GROUND-WATER HYDROLOGY OF STRIP-MINE AREAS IN EASTERN OHIO (CONDITIONS DURING MINING OF TWO WATERSHEDS IN COSHOCTON AND MUSKINGUM COUNTIES)

U.S. Geological Survey

Water Resources Investigations/Open-File Report 81-913

Prepared in cooperation with U.S. Bureau of Mines; U.S. Department of Agriculture, Agricultural Research Service; and Ohio Agricultural Research and Development Center.

U.S. DEPARTMENT OF THE INTERIOR

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GEOLOGICAL SURVEY

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UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

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CONVERSION FACTORS

For the convenience of those readers who prefer to use International System (Metric) units rather than inch-pound units, the conversion factors for terms used in this report are listed below:

To convert from	To	Multiply by
foot (ft)	meter (m)	0.3048
mile (mi)	kilometer (km)	1.609
acre	hectare (ha)	0.4047
gallon per minute (gal/min)	liter per second (L/s)	0.06309
foot^3 per second (ft^3/s)	meter^3 per second (m^3/s)	0.02832

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ABSTRACT

Ground-water conditions during coal strip mining in two small watersheds are described as part of an ongoing study of effects of mining on hydrologic systems. Both watersheds were underlain by stratified sedimentary rocks containing two perched aquifers above clay beds which underlaid the major coal seams. Mining involved removing the overburden rocks, including the top aquifer, stripping the coal seam, and recontouring the overburden spoils to the approximate premining shape of the watershed.

Water levels in the top aquifer declined as mining neared the watersheds, but destruction of observation wells precluded a record of any decline during mining in the watersheds. Depletion of the top aquifer was reflected in base flow of streams, which was reduced and more highly mineralized after mining. Initial saturated thickness of replaced overburden spoils ranged from 0 to 4 feet, based on data from observation wells installed immediately after reclamation. Down-hole specific-conductance measurements of water in the spoils suggest the presence of more highly mineralized water than that in the premining top aquifer. No significant effects of mining are evident on ground-water levels or quality beneath the stripped coal.

INTRODUCTION

Growing use of coal requires better understanding of the impact of coal mining on water resources. A comprehensive study, sponsored by the U.S. Bureau of Mines, is being made to assess the effects of strip mining on hydrology of watersheds (30-50-acres) in eastern Ohio (Hamon and others, 1977). The U.S. Geological Survey is responsible for the ground-water part of the study, involving the following objectives: (1) Description of the hydrogeology of four small watersheds and a control watershed; (2) documentation of ground-water flow and water-quality characteristics for premining and postmining conditions; and (3) development of models to simulate the movement of ground water and solutes in the watersheds.

Earlier reports (U.S. Bureau of Mines, 1978, Hamon and others, 1979) include descriptions of premining ground-water hydrology. This report describes ground-water conditions during the mining phase of two of the watersheds (the "mining phase," as used herein, includes mining and recontouring of spoils). Later reports will document changes as data collection and analysis continue throughout the premining, mining, and postmining phases of the watersheds.

Each watershed (fig. 1) is identified by the first letter of the county in which it is located (except for A06) and a two-digit number indicating the number of the coal seam to be mined. A06 will not be mined and serves as a control watershed in which USDA-ARS (U.S. Department of Agriculture-Agricultural Research Service) has collected historic hydrologic data. J11 and J08 have not yet been mined. C06 and M09, discussed herein, were mined and recontoured during November 1976 to August 1978 and January 1977 to August 1978, respectively, the primary periods addressed by this report.

Mining removed the Middle Kittanning No. 6 coal bed at C06 and the Meigs Creek (Sewickley) No. 9 coal bed at M09. After topsoil removal, mining began along the coal outcrop, where blasted and removed overburden was placed downslope (fig. 2). As coal was stripped and the position of the highwall moved toward the watershed divide, additional ridges of overburden material were formed in the wake of mining. The underclay was left essentially undisturbed. Reclamation included recontouring the spoils to approximate premining watershed shape, replacement of topsoil, and seeding for revegetation.

