F)	SILICA, DIS- SOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DIS- SOLVED (MG/L)	SOLIDS, SUM OF CONSTI- TUENTS, DIS- SOLVED (MG/L)	SOLIDS, DIS- SOLVED (TONS PER DAY)	SOLIDS, RESIDUE AT 105 DEG. C, SUS- PENDED (MG/L)	NITRO- GEN, NO2+NO3 TOTAL (MG/L AS N)	NITRO- GEN, NO2+NO3 DIS- SOLVED (MG/L AS N)
JULY, 1979											
12...	2.2	79	1.9	0.10	3.8	161	145	0.83	--	0.21	--
AUG											
14...	20	82	2.6	.10	4.3	157	148	1.1	--	.43	--
OCT											
16...	12	40	1.2	.10	4.3	69	65	--	--	.61	--
APR, 1980											
09...	10	43	1.2	.10	3.1	103	91	5.3	--	--	.61
MAY											
07...	6.2	53	1.3	.10	4.3	98	88	.71	--	--	.55
SEP											
10...	--	280	--	--	--	478	--	1.2	--	--	--
OCT											
27...	5.2	290	3.5	.10	3.6	517	456	2.5	37	.39	.38
NOV											
05...	6.6	250	2.9	.10	4.7	464	400	.60	17	.45	.44
DEC											
16...	25	140	--	--	--	224	--	1.1	--	--	--
JAN, 1981											
15...	12	250	3.0	.20	5.3	395	373	.10	6	.53	.39
FEB											
20...	2.8	73	2.6	<.10	3.7	145	124	4.7	51	.94	.92
APR											
09...	15	270	3.0	.20	4.6	412	428	3.1	20	.34	--
MAY											
14...	19	260	4.1	.20	4.5	459	402	.90	5	.39	.38
JUNE											
26...	6.4	81	4.9	.10	4.6	214	160	3.0	51	.46	.48
30...	7.8	270	2.1	.20	5.0	446	402	4.1	5	.49	.38
AUG											
12...	3.9	470	2.2	.30	7.5	781	683	.32	5	.20	.21
SEP											
17...	.0	320	2.8	.20	5.4	537	472	5.1	11	.24	.33

DATE	NITRO- GEN,AM- MONIA + ORGANIC TOTAL (MG/L AS N)	NITRO- GEN,AM- MONIA + ORGANIC DIS. (MG/L AS N)	NITRO- GEN, TOTAL (MG/L AS N)	NITRO- GEN DIS- SOLVED (MG/L AS N)	PHOS- PHORUS, TOTAL (MG/L AS P)	ALUM- INUM, TOTAL RECOV- ERABLE (UG/L AS AL)	ALUM- INUM, DIS- SOLVED (UG/L AS AL)	ARSENIC TOTAL (UG/L AS AS)	ARSENIC DIS- SOLVED (UG/L AS AS)	ARSENIC TOTAL IN BOT- TOM MA- TERIAL (UG/G AS AS)	BARIUM, TOTAL RECOV- ERABLE (UG/L AS BA)
JULY, 1979											
12...	--	--	--	--	0.010	--	30	--	<1	--	--
AUG											
14...	--	--	--	--	.020	--	--	--	1	--	--
OCT											
16...	--	--	--	--	.010	--	--	--	--	--	--
APR, 1980											
09...	--	--	--	--	--	--	--	--	--	--	--
MAY											
07...	--	--	--	--	--	--	--	--	--	--	--
SEP											
10...	--	--	--	--	--	--	--	--	--	0	--
OCT											
27...	.34	.16	.73	.54	.030	300	50	1	1	--	100
NOV											
05...	.08	.06	.53	.50	.020	--	--	--	--	--	--
DEC											
16...	--	--	--	--	--	--	--	--	--	--	--
JAN, 1981											
15...	.13	<.10	.66	--	<.010	200	0	1	1	--	100
FEB											
20...	.28	.23	1.2	1.2	.050	--	--	--	--	--	--
APR											
09...	.16	.04	.50	.50	<.010	500	100	0	1	--	100
MAY											
14...	.39	.42	.78	.80	.070	--	--	--	--	--	--
JUNE											
26...	.28	.32	.74	.80	.040	--	--	--	--	--	--
30...	.29	.32	.78	.70	<.010	--	--	--	--	--	--
AUG											
12...	.43	.15	.63	.36	<.010	--	--	--	--	--	--
SEP											
17...	.34	.27	.58	.52	<.010	1600	1000	1	1	--	100

DATE	BARIUM, DIS-SOLVED (UG/L AS BA)	BERYL-LIUM, DIS-SOLVED (UG/L AS BE)	BORON, TOTAL RECOV-ERABLE (UG/L AS B)	BORON, DIS-SOLVED (UG/L AS B)	CADMIUM TOTAL RECOV-ERABLE (UG/L AS CD)	CADMIUM DIS-SOLVED (UG/L AS CD)	CADMIUM RECOV. FM BOT-TOM MA-TERIAL (UG/G AS CD)	CHRO-MIUM, TOTAL RECOV-ERABLE (UG/L AS CR)	CHRO-MIUM, DIS-SOLVED (UG/L AS CR)	CHRO-MIUM, RECOV. FM BOT-TOM MA-TERIAL (UG/G)	COBALT, DIS-SOLVED (UG/L AS CO)
JULY, 1979											
12...	60	2	--	--	--	3	--	--	<2	--	2
AUG											
14...	60	<10	--	--	--	2	--	--	--	--	3
OCT											
16...	--	--	--	--	--	--	--	--	--	--	--
APR, 1980											
09...	--	--	--	--	--	--	--	--	--	--	--
MAY											
07...	--	--	--	--	--	--	--	--	--	--	--
SEP											
10...	--	--	--	--	--	--	<10	--	--	70	--
OCT											
27...	100	--	4	2	0	2	--	10	10	--	--
NOV											
05...	--	--	--	--	--	--	--	--	--	--	--
DEC											
16...	--	--	--	--	--	--	--	--	--	--	--
JAN, 1981											
15...	80	--	10	10	0	1	--	10	10	--	--
FEB											
20...	--	--	--	--	--	--	--	--	--	--	--
APR											
09...	70	--	20	20	0	2	--	<10	<10	--	--
MAY											
14...	--	--	--	--	--	--	--	--	--	--	--
JUNE											
26...	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--
AUG											
12...	--	--	--	--	--	--	--	--	--	--	--
SEP											
17...	100	--	10	<10	10	2	--	20	10	--	--

DATE	COBALT, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS CO)	COPPER, TOTAL RECOV-ERABLE (UG/L AS CU)	COPPER, DIS-SOLVED (UG/L AS CU)	COPPER, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS CU)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE)	IRON, DIS-SOLVED (UG/L AS FE)	IRON, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS FE)	LEAD, TOTAL RECOV-ERABLE (UG/L AS PB)	LEAD, DIS-SOLVED (UG/L AS PB)	LEAD, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS PB)	LITHIUM DIS-SOLVED (UG/L AS LI)
JULY, 1979											
12...	--	--	ND	--	420	30	--	--	6	--	1
AUG											
14...	--	--	4	--	1500	700	--	--	ND	--	4
OCT											
16...	--	--	--	--	780	400	--	--	--	--	--
APR, 1980											
09...	--	--	--	--	9000	40	--	--	--	--	--
MAY											
07...	--	--	--	--	600	10	--	--	--	--	--
SEP											
10...	30	--	--	<10	920	0	3600	--	--	<10	--
OCT											
27...	--	10	2	--	1500	30	--	0	0	--	--
NOV											
05...	--	--	--	--	1100	90	--	--	--	--	--
DEC											
16...	--	--	--	--	570	60	--	--	--	--	--
JAN, 1981											
15...	--	10	0	--	580	330	--	0	0	--	--
FEB											
20...	--	--	--	--	2500	20	--	--	--	--	--
APR											
09...	--	2	6	--	650	30	--	5	0	--	--
MAY											
14...	--	--	--	--	390	<10	--	--	--	--	--
JUNE											
26...	--	--	--	--	2200	<10	--	--	--	--	--
30...	--	--	--	--	490	<10	--	--	--	--	--
AUG											
12...	--	--	--	--	400	120	--	--	--	--	--
SEP											
17...	--	30	17	--	440	170	--	<100	3	--	--

DATE	MANGANESE, TOTAL RECOVERABLE (UG/L AS MN)	MANGANESE, DISSOLVED (UG/L AS MN)	MANGANESE, RECOV. FM BOTTOM MATERIAL (UG/G)	MERCURY TOTAL RECOVERABLE (UG/L AS HG)	MERCURY DISSOLVED (UG/L AS HG)	MERCURY RECOV. FM BOTTOM MATERIAL (UG/G AS HG)	MOLYBDENUM, DISSOLVED (UG/L AS MO)	NICKEL, TOTAL RECOVERABLE (UG/L AS NI)	NICKEL, DISSOLVED (UG/L AS NI)	SELENIUM, TOTAL (UG/L AS SE)	SELENIUM, DISSOLVED (UG/L AS SE)
JULY, 1979 12...	60	40	--	--	<0.5	--	1	--	4	--	<1
AUG 14...	290	270	--	--	<.5	--	<1	--	5	--	<1
OCT 16...	620	620	--	--	--	--	--	--	--	--	--
APR, 1980 09...	490	340	--	--	--	--	--	--	--	--	--
MAY 07...	550	540	--	--	--	--	--	--	--	--	--
SEP 10...	490	480	580	--	--	.00	--	--	--	--	--
OCT 27...	790	670	--	<.1	<.1	--	--	18	12	1	1
NOV 05...	780	860	--	--	--	--	--	--	--	--	--
DEC 16...	640	570	--	--	--	--	--	--	--	--	--
JAN, 1981 15...	720	820	--	<.1	<.1	--	--	32	35	1	1
FEB 20...	440	430	--	--	--	--	--	--	--	--	--
APR 09...	760	890	--	<.1	<.1	--	--	52	54	1	1
MAY 14...	640	650	--	--	--	--	--	--	--	--	--
JUNE 26...	490	490	--	--	--	--	--	--	--	--	--
30...	590	660	--	--	--	--	--	--	--	--	--
AUG 12...	1100	1300	--	--	--	--	--	--	--	--	--
SEP 17...	2100	2400	--	<.1	<.1	--	--	140	100	1	1

DATE	SELENIUM, TOTAL IN BOTTOM MATERIAL (UG/G) (01148)	SILVER, TOTAL RECOVERABLE (UG/L AS AG) (01077)	SILVER, DISSOLVED (UG/L AS AG) (01075)	STRONTIUM, DISSOLVED (UG/L AS SR) (01080)	ZINC, TOTAL RECOVERABLE (UG/L AS ZN) (01092)	ZINC, DISSOLVED (UG/L AS ZN) (01090)	ZINC, RECOV. FM BOTTOM MATERIAL (UG/G AS ZN) (01093)	CARBON, ORGANIC TOTAL (MG/L AS C) (00680)	CYANIDE TOTAL (MG/L AS CN) (00720)	PHENOLS TOTAL (UG/L) (32730)
JULY, 1979 12...	--	--	<2	140	--	20	--	--	--	--
AUG 14...	--	--	--	140	--	30	--	--	--	--
OCT 16...	--	--	--	--	--	--	--	--	--	--
APR, 1980 09...	--	--	--	--	--	--	--	6.2	--	--
MAY 07...	--	--	--	--	--	--	--	--	--	--
SEP 10...	0	--	--	--	--	--	70	--	--	--
OCT 27...	--	0	0	--	10	9	--	--	--	--
NOV 05...	--	--	--	--	--	--	--	3.4	.00	4
DEC 16...	--	--	--	--	--	--	--	--	--	--
JAN, 1981 15...	--	0	0	--	60	30	--	--	--	--
FEB 20...	--	--	--	--	--	--	--	2.5	<.01	0
APR 09...	--	0	0	--	140	120	--	2.4	--	--
MAY 14...	--	--	--	--	--	--	--	2.0	<.01	0
JUNE 26...	--	--	--	--	--	--	--	5.7	--	--
30...	--	--	--	--	--	--	--	2.3	--	--
AUG 12...	--	--	--	--	--	--	--	.7	<.01	<1
SEP 17...	--	<1	<1	--	320	300	--	.8	--	--

NORTH FORK SAND RUN AT MOON RIDGE, MARYLAND (01594935)

DATE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	PH FIELD	PH LAB	TEMPER-ATURE, AIR (DEG C)	TEMPER-ATURE (DEG C)	OXYGEN, DIS-SOLVED (MG/L)	HARD-NESS (MG/L AS CACO3)	HARD-NESS, NONCAR-BONATE (MG/L CACO3)	ACIDITY (MG/L AS H)	ACIDITY (MG/L AS CACO3)
SEP, 1980												
10...	0845	--	--	6.8	--	11.0	15.2	9.5	--	--	--	--
NOV												
05...	1240	.32	122	3.9	4.2	6.0	6.7	11.0	36	36	.3	15
FEB, 1981												
18...	1600	9.5	83	3.5	4.2	10.0	1.8	8.8	29	29	.5	25
MAY												
15...	1045	2.5	92	3.4	4.4	17.0	15.6	9.2	25	25	.3	15
JUNE												
30...	1345	1.3	56	--	5.6	24.0	19.6	7.0	--	--	--	--
AUG												
12...	1220	.35	46	6.5	6.2	--	20.2	--	24	22	--	--

DATE	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)	SODIUM, DIS-SOLVED (MG/L AS NA)	POTAS-SIUM, DIS-SOLVED (MG/L AS K)	ALKA-LINITY LAB (MG/L AS CACO3)	CARBON DIOXIDE DIS-SOLVED (MG/L AS CO2)	SULFATE DIS-SOLVED (MG/L AS SO4)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL)	FLUO-RIDE, DIS-SOLVED (MG/L AS F)	SILICA, DIS-SOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)
SEP, 1980											
10...	--	--	--	--	--	--	280	--	--	--	478
NOV											
05...	9.4	3.1	.5	1.4	.0	.0	45	2.6	.20	5.6	83
FEB, 1981											
18...	7.3	2.5	.4	.8	.0	.0	36	1.2	<.10	4.9	62
MAY											
15...	6.6	2.0	.5	.7	.0	.0	33	.8	<.10	4.1	62
JUNE											
30...	--	--	--	--	1.0	--	26	1.0	<.10	--	50
AUG											
12...	6.4	1.9	.9	.5	2.0	1.2	21	.7	<.10	4.4	47

DATE	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED (MG/L)	SOLIDS, DIS-SOLVED (TONS PER DAY)	SOLIDS, RESIDUE AT 105 DEG. C, SUS-PENDED (MG/L)	SOLIDS, VOLA-TILE, DIS-SOLVED (MG/L)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N)	ARSENIC TOTAL IN BOT-TOM MA-TERIAL (UG/G AS AS)	CADMIUM RECOV. FM BOT-TOM MA-TERIAL (UG/G AS CD)	CHRO-MIUM, RECOV. FM BOT-TOM MA-TERIAL (UG/G)	COBALT, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS CO)	COPPER, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS CU)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE)
SEP, 1980											
10...	--	--	--	--	--	<1	<10	70	30	<10	920
NOV											
05...	71	.07	5	15	.31	--	--	--	--	--	--
FEB, 1981											
18...	54	1.6	<1	6	.98	--	--	--	--	--	--
MAY											
15...	49	.42	21	27	.38	--	--	--	--	--	--
JUNE											
30...	--	.18	42	9	.31	--	--	--	--	--	--
AUG											
12...	38	.04	36	18	.11	--	--	--	--	--	--

DATE	IRON, DIS-SOLVED (UG/L AS FE)	IRON, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS FE)	LEAD, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS PB)	MANGA-NESE, TOTAL RECOV-ERABLE (UG/L AS MN)	MANGA-NESE, DIS-SOLVED (UG/L AS MN)	MANGA-NESE, RECOV. FM BOT-TOM MA-TERIAL (UG/G)	MERCURY RECOV. FM BOT-TOM MA-TERIAL (UG/G AS HG)	SELE-NIUM, TOTAL IN BOT-TOM MA-TERIAL (UG/G)	ZINC, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS ZN)
SEP, 1980									
10...	<10	3600	<10	490	480	580	<0.01	<1	70
NOV									
05...	1600	--	--	--	1300	--	--	--	--
FEB, 1981									
18...	690	--	--	--	650	--	--	--	--
MAY									
15...	530	--	--	--	600	--	--	--	--
JUNE									
30...	--	--	--	--	--	--	--	--	--
AUG									
12...	490	--	--	--	640	--	--	--	--

NORTH FORK SAND RUN NEAR WILSON, MARYLAND (01594936)

DATE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	PH FIELD	PH LAB	TEMPER-ATURE, AIR (DEG C)	TEMPER-ATURE (DEG C)	COLOR (PLAT-INUM-COBALT UNITS)	TUR-BID-ITY (NTU)	OXYGEN, DIS-SOLVED (MG/L)	HARD-NESS (MG/L AS CACO3)
JULY, 1979											
12...	1000	0.60	220	6.9	6.5	--	17.5	3	--	--	95
AUG											
14...	1030	1.4	154	6.1	6.4	--	17.0	5	--	--	53
OCT											
16...	1030	--	88	4.8	--	--	9.0	<1	--	--	27
APR, 1980											
09...	1230	24	53	5.0	--	17.0	9.5	--	--	9.4	21
MAY											
07...	1015	4.0	78	4.9	--	15.5	10.5	--	--	8.8	33
SEP											
10...	1030	1.2	--	6.0	--	14.0	15.9	--	--	8.3	--
OCT											
27...	1100	1.3	178	6.2	6.4	11.0	3.1	--	1.0	11.0	77
NOV											
05...	1050	1.2	185	6.3	6.7	--	6.1	--	.75	--	80
DEC											
16...	1100	3.5	87	5.1	6.0	.0	2.5	--	--	12.0	--
JAN, 1981											
15...	1300	1.2	547	5.0	5.0	-3.0	.0	--	3.7	12.6	230
FEB											
18...	1300	16	86	4.4	4.7	15.0	3.3	--	3.5	12.5	36
APR											
09...	1330	3.1	192	3.8	4.5	11.0	10.3	--	2.0	9.7	74
MAY											
15...	1145	5.5	139	4.3	6.0	16.0	13.0	--	2.1	9.6	55
JUNE											
26...	1445	5.7	186	4.4	3.9	21.0	18.5	--	8.6	8.8	70
30...	0945	3.3	133	5.1	4.8	24.1	15.5	--	2.7	8.1	51
AUG											
12...	1225	.80	165	6.0	6.9	--	19.1	--	6.0	--	78
SEP											
17...	1500	3.1	98	6.2	6.9	15.0	15.0	--	6.3	7.9	35

DATE	HARD-NESS, NONCAR-BONATE (MG/L CACO3)	ACIDITY (MG/L AS H)	ACIDITY (MG/L AS CACO3)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)	SODIUM, DIS-SOLVED (MG/L AS NA)	POTAS-SIUM, DIS-SOLVED (MG/L AS K)	BICAR-BONATE FET-FLD (MG/L AS HCO3)	CAR-BONATE FET-FLD (MG/L AS CO3)	ALKA-LINITY FIELD (MG/L AS CACO3)	ALKA-LINITY LAB (MG/L AS CACO3)
JULY, 1979											
12...	87	--	--	27	6.7	0.8	0.8	10	0	8.0	--
AUG											
14...	48	--	--	15	3.8	.6	1.0	6	0	5.0	--
OCT											
16...	26	--	--	7.5	2.1	.5	.6	--	--	1.0	--
APR, 1980											
09...	20	.1	5.0	5.4	1.8	.4	.8	--	--	1.0	--
MAY											
07...	32	.1	5.0	9.0	2.5	.6	.6	--	--	1.0	--
SEP											
10...	--	.0	.0	--	--	--	--	--	--	13-	--
OCT											
27...	65	.1	5.0	22	5.3	.6	1.9	--	--	--	12
NOV											
05...	66	.1	5.0	22	6.0	.8	1.4	--	--	--	14
DEC											
16...	--	.0	.0	--	--	--	--	--	--	3.3	--
JAN, 1981											
15...	231	1.2	60	68	15	1.4	2.1	--	--	--	1.0
FEB											
18...	36	.3	15	9.8	2.7	.6	.8	--	--	--	.0
APR											
09...	74	.7	35	21	5.3	.6	1.1	--	--	--	.0
MAY											
15...	54	.1	5.0	16	3.7	.8	.9	--	--	--	1.0
JUNE											
26...	68	.3	15	20	4.9	.6	1.0	--	--	2.0	.0
30...	48	.1	5.0	17	2.0	.6	.6	--	--	--	3.0
AUG											
12...	61	.3	15	22	5.5	1.1	.9	--	--	--	17
SEP											
17...	27	.1	5.0	11	1.9	.6	.9	--	--	8.0	7.0

DATE	CARBON DIOXIDE DIS- SOLVED (MG/L AS CO2)	SULFATE DIS- SOLVED (MG/L AS SO4)	CHLO- RIDE, DIS- SOLVED (MG/L AS CL)	FLUO- RIDE, DIS- SOLVED (MG/L AS F)	SILICA, DIS- SOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DIS- SOLVED (MG/L)	SOLIDS, SUM OF CONSTI- TUENTS, DIS- SOLVED (MG/L)	SOLIDS, DIS- SOLVED (TONS PER DAY)	SOLIDS, RESIDUE AT 105 DEG. C, SUS- PENDED (MG/L)	NITRO- GEN, NO2+NO3 TOTAL (MG/L AS N)	NITRO- GEN, NO2+NO3 DIS- SOLVED (MG/L AS N)
JULY, 1979											
12...	2.0	88	1.6	0.10	4.8	155	136	0.25	--	0.14	--
AUG											
14...	7.6	50	.7	.10	5.0	91	80	.34	--	.33	--
OCT											
16...	31	29	1.1	.10	4.6	50	47	--	--	.61	--
APR, 1980											
09...	19	20	.7	<.10	3.6	50	34	3.2	--	--	.71
MAY											
07...	24	32	.9	.10	4.1	58	51	.63	--	--	.58
SEP											
10...	--	48	--	--	--	104	--	.34	--	--	--
OCT											
27...	15	66	3.7	<.10	4.6	143	115	.50	4	.32	.32
NOV											
05...	14	68	2.0	.20	4.8	128	116	.41	1	.37	.37
DEC											
16...	50	34	--	--	--	52	--	.49	--	--	--
JAN, 1981											
15...	19	220	1.3	.10	7.9	390	331	1.3	31	.48	.52
FEB											
18...	.0	35	1.3	<.10	4.5	64	56	2.8	9	.99	.97
APR											
09...	.0	82	1.7	<.10	5.2	136	119	1.1	14	.63	.62
MAY											
15...	97	55	1.2	<.10	4.0	93	83	1.4	9	.46	.45
JUNE											
26...	154	70	1.1	<.10	4.7	141	108	2.2	16	.39	.41
30...	46	54	1.4	<.10	4.7	103	83	.92	8	.50	.45
AUG											
12...	33	62	.9	<.10	4.8	125	109	.27	7	.23	.20
SEP											
17...	9.8	32	1.6	<.10	4.0	83	58	.69	12	.40	.37

DATE	NITRO- GEN,AM- MONIA + ORGANIC TOTAL (MG/L AS N)	NITRO- GEN,AM- MONIA + ORGANIC DIS. (MG/L AS N)	NITRO- GEN, TOTAL (MG/L AS N)	NITRO- GEN DIS- SOLVED (MG/L AS N)	PHOS- PHORUS, TOTAL (MG/L AS P)	ALUM- INUM, TOTAL RECOV- ERABLE (UG/L AS AL)	ALUM- INUM, DIS- SOLVED (UG/L AS AL)	ARSENIC TOTAL (UG/L AS AS)	ARSENIC DIS- SOLVED (UG/L AS AS)	ARSENIC TOTAL IN BOT- TOM MA- TERIAL (UG/G AS AS)	BARIUM, TOTAL RECOV- ERABLE (UG/L AS BA)
JULY, 1979											
12...	--	--	--	--	<0.010	--	30	--	<1	--	--
AUG											
14...	--	--	--	--	<.010	--	--	--	3	--	--
OCT											
16...	--	--	--	--	<.010	--	--	--	--	--	--
APR, 1980											
09...	--	--	--	--	--	--	--	--	--	--	--
MAY											
07...	--	--	--	--	--	--	--	--	--	--	--
SEP											
10...	--	--	--	--	--	--	--	--	--	<1	--
OCT											
27...	.32	.29	.64	.61	.010	100	50	<1	<1	--	100
NOV											
05...	.09	<.10	.46	.37	.010	--	--	--	--	--	--
DEC											
16...	--	--	--	--	--	--	--	--	--	--	--
JAN, 1981											
15...	.38	.22	.86	.74	<.010	300	100	1	1	--	100
FEB											
18...	.28	.16	1.3	1.1	<.010	--	--	--	--	--	--
APR											
09...	.16	.10	.79	.72	<.010	800	800	1	1	--	100
MAY											
15...	.49	.48	.95	.93	.020	--	--	--	--	--	--
JUNE											
26...	.31	.21	.70	.62	<.010	--	--	--	--	--	--
30...	.39	.33	.89	.78	<.010	--	--	--	--	--	--
AUG											
12...	--	--	--	--	--	--	--	--	--	--	--
12...	.44	.19	.67	.39	.020	--	--	--	--	--	--
SEP											
17...	.32	.20	.72	.62	.020	100	30	1	1	--	100