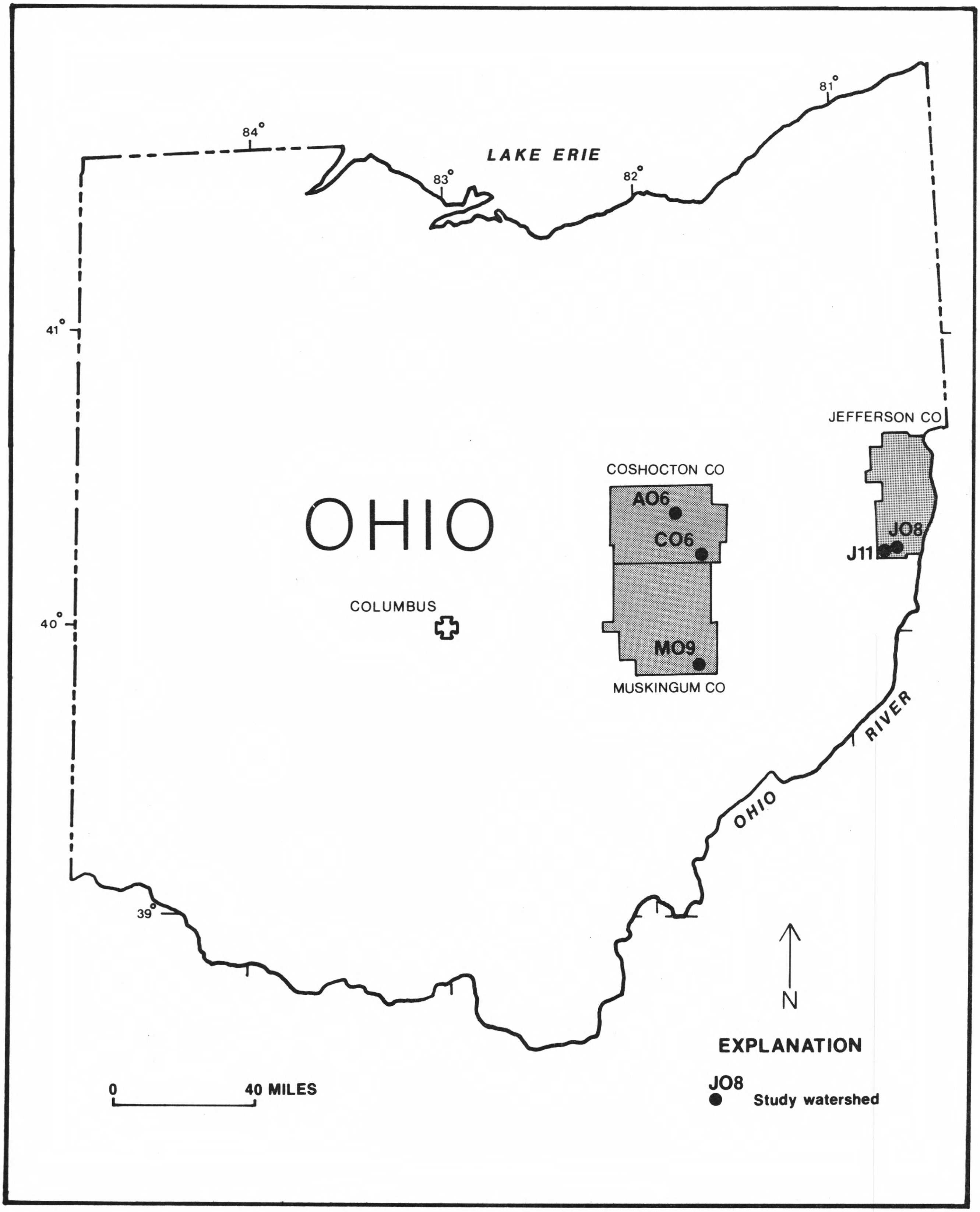


Figure 1.--Location of study watersheds.