DATE	BARIUM, DIS-SOLVED (UG/L AS BA)	BERYL-LIUM, DIS-SOLVED (UG/L AS BE)	BORON, TOTAL RECOV-ERABLE (UG/L AS B)	BORON, DIS-SOLVED (UG/L AS B)	CADMIUM TOTAL RECOV-ERABLE (UG/L AS CD)	CADMIUM DIS-SOLVED (UG/L AS CD)	CADMIUM RECOV. FM BOT-TOM MA-TERIAL (UG/G AS CD)	CHRO-MIUM, TOTAL RECOV-ERABLE (UG/L AS CR)	CHRO-MIUM, DIS-SOLVED (UG/L AS CR)	CHRO-MIUM, RECOV. FM BOT-TOM MA-TERIAL (UG/G)	COBALT, DIS-SOLVED (UG/L AS CO)
JULY, 1979											
12...	50	4	--	--	--	<2	--	--	<2	--	4
AUG											
14...	70	<10	--	--	--	<2	--	--	--	--	7
OCT											
16...	--	--	--	--	--	--	--	--	--	--	--
APR, 1980											
09...	--	--	--	--	--	--	--	--	--	--	--
MAY											
07...	--	--	--	--	--	--	--	--	--	--	--
SEP											
10...	--	--	--	--	--	--	<10	--	--	30	--
OCT											
27...	60	--	2	<10	<10	4	--	20	<10	--	--
NOV											
05...	--	--	--	--	--	--	--	--	--	--	--
DEC											
16...	--	--	--	--	--	--	--	--	--	--	--
JAN, 1981											
15...	80	--	10	10	<10	5	--	10	10	--	--
FEB											
18...	--	--	--	--	--	--	--	--	--	--	--
APR											
09...	60	--	10	10	<10	2	--	<10	<10	--	--
MAY											
15...	--	--	--	--	--	--	--	--	--	--	--
JUNE											
26...	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--
AUG											
12...	--	--	--	--	--	--	--	--	--	--	--
SEP											
17...	100	--	20	10	<10	1	--	10	10	--	--

DATE	COBALT, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS CO)	COPPER, TOTAL RECOV-ERABLE (UG/L AS CU)	COPPER, DIS-SOLVED (UG/L AS CU)	COPPER, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS CU)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE)	IRON, DIS-SOLVED (UG/L AS FE)	IRON, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS FE)	LEAD, TOTAL RECOV-ERABLE (UG/L AS PB)	LEAD, DIS-SOLVED (UG/L AS PB)	LEAD, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS PB)	LITHIUM DIS-SOLVED (UG/L AS LI)
JULY, 1979											
12...	--	--	<1	--	870	110	--	--	5	--	3
AUG											
14...	--	--	3	--	910	240	--	--	<1	--	5
OCT											
16...	--	--	--	--	480	250	--	--	--	--	--
APR, 1980											
09...	--	--	--	--	1500	220	--	--	--	--	--
MAY											
07...	--	--	--	--	340	150	--	--	--	--	--
SEP											
10...	<10	--	--	<10	1300	350	3400	--	--	10	--
OCT											
27...	--	<1	4	--	1100	640	--	<1	<1	--	--
NOV											
05...	--	--	--	--	430	180	--	--	--	--	--
DEC											
16...	--	--	--	--	520	370	--	--	--	--	--
JAN, 1981											
15...	--	40	1	--	10000	12000	--	<1	<1	--	--
FEB											
18...	--	--	--	--	1400	750	--	--	--	--	--
APR											
09...	--	5	2	--	960	740	--	7	<1	--	--
MAY											
15...	--	--	--	--	1100	250	--	--	--	--	--
JUNE											
26...	--	--	--	--	4600	4100	--	--	--	--	--
30...	--	--	--	--	1800	340	--	--	--	--	--
AUG											
12...	--	--	--	--	2300	530	--	--	--	--	--
SEP											
17...	--	10	2	--	1300	110	--	<100	3	--	--

DATE	MANGANESE, TOTAL RECOVERABLE (UG/L AS MN)	MANGANESE, DISSOLVED (UG/L AS MN)	MANGANESE, RECOV. FM BOTTOM MATERIAL (UG/G)	MERCURY TOTAL RECOVERABLE (UG/L AS HG)	MERCURY DISSOLVED (UG/L AS HG)	MERCURY RECOV. FM BOTTOM MATERIAL (UG/G AS HG)	MOLYBDENUM, DISSOLVED (UG/L AS MO)	NICKEL, TOTAL RECOVERABLE (UG/L AS NI)	NICKEL, DISSOLVED (UG/L AS NI)	SELENIUM, TOTAL (UG/L AS SE)	SELENIUM, DISSOLVED (UG/L AS SE)
JULY, 1979											
12...	560	570	--	--	<0.5	--	3	--	7	--	<1
AUG											
14...	650	680	--	--	<.5	--	<1	--	8	--	<1
OCT											
16...	340	350	--	--	--	--	--	--	--	--	--
APR, 1980											
09...	290	280	--	--	--	--	--	--	--	--	--
MAY											
07...	310	310	--	--	--	--	--	--	--	--	--
SEP											
10...	370	380	78	--	--	<.01	--	--	--	--	--
OCT											
27...	870	780	--	<.1	<.1	--	--	9	7	<1	<1
NOV											
05...	470	480	--	--	--	--	--	--	--	--	--
DEC											
16...	320	310	--	--	--	--	--	--	--	--	--
JAN, 1981											
15...	1600	1600	--	<.1	<.1	--	--	38	35	<1	<1
FEB											
18...	410	430	--	--	--	--	--	--	--	--	--
APR											
09...	490	460	--	<.1	<.1	--	--	15	13	<1	<1
MAY											
15...	390	380	--	--	--	--	--	--	--	--	--
JUNE											
26...	460	510	--	--	--	--	--	--	--	--	--
30...	440	480	--	--	--	--	--	--	--	--	--
AUG											
12...	620	660	--	--	--	--	--	--	--	--	--
SEP											
17...	370	410	--	<.1	<.1	--	--	10	5	<1	<1

DATE	SELENIUM, TOTAL IN BOTTOM MATERIAL (UG/G)	SILVER, TOTAL RECOVERABLE (UG/L AS AG)	SILVER, DISSOLVED (UG/L AS AG)	STRONTIUM, DISSOLVED (UG/L AS SR)	ZINC, TOTAL RECOVERABLE (UG/L AS ZN)	ZINC, DISSOLVED (UG/L AS ZN)	ZINC, RECOV. FM BOTTOM MATERIAL (UG/G AS ZN)	CARBON, ORGANIC TOTAL (MG/L AS C)	CYANIDE TOTAL (MG/L AS CN)	PHENOLS TOTAL (UG/L)
JULY, 1979										
12...	--	--	<2	120	--	20	--	--	--	--
AUG										
14...	--	--	--	60	--	40	--	--	--	--
OCT										
16...	--	--	--	--	--	--	--	--	--	--
APR, 1980										
09...	--	--	--	--	--	--	--	9.9	--	--
MAY										
07...	--	--	--	--	--	--	--	2.1	--	--
SEP										
10...	<1	--	--	--	--	--	6	--	--	--
OCT										
27...	--	<1	<1	--	30	30	--	--	--	--
NOV										
05...	--	--	--	--	--	--	--	2.9	<.01	3
DEC										
16...	--	--	--	--	--	--	--	--	--	--
JAN, 1981										
15...	--	<1	0	--	100	70	--	--	--	--
FEB										
18...	--	--	--	--	--	--	--	1.8	<.01	<1
APR										
09...	--	<1	<1	--	60	30	--	--	--	--
MAY										
15...	--	--	--	--	--	--	--	4.6	<.01	<1
JUNE										
26...	--	--	--	--	--	--	--	3.8	--	--
30...	--	--	--	--	--	--	--	1.7	--	--
AUG										
12...	--	--	--	--	--	--	--	3.5	<.01	<1
SEP										
17...	--	<1	<1	--	50	10	--	2.3	--	--

DATE	TIME	STREAMFLOW, INSTANTANEOUS (CFS)	SPECIFIC CONDUCTANCE (UMHOS)	PH FIELD	PH LAB	TEMPERATURE, AIR (DEG C)	TEMPERATURE (DEG C)	OXYGEN, DISSOLVED (MG/L)	HARDNESS (MG/L AS CACO3)	HARDNESS, NONCARBONATE (MG/L CACO3)	ACIDITY (MG/L AS H)	ACIDITY (MG/L AS CACO3)
APR, 1979 18...	1130	8.0	140	5.4	--	12.0	7.5	11.1	43	37	--	--
AUG 21...	1330	1.9	260	4.2	--	21.5	18.5	7.3	95	95	.6	30
NOV 15...	1330	6.1	148	4.8	--	2.5	3.5	11.6	56	57	.3	15
NOV, 1980 05...	0945	2.6	447	6.9	7.3	5.0	5.7	9.9	180	163	.1	5.0
MAY, 1981 14...	1700	3.3	345	6.3	7.4	27.0	18.5	7.9	140	122	.1	5.0
JUNE 30...	1145	7.0	405	7.8	6.8	--	17.8	--	180	158	--	--
AUG 12...	1045	1.2	535	7.1	7.2	--	19.3	8.6	270	253	--	--

DATE	CALCIUM DISSOLVED (MG/L AS CA)	MAGNESIUM, DISSOLVED (MG/L AS MG)	SODIUM, DISSOLVED (MG/L AS NA)	POTASSIUM, DISSOLVED (MG/L AS K)	ALKALINITY LAB (MG/L AS CACO3)	CARBON DIOXIDE DISSOLVED (MG/L AS CO2)	SULFATE DISSOLVED (MG/L AS SO4)	CHLORIDE, DISSOLVED (MG/L AS CL)	FLUORIDE, DISSOLVED (MG/L AS F)	SILICA, DISSOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L)
APR, 1979 18...	13	2.6	0.6	0.8	--	46	45	1.5	0.10	3.7	--
AUG 21...	29	5.4	.9	1.3	--	.0	100	1.3	.10	5.1	154
NOV 15...	17	3.4	1.7	.9	--	.0	62	1.2	.10	5.1	106
NOV, 1980 05...	57	9.1	17	2.7	17	4.1	190	2.8	.30	4.5	318
MAY, 1981 14...	46	7.3	4.5	1.7	23	22	130	2.0	.10	4.6	234
JUNE 30...	58	7.8	7.3	1.7	19	.6	150	1.5	.10	4.6	283
AUG 12...	89	12	8.4	2.0	19	2.9	240	1.4	.10	5.7	409

DATE	SOLIDS, SUM OF CONSTITUENTS, DISSOLVED (MG/L)	SOLIDS, DISSOLVED (TONS PER DAY)	SOLIDS, RESIDUE AT 105 DEG. C, SUSPENDED (MG/L)	SOLIDS, VOLATILE, DISSOLVED (MG/L)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N)	ARSENIC TOTAL IN BOTTOM MATERIAL (UG/G AS AS)	CADMIUM RECOV. FM BOTTOM MATERIAL (UG/G AS CD)	CHROMIUM, RECOV. FM BOTTOM MATERIAL (UG/G)	COBALT, RECOV. FM BOTTOM MATERIAL (UG/G AS CO)	COPPER, RECOV. FM BOTTOM MATERIAL (UG/G AS CU)	IRON, TOTAL RECOVERABLE (UG/L AS FE)
APR, 1979 18...	71	1.5	--	--	0.58	--	--	--	--	--	2900
AUG 21...	145	.79	--	--	--	11	<10	20	10	10	2100
NOV 15...	92	1.7	--	--	.48	--	--	--	--	--	2500
NOV, 1980 05...	294	2.3	5	24	.41	--	--	--	--	--	--
MAY, 1981 14...	210	2.1	18	29	.49	--	--	--	--	--	--
JUNE 30...	243	5.4	12	26	.41	--	--	--	--	--	--
AUG 12...	371	1.3	8	26	.23	--	--	--	--	--	--

DATE	IRON, SUSPENDED RECOVERABLE (UG/L AS FE)	IRON, DISSOLVED (UG/L AS FE)	IRON, RECOV. FM BOTTOM MATERIAL (UG/G AS FE)	LEAD, RECOV. FM BOTTOM MATERIAL (UG/G AS PB)	MANGANESE, TOTAL RECOVERABLE (UG/L AS MN)	MANGANESE, SUSPENDED RECOV. (UG/L AS MN)	MANGANESE, DISSOLVED (UG/L AS MN)	MANGANESE, RECOV. FM BOTTOM MATERIAL (UG/G)	MERCURY RECOV. FM BOTTOM MATERIAL (UG/G AS HG)	SELENIUM, TOTAL IN BOTTOM MATERIAL (UG/G)	ZINC, RECOV. FM BOTTOM MATERIAL (UG/G AS ZN)
APR, 1979 18...	2600	270	--	--	340	20	320	--	--	--	--
AUG 21...	1600	470	46000	10	560	0	590	480	.00	0	140
NOV 15...	2000	490	--	--	610	30	580	--	--	--	--
NOV, 1980 05...	--	80	--	--	--	--	460	--	--	--	--
MAY, 1981 14...	--	30	--	--	--	--	440	--	--	--	--
JUNE 30...	--	<10	--	--	--	--	380	--	--	--	--
AUG 12...	--	140	--	--	--	--	480	--	--	--	--