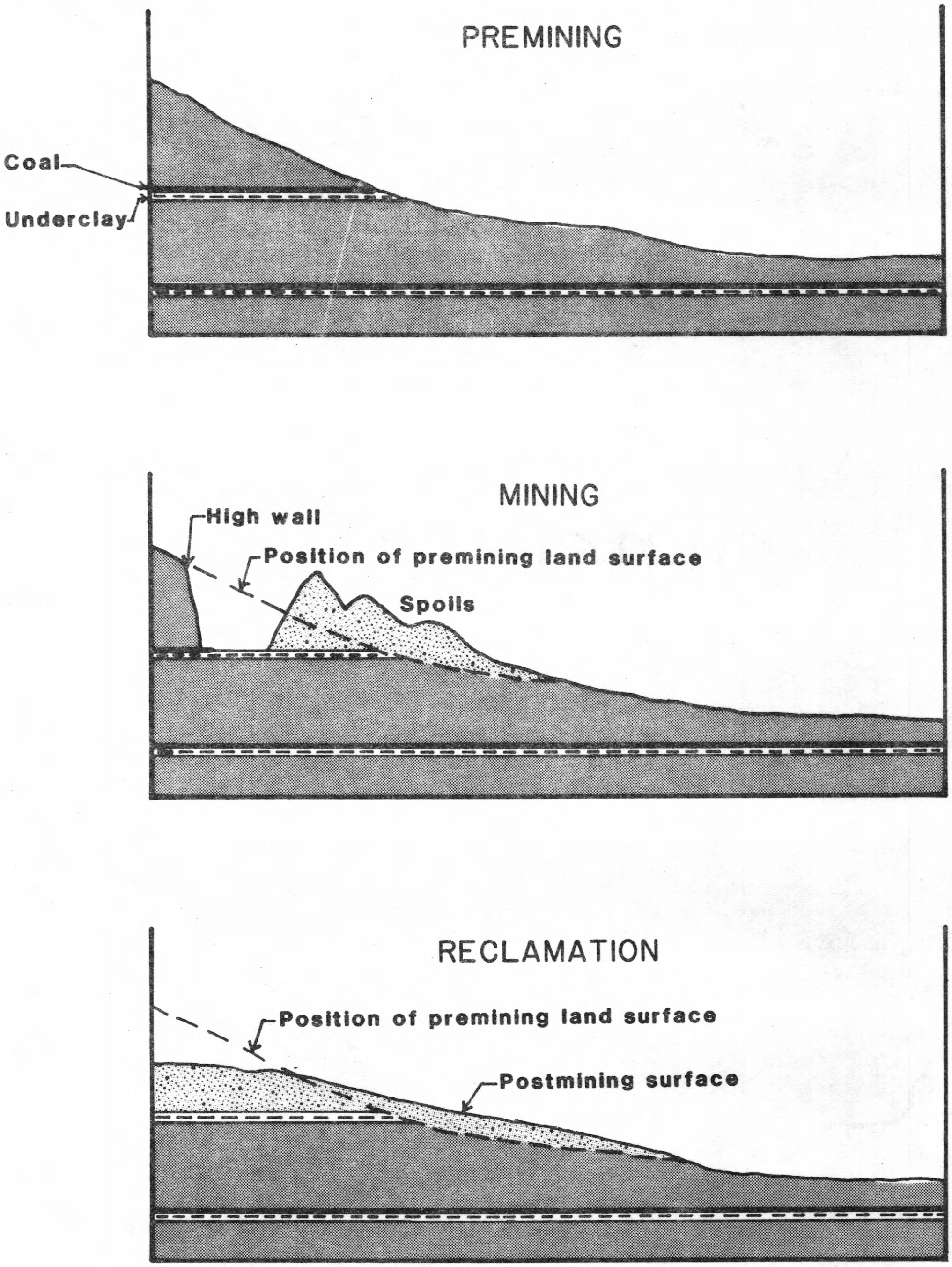


Figure 2.--Schematic sections illustrating strip-mining process.

WATERSHED C06

Summary of Premining Conditions

Premining conditions at C06, then a forested 51-acre watershed, are described by U.S. Bureau of Mines (1978). Stratigraphy (fig. 3) consisted of nearly flat-lying interbedded shale, sandstone, limestone, coal, and clay of the Pennsylvanian System. Relatively impermeable clay beds that underlaid the major coal seams formed bases for two major perched saturated zones above the regional ground-water system (fig. 4). The presence of the perched zones was determined by the drilling of observation wells and subsequent monitoring of the water levels. The saturated zones are referred to as "aquifers" for convenience, even though they typically yield less than 1 gal/min to wells. Observation wells (fig. 5) were cased so that each was open to only one aquifer. The top aquifer was above the clay that underlaid the Middle Kittanning No. 6 coal bed, which cropped out in the watershed. Recharge was from precipitation within the watershed and discharge was downward as leakage through the underclay or laterally as springflow, seepage, or evapotranspiration. The middle aquifer was above the clay that underlies the Brookville No. 4 coal bed. Recharge to the middle aquifer was by leakage through the overlying clay and by precipitation where the clay is absent; discharge occurred as downward leakage through the underclay or laterally as base flow to the stream or evapotranspiration. The deep aquifer is part of the regional flow system and is recharged and discharged mainly outside the watershed.

Premining ground-water quality at C06 showed considerable spatial variability. Much water was of the calcium bicarbonate type but calcium sulfate and sodium bicarbonate types were also present. Mineralization of water was greater in the middle and deep aquifers, as indicated by specific-conductance measurements. Specific conductance ranged from 120 to 520 µmho/cm (micromhos per centimeter) in the top aquifer, 280 to 905 in the middle aquifer, and 258 to 1,110 in the deep aquifer (U.S. Bureau of Mines, 1978).

Data Collection During Mining

Little ground-water data were collected during mining because all wells except W10-3 (fig. 5) were destroyed within 2 months after mining began. Monthly water-level measurements continued at W10-3 until July 1977, after which an hourly record was obtained through August 1978. Springflow was monitored by USDA-ARS at one location (fig. 5) until the gage was damaged by overburden placement early in the mining operation. Continuous stream-discharge data were also