APPENDIX B

Lithologic and Geophysical Well Logs

Lithologic Log for Deep Well At
Mettiki Mine Well Cluster #1
Garrett County, Maryland

Well FA 31
State Permit: GA-73-2142
Altitude: 2,618 feet

Depth (ft)	Description
0 - 17	Overburden
17 - 30	Shale, red and gray, very soft
30 - 60	Shale, red and gray, medium-hard
60 - 70	Sandstone, with thin coal at 64 ft
70 - 76	Shale, black
76 - 77	Sandstone, gray, well-cemented, with some thin shale
77 - 81	Sandstone, gray
81 - 81.5	Sandstone, softer gray, with some carbon films
81.5- 82.5	Sandstone, gray, harder
82.5- 93	Shale; some sandstone, with thin coal at base
93 - 96	Shale, dark gray to black
96 - 100	Shale, medium-gray, with some hard zones; gritty but soft
100 - 110	Sandstone, gray, hard, with some soft zones
110 - 112	Sandstone, coarse; slight reaction with acid; more water
112 - 120	Sandy shale, gray, soft
120 - 125	Sandy shale, gray, harder
125 - 132	Sandy shale, gray, softer
132 - 142	Sandstone, gray; reacts with acid
142 - 161.5	Shale, gray
161.5- 176	Sandstone, light-gray; some more water
176 - 177.5	Coal
177.5- 178	Sandstone, light-gray
178 - 188	Shale, gray
188 - 210	Sandstone, light-gray, fine-grained, hard, well-cemented
210 - 212	Sandstone, somewhat softer
212 - 232	Sandstone, light-gray, hard
232 - 237	Shale, medium-gray
237 - 238	Shale, harder
238 - 238.5	Shale, softer
238.5- 247	Shale, medium-gray, harder; slight reaction with acid
247 - 256	Shale, medium-gray, softer
256 - 265	Shale, harder
265 - 282	Shale, dark-gray
282 - 292	Shale, light-gray
292 - 300	Shale, gray, having some thin, hard zones; some reaction with acid

Well FA 31--Continued

Depth (ft)	Description
300 - 321	Shale, gray, soft; some reaction with acid
321 - 325	Shale, gray, with some thin, hard zones
325 - 342	Sandstone, clean quartz, very hard
324 - 357	Sandstone, gray, disaggregated, less hard
357 - 372	Sandstone, gray, medium-grained, with some medium-gray shale
372 - 392	Sandstone, gray, medium-grained, disaggregated
392 - 417	Shale, medium, some thin, hard zones; very thin coal around 408 ft
417 - 433	Sandy shale, medium-gray
433 - 474	Sandstone, gray, medium- to coarse-grained, moderately hard; large fracture at 468 ft
474 - 478	Shale, black
478 - 480.5	Coal
480.5- 481	Parting
481 - 484.7	Coal
484.7 487	Shale
487 - 501	Shale, medium-gray, with soft, light-gray shale at base
501 - 522	Shale, medium- to dark-gray
522 - 531	Shale and sandy shale; some thin sandstones
531 - 541	Shale, mostly dark with some sandstone layers
541 - 543.5	Sandstone, light gray, fine-grained; interlaminated with medium-gray shale
543.5- 543.8	Sandstone, light-gray, fine-grained
543.8- 544.1	Shale, medium-gray, silty or sandy
544.1- 544.3	Sandstone, light-gray, fine-grained
544.3- 544.5	Shale, medium-gray, silty
544.5- 546	Sandstone, light-gray, interlaminated with medium-gray silty, shale
546 - 550.6	Sandstone, light-gray, fine-grained
550.6- 551	Sandstone, light-gray, fine-grained interlaminated with medium gray, silty shale
551 - 552.7	Sandstone, light-gray, fine-grained, with very small shale lenses
552.7- 553	Sandstone, light-gray, fine-grained, interlaminated with medium-gray silty shale
553 - 553.9	Sandstone, light-gray, fine-grained
553.9- 554.5	Sandstone, light-gray, fine-grained, interlaminated with medium-gray silty shale
554.5- 555.9	Sandstone, light-gray, fine-grained
555.9- 556	Sandstone, light-gray, fine-grained, interlaminated with medium-gray silty shale
556 - 558.2	Sandstone, light- to medium-gray, fine-grained

Well FA 31--Continued

Depth (ft)		Description
558.2-	558.8	Sandstone, light-gray, fine-grained, interlaminated with medium-gray shale
558.8-	559.6	Sandstone, light-gray, fine-grained, with very small, thin, medium-gray shale lenses
559.6-	559.6	Shale, dark-gray
559.9-	560	Sandstone, light-gray, fine-grained, interlaminated with medium-gray shale
560 -	561.2	Shale, medium-gray
561.2-	570.2	Sandstone, light-gray, fine- to medium-grained, very clean
570.2-	572.9	Sandstone, light-gray, fine-grained, interlaminated with medium-gray shale
572.9-	585.2	Sandstone, light-gray, fine- to medium-grained
585.2-	585.3	Shale, dark-gray
585.3-	585.5	Sandstone, light-gray, fine-grained
585.5-	586.1	Shale, dark-gray
586.1-	591	Sandstone, light-gray, medium-grained
591 -	603.5	Sandstone, gray, well-cemented, with some dark-gray clay seams and some irregular, coaly seams containing pyrite
603.5-	616.5	Similar to above, but also some thin, soft, white seams (gypsum)
616.5-	616.7	Shale, dark
616.7-	617	Sandstone, gray
617 -	618	Shale, gray, with some coal and some sandstone
618 -	620.5	Shale, dark with coal
620.5-	621	Grades downward into sandstone
621 -	631	Sandstone, gray, with some dark seams, some coaly seams with pyrite
631 -	636.3	Sandstone, gray
636.3-	638	Shale, dark
638 -	641	Coal, with some dark shale; about 2 ft of coal ground up; dark shale and coal contain pyrite
641 -	643	Shale, dark, with fragments of sandstone
643 -	650	Siltstone, medium-gray, sandier in places
650 -	651	Shale, dark, loose
651 -	656	Siltsone, medium-gray, gritty, or silty sandstone
656 -	661	Becomes grittier downwards; sandstone at base
661 -	665.5	Sandstone, gray, fine- to medium-grained, coarser, at base
665.5-	671	Sandstone, gray, coarse-grained, coarsens downward
671 -	679.1	Sandstone, gray, medium- to coarse-grained, pebbly in parts
679.1-	681	Sandstone, gray, medium-grained, coarsens downward

Well FA 31--Continued

Depth (ft)		Description
681 -	690.8	Sandstone, gray, coarse-grained, pebbly
690.8-	691	Shale, dark
691 -	694	Shale, medium-gray, medium-hard, grades downward into very fine-graned sandstone, then coarsens to fine-grained sandstone
694 -	696.5	Sandstone, medium-gray, very fine- to fine-grained
696.5-	701	Shale, light-gray, soft
701 -	702.5	Sandy shale or siltstone, gray
702.5-	704.8	Mudstone, brown, brecciated
704.8-	711	Shale, greenish
711 -	714	Siltstone, gray
714 -	719	Shale, black, with variable thicknesses of coal (less than 0.01 to 0.5 ft thick)
719 -	721	Siltstone, gray
721 -	730.2	Siltstone, gray, in places very fine-grained sandstone
730.2-	732	Sandstone, gray, fine-grained
732 -	732.4	Siltstone, medium-gray, or very fine-grained sandstone
832.4-	741	Sandstone, gray, medium-grained
741 -	751	Sandstone, medium-gray, medium-grained, with thin (less than 0.2 ft) conglomeritic zones; some cross-bedding
751 -	761	Sandstone, gray, medium-grained, in places conglomeritic, some cross-bedding, some coaly or shaly partings
761 -	771	Sandstone, gray, medium-grained, pebbly in places, coarsens toward bottom, coaly, pyrite-bearing partings
771 -	774.5	Sandstone, gray, coarse-grained, with pebbles and pyrite, black partings
774.5-	780	Conglomerate, gray, pebbles dominant
780 -	781	Similar to above, but fewer pebbles
781 -	786.5	Sandstone, light-gray, medium- to coarse-grained
786.5-	786.8	Conglomerate, light-gray, coaly film present at top and bottom
786.8-	787.4	Sandstone, light-gray, fine-grained, with very thin coaly streaks
787.4-	812	Shale, medium-gray, silty
812 -	814.9	Sandstone, light-gray, fine- to medium-grained
814.9-	815.2	Sandstone, medium-gray, fine-grained, interlaminated with carbonaceous films
815.2-	819	Sandstone, light-gray, medium-grained
819 -	819.2	Coal
819.2-	825	Sandstone, light-gray, medium-grained

Well FA 31--Continued

Depth (ft)	Description
825 - 827.5	Shale, medium-gray
827.5 834	Sandstone, light-gray, medium-grained, with some coaly, pyrite-bearing seams; some cross-bedding
834 - 837.5	Siltstone, medium-gray
837.5- 838.5	Shale, medium-gray
838.5- 841	Sandstone, light-gray, medium-grained
841 - 845	Sandstone, light-gray, medium-grained, with thin, dark streaks
845 - 856.5	Siltstone, medium-gray, with thin streaks of sandstone
856.5- 865.2	Sandstone, gray, fine- to medium-grained
865.2- 869	Shale and clay, medium-gray, coaly at top
869 - 871	Sandstone, gray, fine-grained, some shaly and coaly streaks
871 - 872	Sandy shale, gray, with coaly seams
872 - 872.5	Sandstone, gray
872.5- 881	Sandstone, grades down to lighter-gray, less shaly, with thin, coaly seans
881 - 883.4	Sandstone, gray, fine- to medium-grained, with coaly seams and some shale clasts; plant fossil at 882 ft
883.4- 886	Shale, medium-gray, with some coaly seams
886 - 888.5	Sandstone, gray, fine- to medium-grained, mostly light but some darker
888.5- 889.7	Sandstone, light-gray, medium-grained, with some darker, fine-grained sandstone
889.7- 891	Shale, medium-gray, abrupt contact at top
891 - 896.5	Shale, dark-gray
896.5- 901	Shale, dark-gray, with some silty or coaly zones
901 - 915	Shale, dark-gray, a calcite-filled fracture at 908 ft
915 - 918.5	Coal, with some shale near the top
918.5- 921	Shale, dark-gray
921 - 923.9	Shale, gray, or siltstone
923.9- 924	Coal
924 - 929	Shale, gray, or siltstone with thin sandstone
929 - 931	Sandstone, gray
931 - 934.7	Sandstone, gray, with streaks of thin, black shale
934.7- 936.9	Shale, black, with some gray sandstone
936.9- 937.4	Coal
937.4- 937.7	Shale, carbonaceous

Well FA 31--Continued

Depth (ft)	Description
937.7- 938.5	Coal
938.5- 939	Shale, black
939 - 940.8	Clay, gray
940.8- 941	Shale
941 - 941.5	Shale, gray
941.5- 942	Clay, gray
942 - 942.5	Shale, gray
942.5- 942.6	Clay, gray
942.6- 943.6	Shale, gray
943.6- 944	Clay, gray, shaly at base
944 - 945	Shale, gray
945 - 949.4	Siltstone, black, with plant fossils
949.4- 949.8	Shale, carbonaceous, with plant fossils
949.8- 952	Shale, black, or siltstone
952 - 952.3	Clay, black, fissile, with thin coal seam at base
952.3- 961	Siltstone, dark gray
961 - 963.4	Shale, gray
963.4- 963.8	Coal
963.8- 964.2	Shale, black
964.2- 965	Shale, gray
965 - 967.7	Shale, carbonaceous
965.7- 968.5	Shale, gray
968.5- 968.9	Coal, with seams of shale
968.9- 969.4	Shale, gray
969.4- 971	Siltstone, gray
971 - 972.9	Shale, dark-gray, with thin sandstone
972.9- 976.5	Sandstone, gray, medium-grained, with thin layers of gray shale
976.5- 977.5	Shale, gray
977.5- 978.2	Sandstone, gray, medium- and coarse-grained, with thin layers of shale
978.2- 978.5	Conglomerate
978.5- 978.7	Shale, gray
978.7- 979.5	Shale, black, with coal seam (less than 0.01 ft)
979.5- 980.3	Coal
980.3- 981	Shale, dark-gray, with 0.2 ft of black clay in middle
981 - 988	Siltstone, gray, grading downward into medium-grained sandstone
988 - 991.5	Sandstone, gray, medium-grained, with seams of dark shale
991.5-1,001	Siltstone, gray, interbedded with gray sandstone