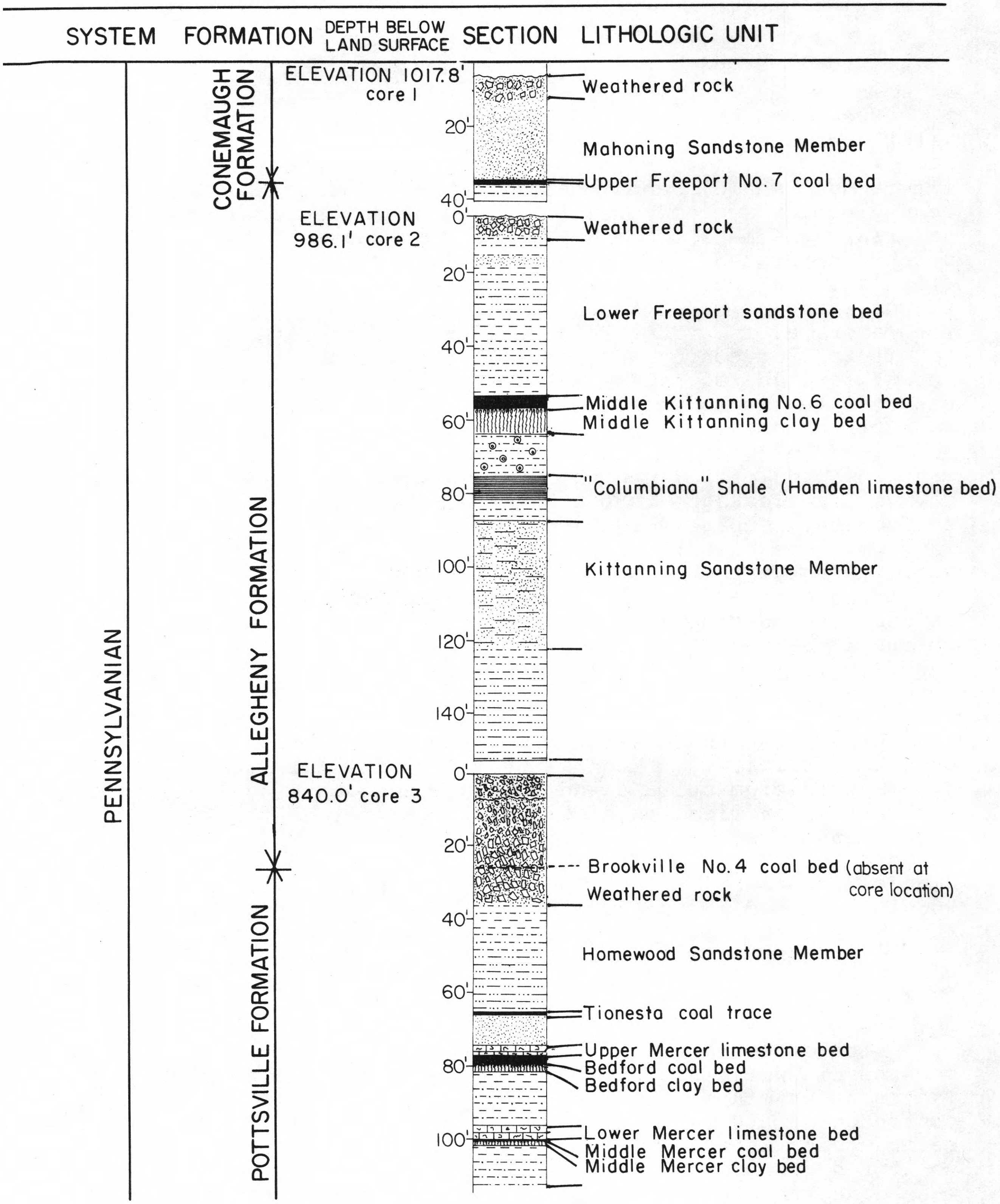