Well FA 31--Continued

Depth (ft)	Description
1,001 -1,002.7	Siltstone, gray
1,002.7-1,003.7	Coal
1,003.7-1,004.6	Shale, gray
1,004.6-1,006.5	Siltstone, gray, grading downward into brownish-gray sandstone
1,006.5-1,014.5	Sandstone, brownish-gray, fine- to medium-grained
1,014.5-1,021	Siltstone, gray, with some sandstone interbedded
1,021 -1,031	Sandstone, gray, fine- to medium-grained, with some zones of dark shale and some iron concretions
1,031 -1,034.3	Sandstone, gray, fine-grained, with some siltstone
1,034.3-1,035.3	Similar as above, but somewhat coarser
1,035.3-1,041	Sandstone, greenish-gray, lighter, medium-grained
1,041 -1,051	Sandstone, greenish-gray, light, medium-grained, micaceous, with some pyrite; recovered in one piece
1,051 -1,061	Same as above, but with a streak of coal at 1,055.8 ft
1,061 -1,071	Sandstone, greenish-gray, fine- to medium-grained
1,071 -1,075	Sandstone, gray, fine-grained, with some shale clasts
1,075 -1,075.5	Shale, dark-gray, fissile, with streaks of siltstone or sandstone
1,075.5-1,076.8	Siltstone, dark-gray, with streaks of sandstone and a very thin coal streak
1,076.8-1,077.5	Sandstone, gray, fine- to medium-grained
1,077.5-1,081	Siltstone, medium-gray
1,081 -1,091	Siltstone, medium-gray, with some plant fossils
1,091 -1,106.2	Siltstone, medium-gray, with some very fine-grained sandstone and some very thin coal streaks; plant remains
1,106.2-1,109	Sandstone, light-gray, fine- to medium-grained, micaceous
1,109 -1,111	Sandstone, very light gray, medium-grained, micaceous
1,111 -1,116.2	Sandstone, gray, medium-grained, some pebbles near top, lots more at base
1,116.2-1,117.7	Shale, green
1,117.7-1,119	Shale, grayish-green, silty; or sandstone
1,119 -1,121	Shale, red
1,121 -1,130	Shale, red, with green mottles
1,130 -1,131	Shale, gray
BOTTOM OF HOLE	

Lithologic Log for Deep Well At
Mettiki Mine Well Cluster #2
Garrett County, Maryland

Well FB 22
State Permit: GA-73-2146
Altitude: 2,530 feet

Depth (ft)	Description
0 - 22	Overburden - mostly yellow-red clay loam with some boulders; wet zone at 13 ft
22 - 37	Shale, medium-gray, hard; more water at 35 and 37 ft
37 - 53	Similar to above, softer
53 - 56	Similar to above, softer and darker
56 - 62	Shale, medium-gray, soft
62 - 67	Shale, gray, with some thin beds of red shale
67 - 71	Shale, medium-gray
71 - 83	Similar to above, softer; about 30 gal/min water coming in at 79 ft; thin, hard streaks at 79-83 ft
83 - 85	Sandstone, dirty gray
85 - 90	Shale, dark-gray, with some pyrite
90 - 91.5	Coal
91.5- 104	Shale, medium-gray
104 - 119	Shale, lighter-gray
119 - 134	Sandstone, gray, fine- to medium-grained
134 - 140	Sandstone, gray, not quite as hard, fine-grained
140 - 162	Sandstone, light-gray, harder, fine- to medium-grained
162 - 164	Sandstone, gray, with some hard, gray shale
164 - 182	Sandstone, light-gray, medium-grained
182 - 186	Shale, dark, sandy
186 - 188	Coal, with shale parting
188 - 192	Shale, gray
192 - 207	Sandstone, gray, fine- to medium-grained, with some thin, gray shale included
207 - 222	Sandstone, very light gray, clean, medium-grained
222 - 236	Shaly sandstone, medium-gray, fine-grained, and sandy shale
236 - 245	Shale, red
245 - 252	Shale, medium-gray; some reaction with acid
252 - 267	Siltstone, medium-gray; slight reaction with acid
267 - 282	Sandstone, medium-gray, fine-grained
282 - 295	Sandstone, reddish-gray, medium-grained; reacts with acid
295 - 298	Shale, dark gray
298 - 300.5	Coal

Well FB 22--Continued

Depth (ft)	Description
300.5- 307	Shale, dark-gray
307 - 311	Clay, light-gray, very sticky
311 - 312	Shale, gray
312 - 317	Sandstone, gray, medium-grained
317 - 327	Shale, light-gray
327 - 342	Shale, medium-gray, sandy
342 - 357	Sandstone, gray, fine- to medium-grained, with shaly sandstone
357 - 387	Sandstone, medium-gray, fine- to medium-grained
387 - 402	Sandstone, darker-gray, fine- to medium-grained
402 - 417	Sandstone, greenish-gray, fine- to medium-grained, with some sandy shale; reacts with acid
417 - 433	Sandstone, greenish-gray, mixed with red sandy shale; reacts with acid
433 - 447	Shale, gray; some sandy shale
447 - 462	Sandstone, gray, fine- to medium-grained; some sandy shale and shale
462 - 501	Sandstone, gray, medium-grained, with some mica
501 - 504	Shale, gray
504 - 506	Coal
506 - 509	Shale and coal
509 - 512	Coal
512 - 515	Shale and clay
515 - 522	Clay, light- to medium-gray
522 - 523.5	Similar to above, darker
523.5- 528	Similar to above, lighter
528 - 528.7	Clay, light-gray, sandy
528.7- 542.4	Claystone, medium-gray, with some scattered sandy zones
542.4- 544	Shale, dark-gray
544 - 550	Sandstone, light-gray, fine- to medium-grained; well cemented
550 - 560.5	Sandstone, light-gray, medium-grained, clean; becoming coarser downward
560.5- 562	Claystone, dark-gray
562 - 575	Sandstone, alternating light-gray, fine-grained, medium-grained; siltstone and shale
575 - 580	Sandstone, light-gray, fine-grained; some very thin shaly or coaly streaks
580 - 590	Sandstone, light-gray, fine- to medium-grained, clean; with some very thin coaly streaks; plant fossil, cross-bedding

Well FB 22--Continued

Depth (ft)	Description
590 - 595	Sandstone, light-gray, medium-grained, clean
595 - 612	Sandstone, light- to medium-gray, very fine to fine; dense; more porous near base
612 - 621	Sandstone, light-gray, medium- to coarse-grained at top; grades to medium-grained at bottom
521 - 623	Sandstone, light-gray, medium- to coarse-grained, with shaly seams and clasts and some coaly seams
623 - 638	Sandstone, light-gray, fine-grained; sharp contact at top; few seams and clasts
638 - 640	Sandstone, light-gray, medium- to coarse-grained

Lithologic Log for Deep Well At
Mettiki Mine Well Cluster #3
Garrett County, Maryland

Well FB 26
State Permit: GA-73-2179
Altitude: 2,755 feet

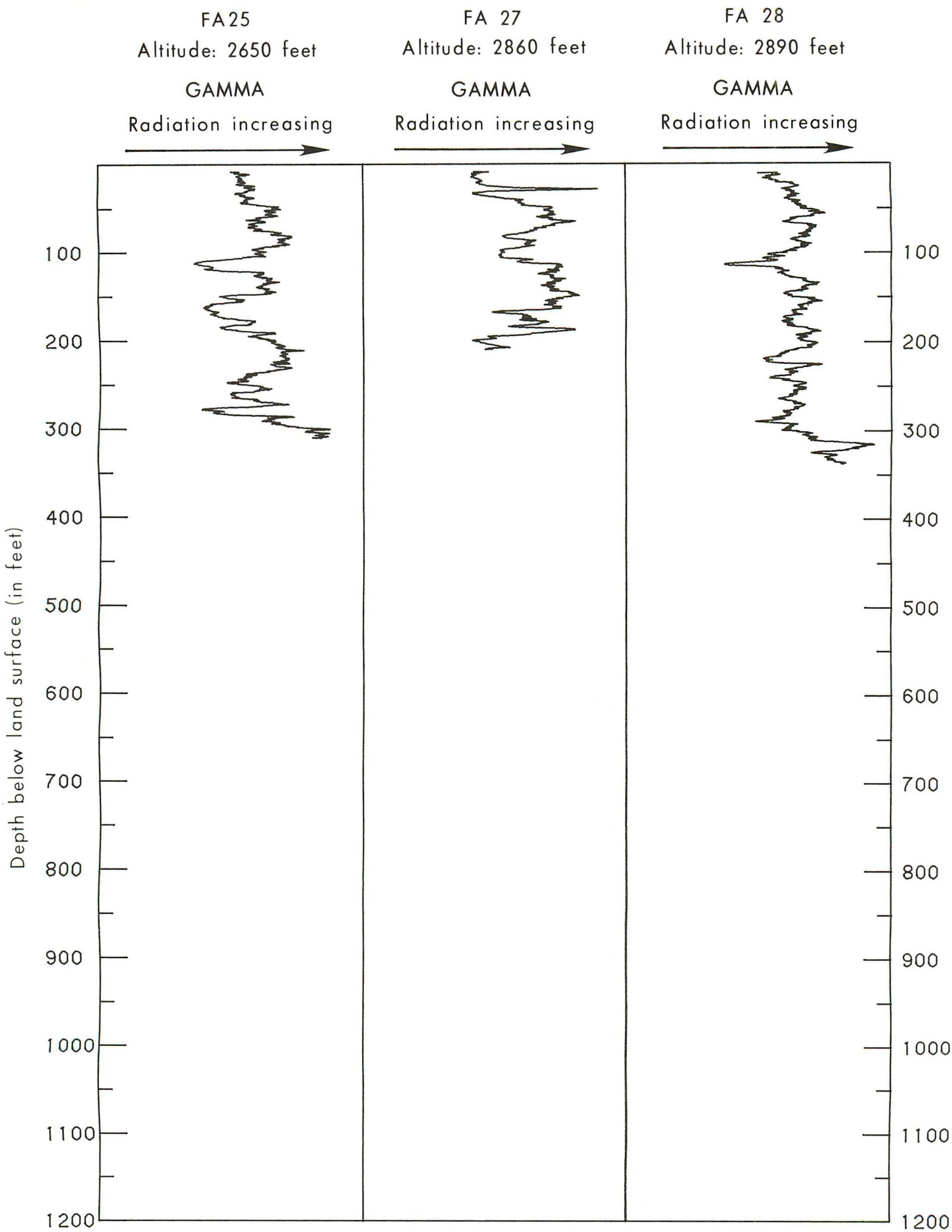
Depth (ft)	Description
0 - 15	Overburden
15 - 18	Shale, gray, clayey, soft
18 - 21	Shale, gray, medium hard
21 - 23	Shale, dark-gray, soft
23 - 24.8	Coal
24.8- 36	Shale, light-gray, soft
36 - 38	Shale, dark-gray, soft
38 - 40	Coal
40 - 46	Shale, dark-gray, soft; water at 42 ft
46 - 52	Shale, gray, soft; water at base
52 - 55	Shale, gray, sandy, hard; water at base
55 - 62	Sandstone, gray, hard
62 - 73	Shale, dark-gray, soft to medium-hard
73 - 75.5	Coal
75.5- 82	Shale, dark-gray, soft; water at 76 ft
82 - 87	Shale, gray, medium-hard
87 - 92	Shale, dark-gray, soft; trace of coal at 88 ft
92 - 107	Sandstone, gray, hard
107 - 120	Shale, dark-gray, soft
120 - 127	Shale, lighter-gray, soft to medium-hard
127 - 133	Shale, reddish-gray and greenish-gray
133 - 151	Shale, greenish-gray
151 - 162	Shale, greenish-gray, with thin streaks of darker material
162 - 166	Sandstone, brown, very hard
166 - 172	Sandstone, brown and gray; very hard
172 - 193	Sandstone, gray, fine-grained
193 - 202	Shale, gray, sandy
202 - 215	Siltstone, greenish-gray, sandy
215 - 222	Sandstone, gray, silty
222 - 225	Shale, gray
225 - 230	Shale, red
230 - 245	Shale, greenish-gray, sandy
245 - 248	Shale, brown, soft
248 - 250	Shale, gray, soft
250 - 251	Sandstone, gray
251 - 252	Shale, brownish-gray
252 - 259	Shale, gray