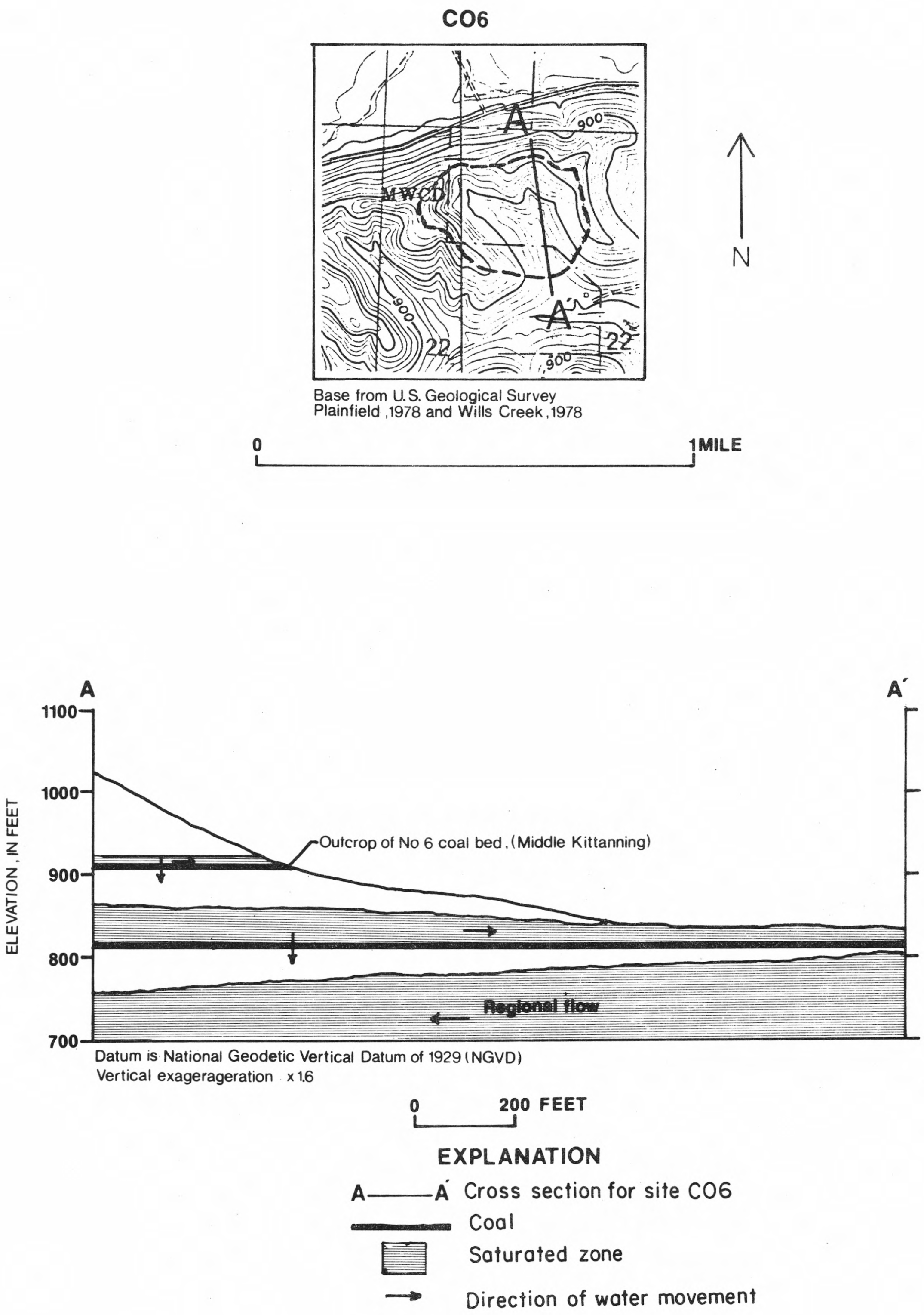


Figure 3.--Stratigraphic column for C06.



Base from U.S. Geological Survey
Plainfield, 1978 and Wills Creek, 1978

Datum is National Geodetic Vertical Datum of 1929 (NGVD)
Vertical exagerageration x 1.6

Figure 4.--Cross section of C06 illustrating pre-mining ground-water occurrence and flow.

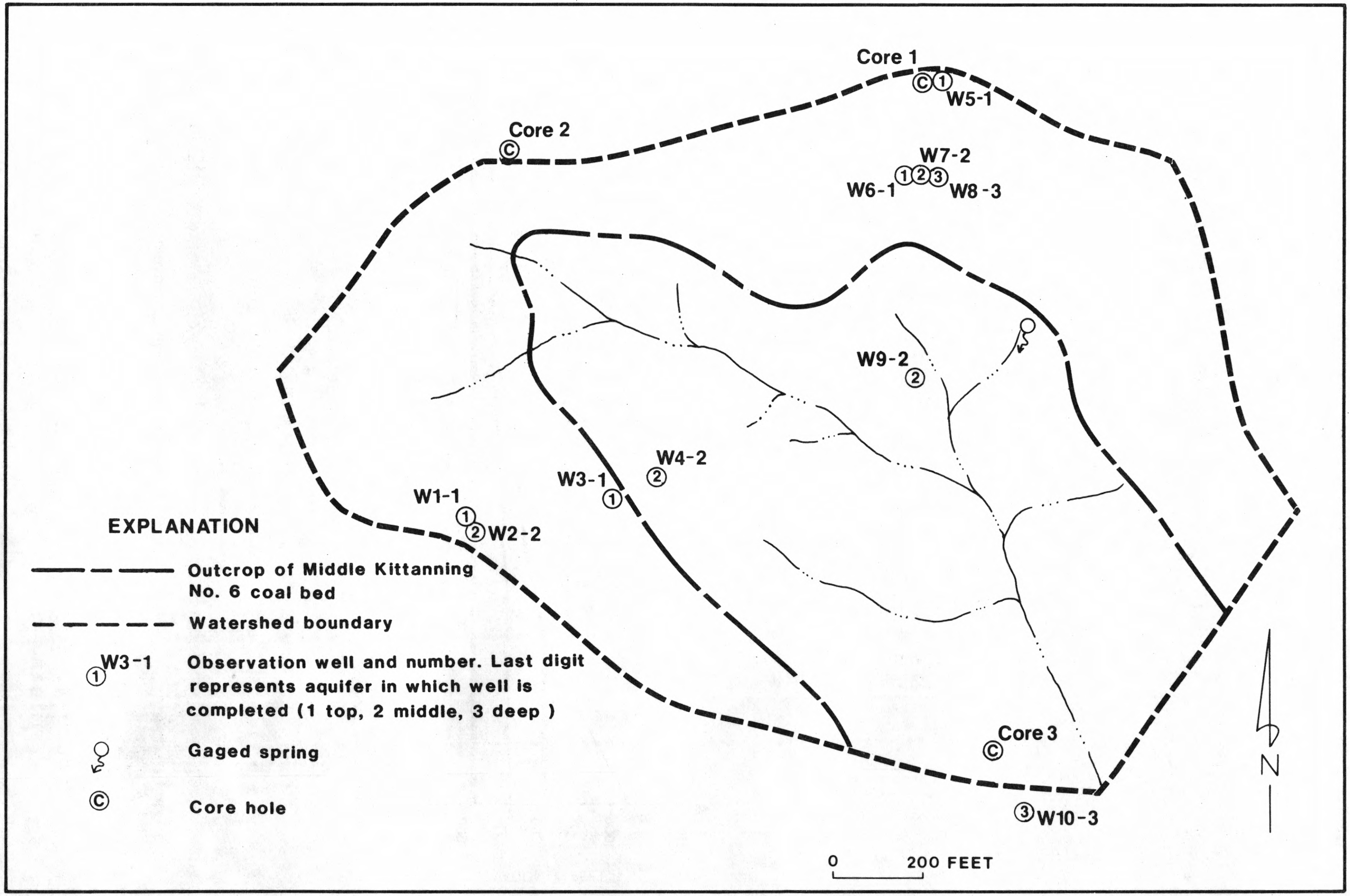


Figure 5.--Premining locations of observation wells, gaged spring, and coal outcrop at C06.

collected by that agency at the mouth of the watershed throughout mining and reclamation.

Five water samples from well W10-3 were collected and analyzed during the mining phase. Four base flow samples were collected at the mouth of the watershed by USDA-ARS and analyzed by Ohio Agriculture Research and Development Center.

Details of the methods of data collection are given by the U.S. Bureau of Mines (1978).

Ground-Water Hydrology During Mining

Beginning in August 1976, mining of No. 6 coal in the adjacent watershed to the west caused the top aquifer water table in C06 to decline (fig. 6; well locations shown in fig. 5). Water levels in observation wells nearest the watershed divide, W1-1 and W5-1, declined several feet. Water-level declines in wells nearest the coal outcrop, W3-1 and W6-1, probably reflect only the seasonal trend. As rock overburden and coal were removed in the adjacent watershed, the aquifer was narrowed, causing an increased hydraulic gradient in and drainage from the aquifer. Destruction of wells prevented documentation of any water-level decline as mining progressed into watershed C06 starting in November 1976, but springflow from the top aquifer at the gaged site (fig.5) gradually decreased and ceased on January 3, 1977.

Most water in the top aquifer drained as these rocks were removed and formed into spoils piles. Although no data are available to indicate the amount of water within the spoils during the mining phase, most water was probably derived from infiltration of precipitation during that period. Water ponded in some low areas between spoils ridges.

The low-flow part of the streamflow hydrograph (fig. 7) reflects ground-water conditions during the mining phase. Precipitation during this period was not abnormally high or low, based on data collected by USDA-ARS. Relatively low-base flow during September 1976 to August 1977 was at least partly due to dewatering and destruction of the top aquifer during mining; base flow decreased to a rate supplied mainly by the middle aquifer. Later increases (after August 1977) were probably caused by water that had infiltrated into and moved through the overburden spoils.

The hydrograph for well W10-3 (fig. 8), the only water-level record for the mining phase, shows no discernible effects of mining.