Well FB 26--Continued

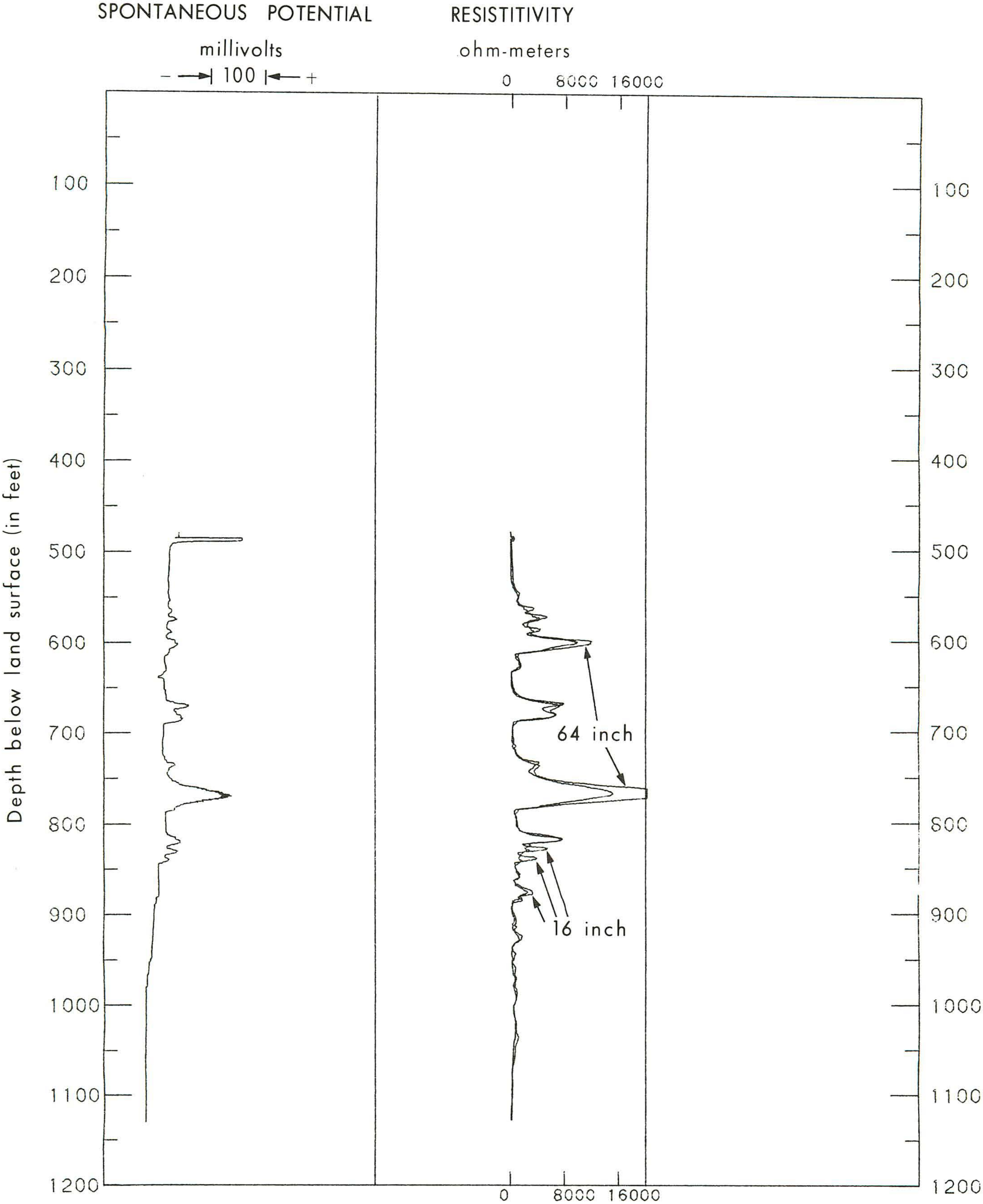
Depth (ft)	Description
259 - 270	Shale, dark-brown
270 - 273	Coal
273 - 277	Shale, gray, sandy
277 - 291	Siltstone, gray
291 - 310	Shale, gray
310 - 312	Shale, darker-gray
312 - 318	Shale, light-gray, with streak of dark-gray shale
318 - 321	Sandstone, light-gray, very fine, silty, or sandy siltstone
321 - 352	Sandstone, very light gray, fine-grained, with a thin seam of black shale at 344 ft
352 - 355	Shale, black
355 - 358	Sandstone, light-gray, fine-grained
358 - 359	Shale, black
359 - 361	Coal
361 - 364	Siltstone, medium-gray
364 - 368	Shale, medium-gray
368 - 372	Siltstone, medium-gray
372 - 380	Shale, medium-gray
380 - 383	Shale, medium-gray, and siltstone
383 - 384.5	Sandstone, gray, fine- to medium-grained
384.5- 389	Shale, medium-gray
389 - 411	Sandstone, light-gray, medium-grained
411 - 414	Shale, gray
414 - 418	Shale, red
418 - 420	Shale, gray
420 - 422	Shale, red
422 - 432	Shale, mixed red and gray
432 - 447	Shale, medium-gray
447 - 452	Shale, gray, with hard zones
452 - 462	Shale, gray
462 - 468	Shale, gray, with hard zones
468 - 476	Shale, gray, harder, and siltstone
476 - 478	Shale, black
478 - 481	Coal
481 - 487	Shale, very dark gray
487 - 490	Shale, medium-gray
490 - 493	Shale, medium-gray, harder
493 - 498	Clay, very light gray, soft
498 - 501	Shale, gray
501 - 517	Shale, light-gray
517 - 522	Shale or siltstone, medium-gray, sandy, with some red shale

Well FB 26--Continued

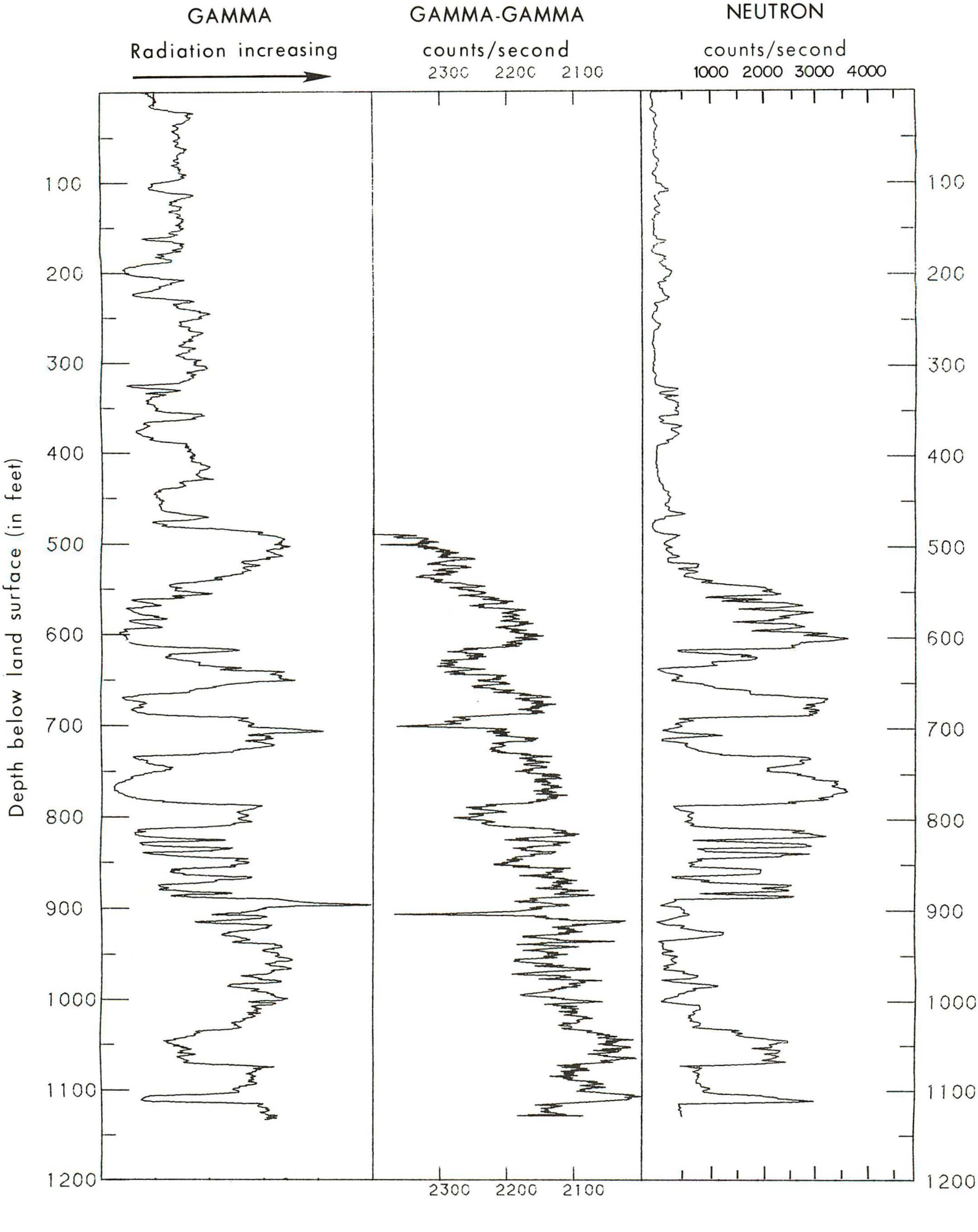
Depth (ft)	Description
522 - 537	Shale and siltstone, medium-gray
537 - 545	Siltstone and sandy siltstone, medium-gray
545 - 552	Siltstone, darker-gray, sandy
552 - 567	Shale, gray, hard, and slightly sandy shale
567 - 595	Shale, gray, soft
595 - 612	Shale or siltstone, greenish-gray, sandy, harder
612 - 627	Shale or siltstone, greenish-gray and some dark maroon; not as hard
627 - 655	Shale or siltstone, greenish-gray
655 - 665	Shale, black
665 - 668	Coal
668 - 669.5	Parting
669.5- 673	Coal
673 - 676	Shale, black and gray
676 - 682	Shale, gray, sandy
682 - 687	Sandstone, light-gray, very fine-grained
687 - 772	Siltstone, gray, very hard, with some sandstone; water (less than 1 gal/min) at 767 ft
772 - 808	Sandstone, light-gray; some more water at 780 ft
808 - 825.4	Sandstone, medium-gray, fine-grained, with siltstone clasts at 811.7-812 ft; some dark-gray shaly or silty zones at base; also scattered, very thin coaly seams
825.4- 832	Shale, black

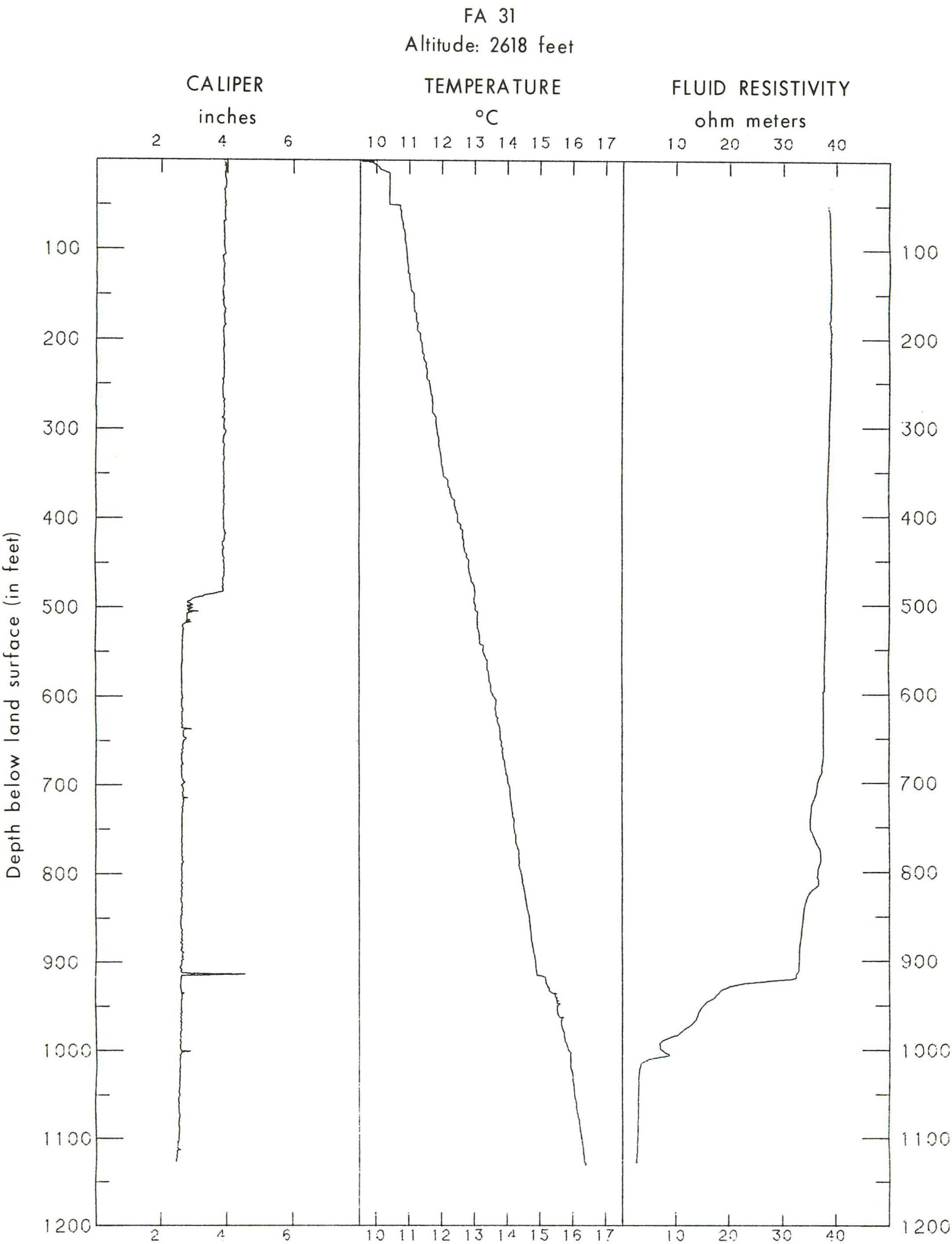

FA25
Altitude: 2650 feet
GAMMA
Radiation increasing
FA 27
Altitude: 2860 feet
GAMMA
Radiation increasing
FA 28
Altitude: 2890 feet
GAMMA
Radiation increasing
Depth below land surface (in feet)
100
200
300
400
500
600
700
800
900
1000
1100
1200