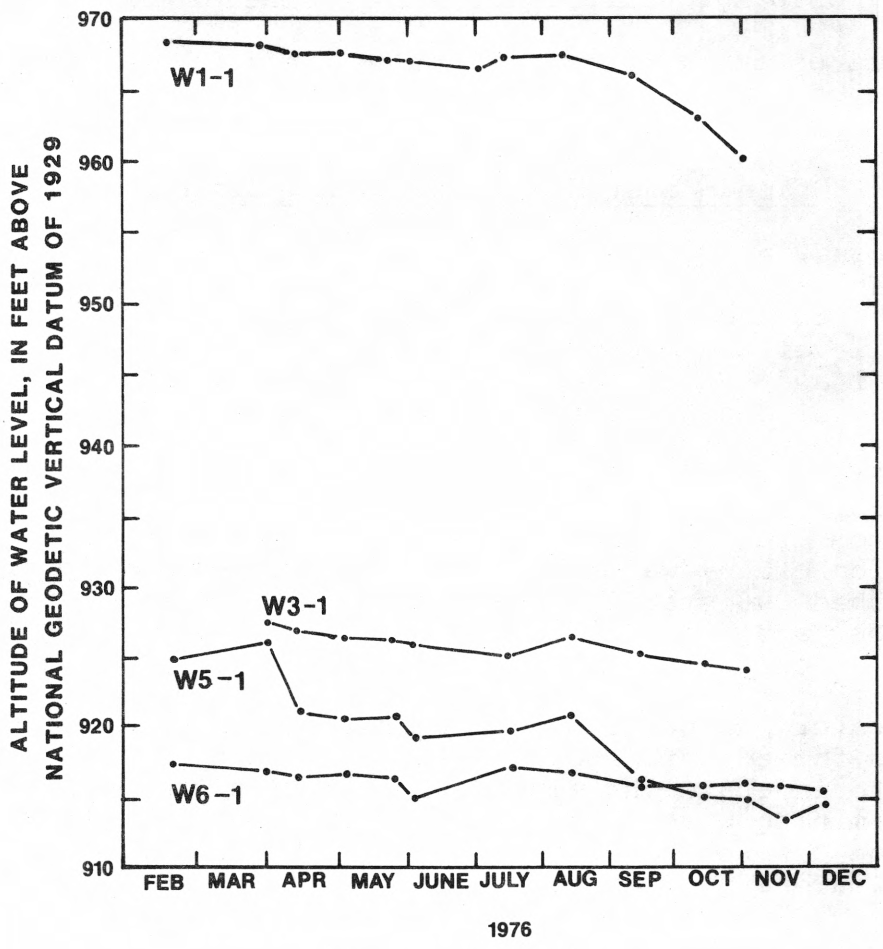


Figure 6.--Hydrographs for observation wells completed in top aquifer at C06

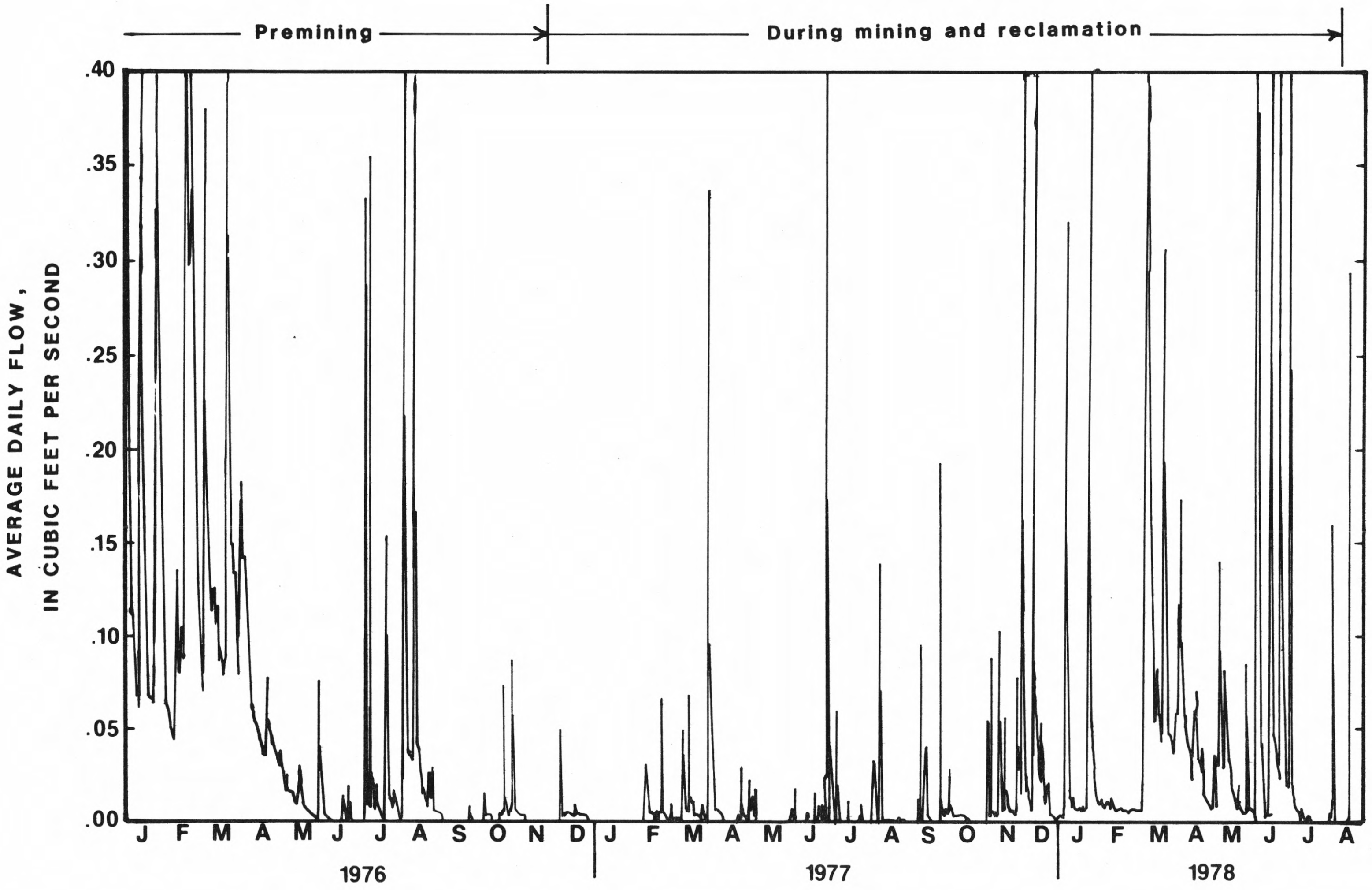


Figure 7.--Hydrograph of streamflow at mouth of C06 (based on preliminary data from U.S. Department of Agriculture, Agricultural Research Service).