FA 31
Altitude: 2618 feet



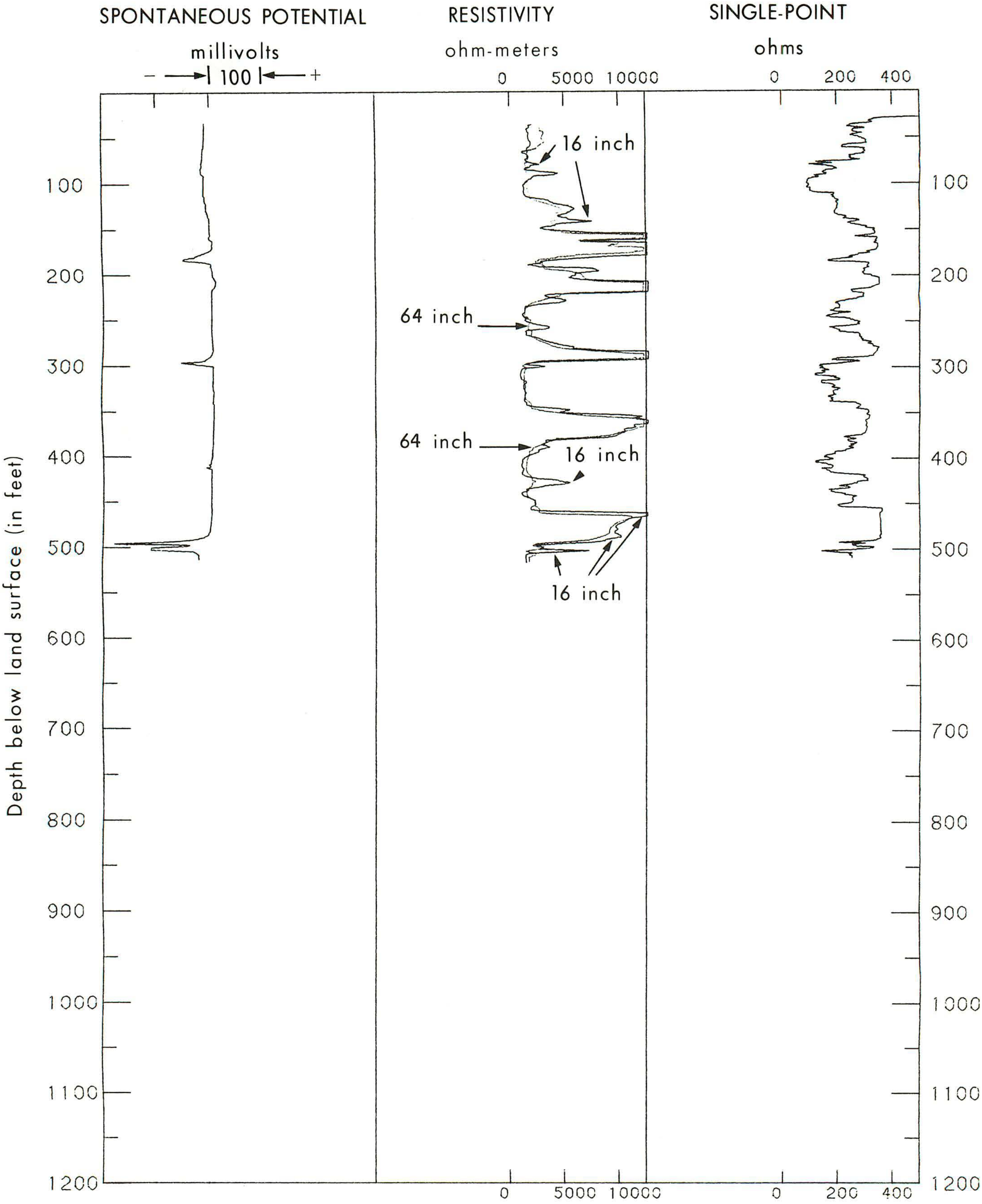
FA 31
Altitude: 2618 feet

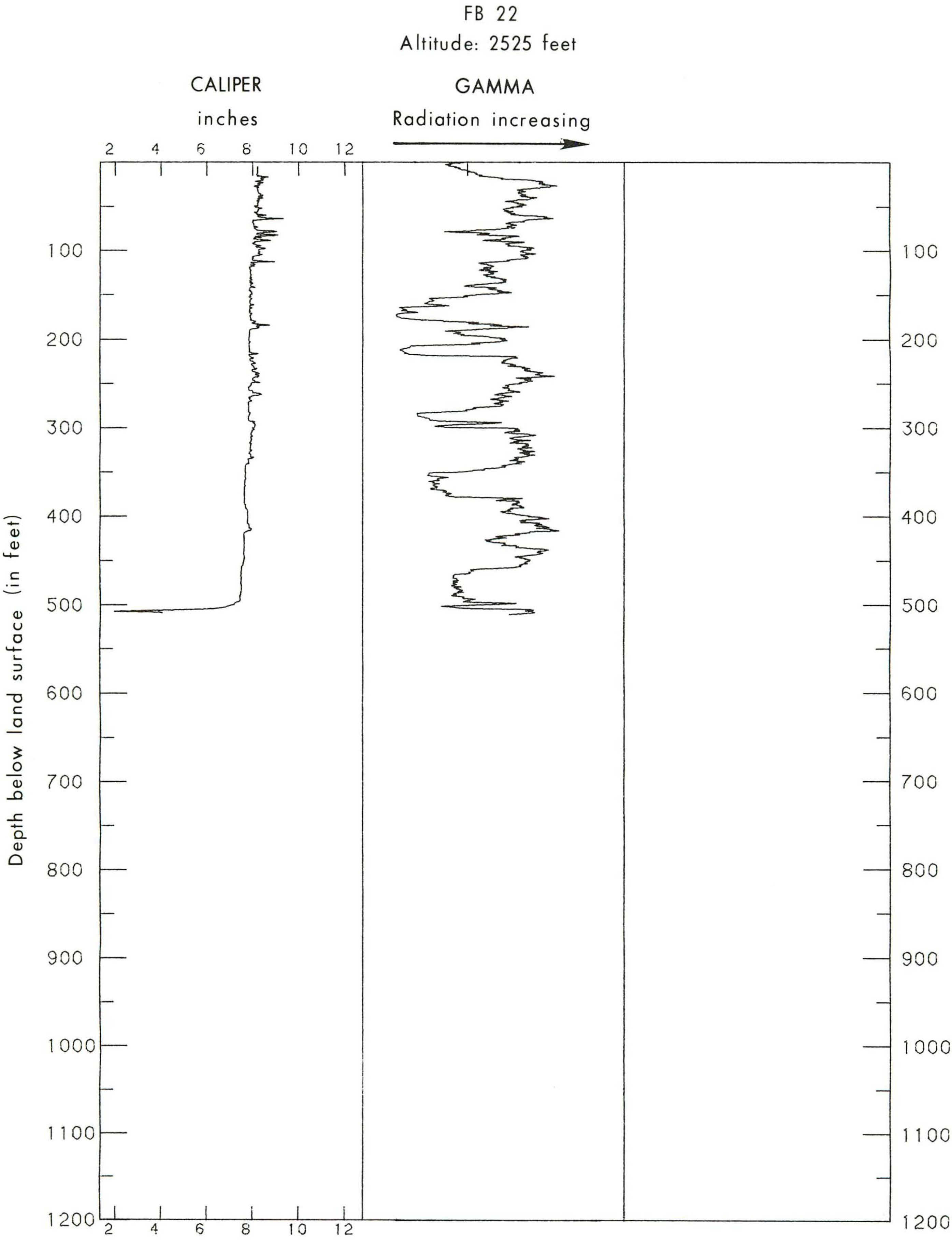


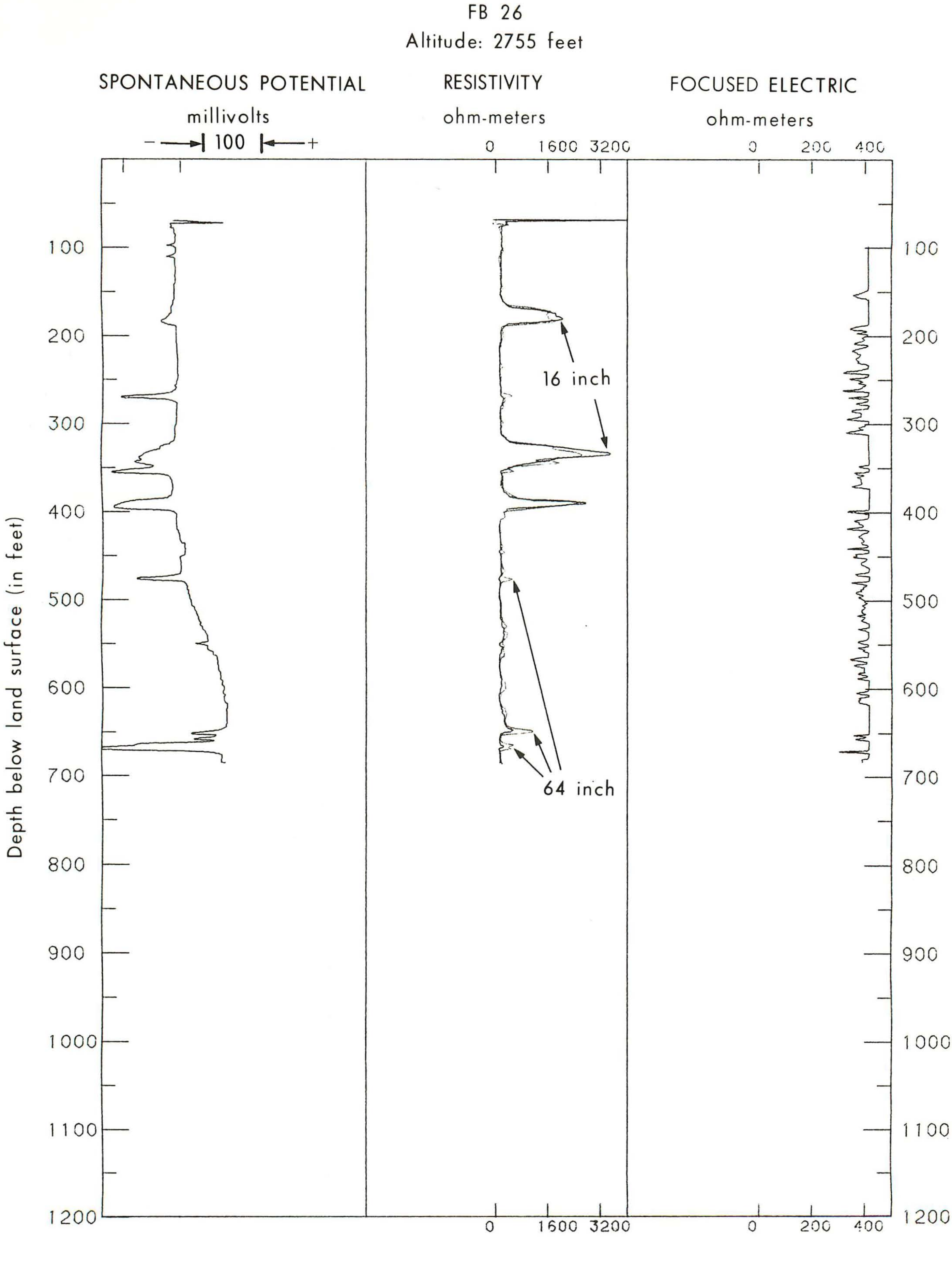

FA 31
Altitude: 2618 feet
CALIPER
inches
TEMPERATURE
°C
FLUID RESISTIVITY
ohm meters
Depth below land surface (in feet)

FB 22

Altitude: 2525 feet

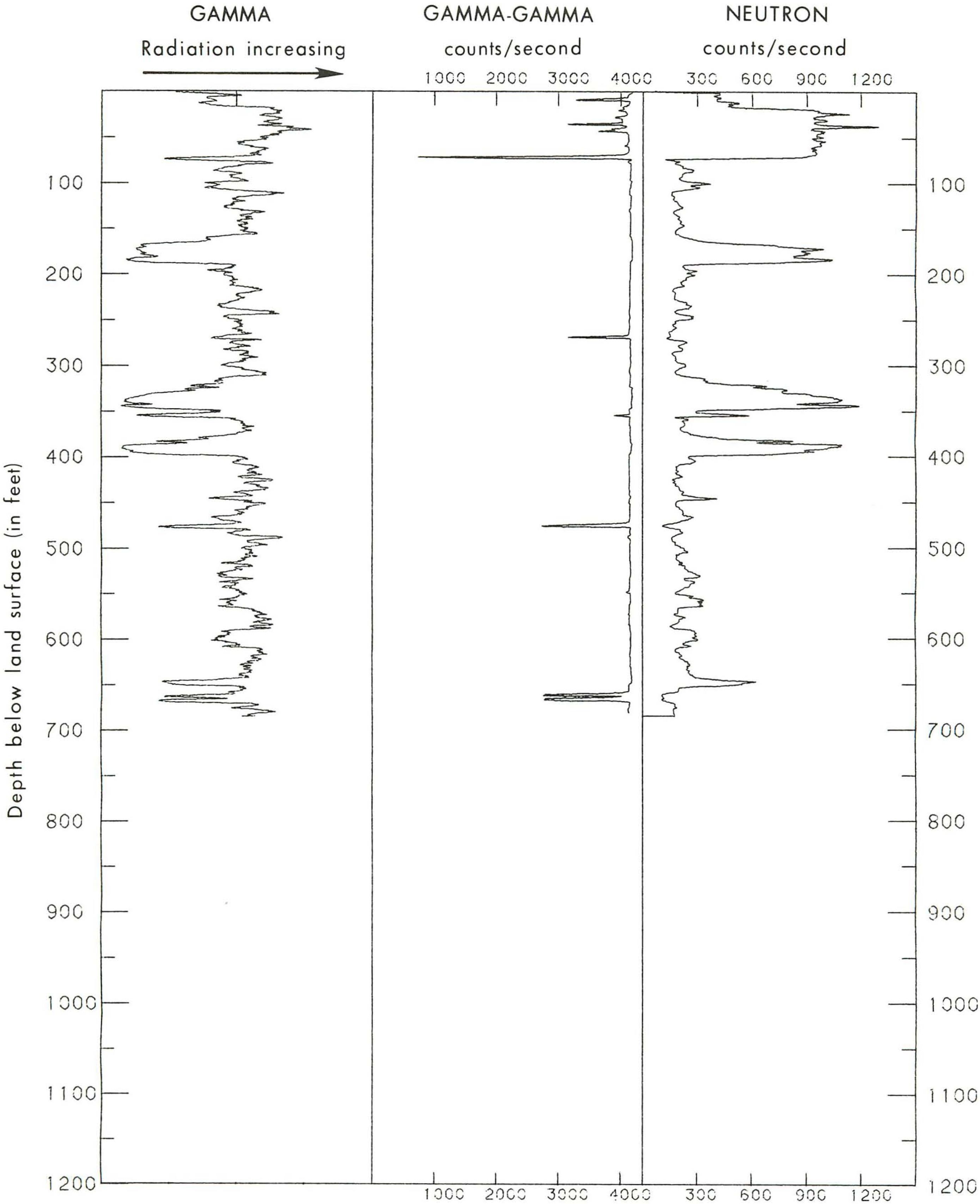


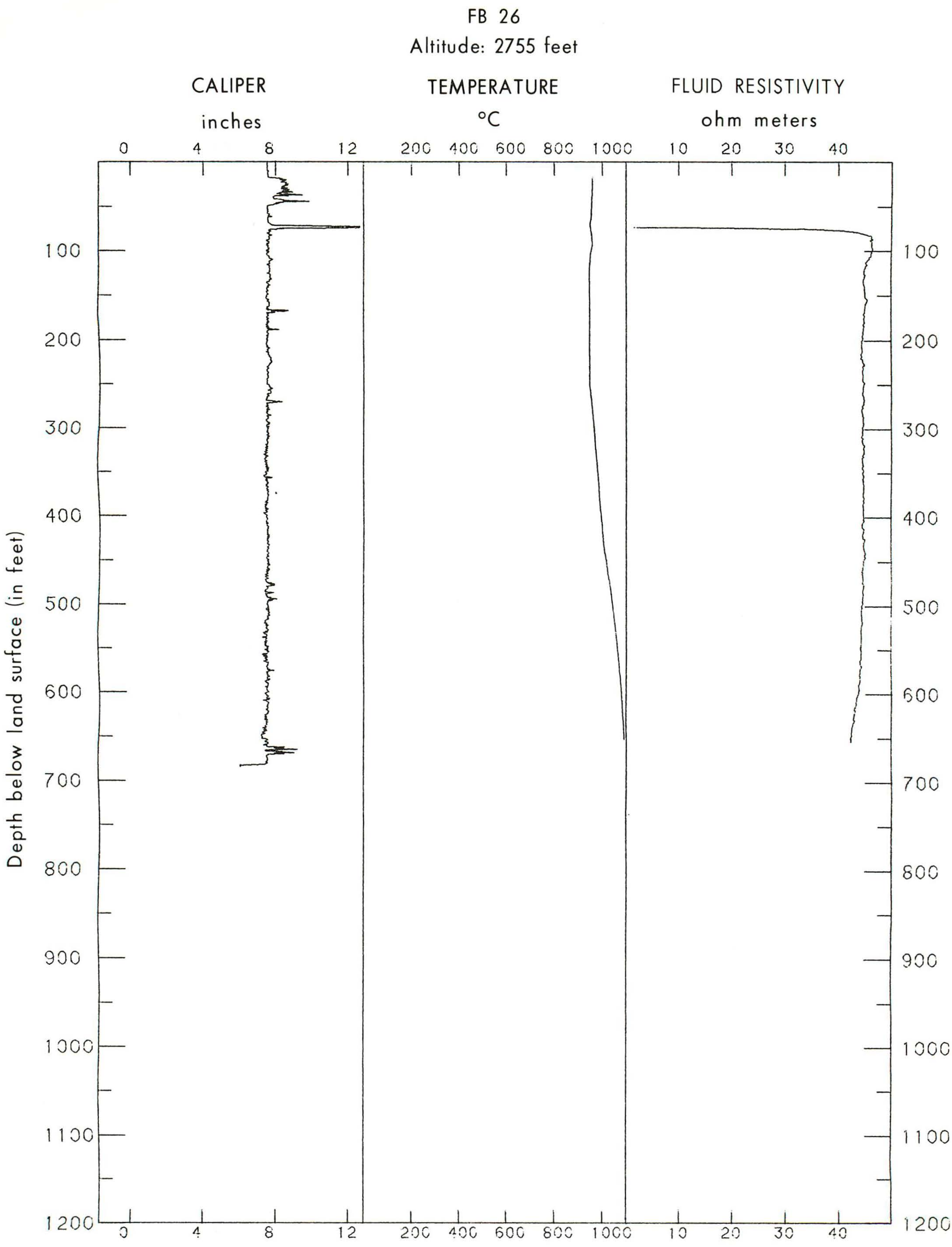

FB 22
Altitude: 2525 feet
CALIPER
inches
GAMMA
Radiation increasing
2 4 6 8 10 12
Depth below land surface (in feet)
100
200
300
400
500
600
700
800
900
1000
1100
1200


FB 26
Altitude: 2755 feet
SPONTANEOUS POTENTIAL
millivolts
100
RESISTIVITY
ohm-meters
0 1600 3200
FOCUSED ELECTRIC
ohm-meters
0 200 400
16 inch
64 inch
Depth below land surface (in feet)
100
200
300
400
500
600
700
800
900
1000
1100
1200

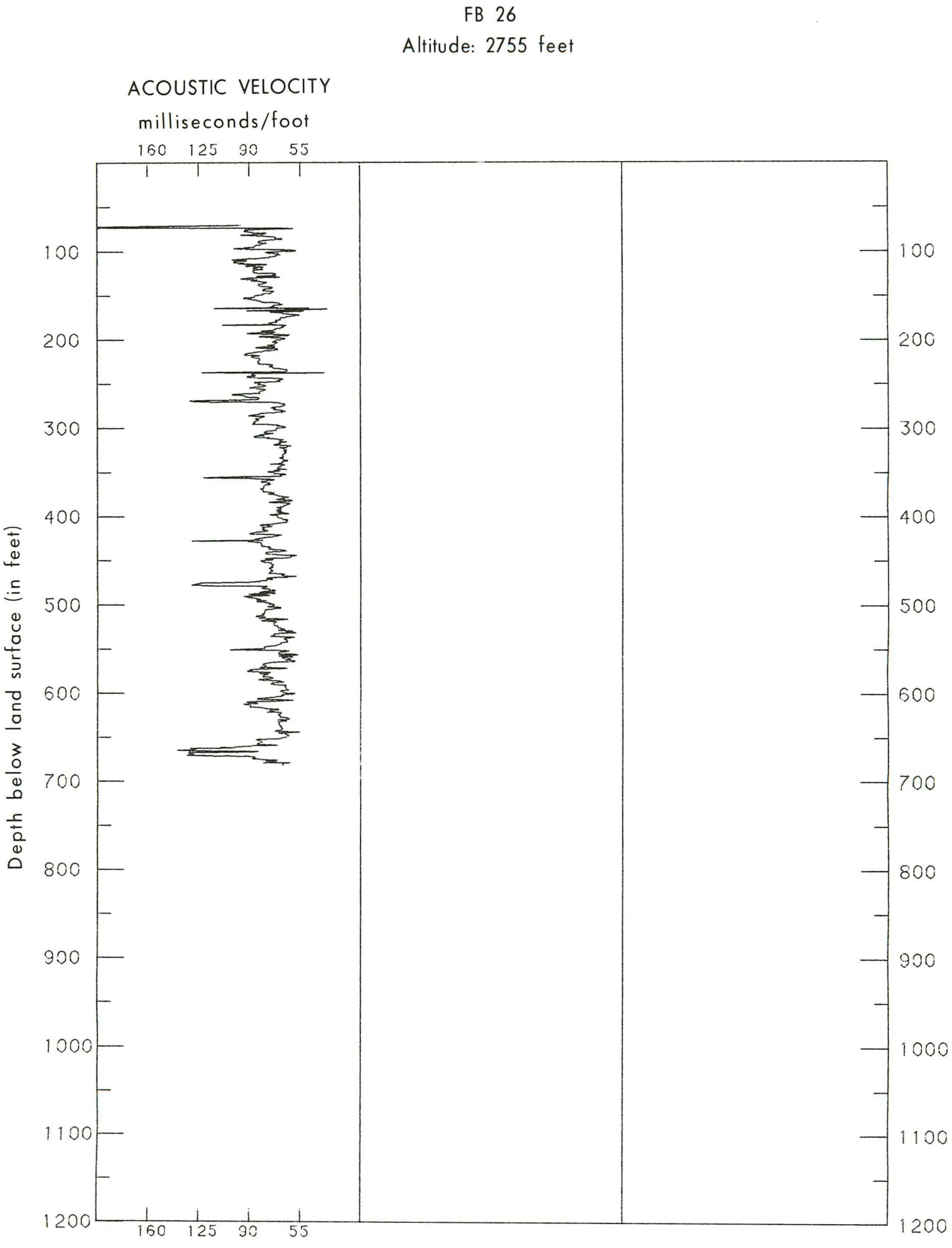
FB 26

Altitude: 2755 feet





FB 26
Altitude: 2755 feet
CALIPER
inches
TEMPERATURE
°C
FLUID RESISTIVITY
ohm meters
0 4 8 12
200 400 600 800 1000
10 20 30 40
Depth below land surface (in feet)
100
200
300
400
500
600
700
800
900
1000
1100
1200


FB 26
Altitude: 2755 feet
ACOUSTIC VELOCITY
milliseconds/foot
160 125 90 55
Depth below land surface (in feet)
100
200
300
400
500
600
700
800
900
1000
1100
1200

MARYLAND GEOLOGICAL SURVEY
The Rotunda
711 W. 40th Street
Baltimore, Maryland 21211

Selected Reports of Investigations:

1. Chemical quality of water and trace elements in the Patuxent River Basin, by S.G. Heidel and W.W. Frenier, 1965, 40 p. $3.50*
3. Water resources of the Salisbury area, Maryland, by D. H. Boggess and S.G. Heidel, 1968, 69 p. 3.00
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