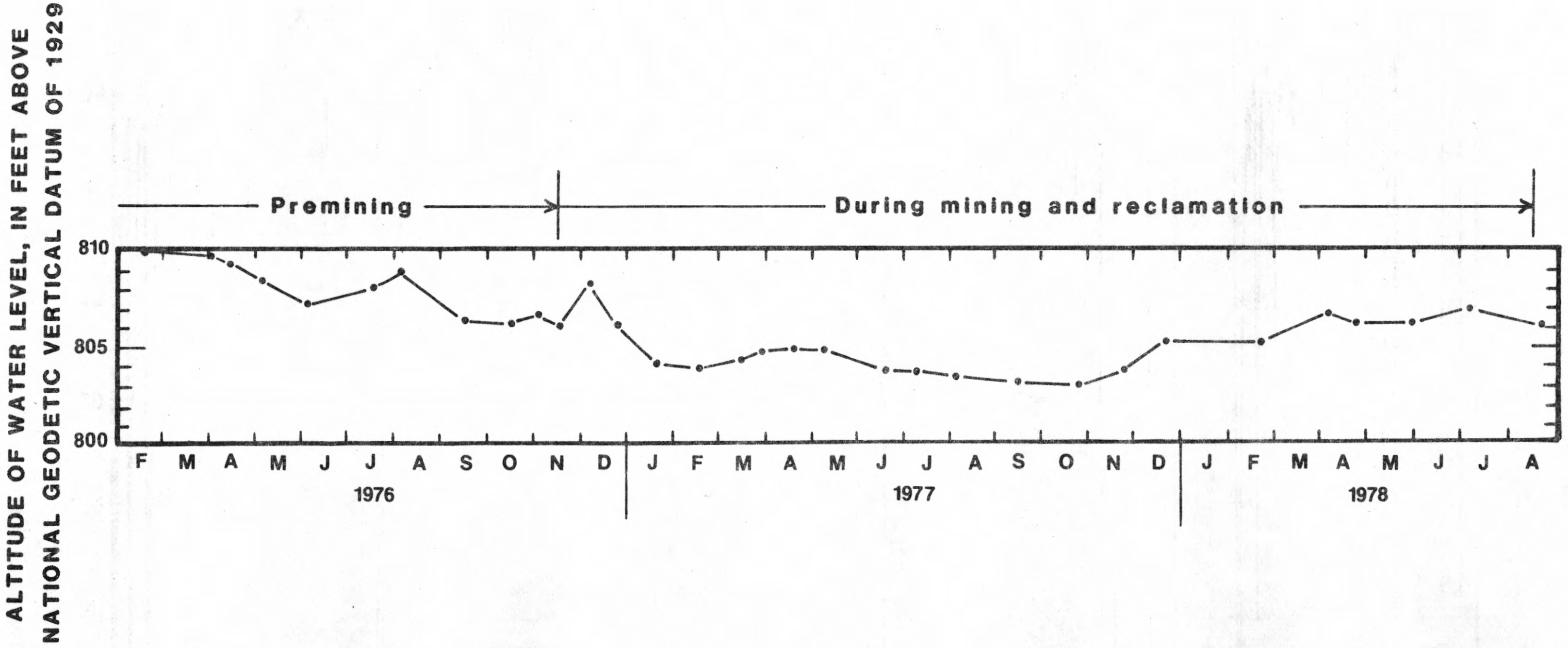


Figure 8.--Hydrograph for well W10-3 at C06.

Observation wells were installed after reclamation to monitor water levels in the spoils and in the middle and deep aquifers. Initial data indicate that little of the spoils was saturated; two wells were dry and a third well contained 4 feet of water. Initial data from deeper wells suggest that water levels in the middle and deep aquifers did not change substantially during the mining phase. Data will continue to be collected and analyzed during the postmining phase and will be included in a future report.

Ground-Water Quality During Mining

Chemical analyses of water from well W10-3 during the mining phase of C06 (table 1) show no definitive trends, although some constituent values varied from sample to sample.

Base-flow samples collected at the mouth of the watershed had dissolved-solids concentrations as follows:

December 20, 1976 ---------- 122 mg/L
February 12, 1977 ---------- 210
March 18, 1977 ------------- 112
March 6, 1978 -------------- 602

The last value suggests an increase in mineralization over premining base flow, which had a dissolved-solids concentration range of 114 to 141 mg/L (U.S. Bureau of Mines, 1978). The increase reflects a change from the top aquifer to the middle aquifer and overburden spoils as the main contributors to base flow.

Analyses of initial samples from postmining observation wells suggest no immediate large changes in middle and deep aquifer water quality associated with mining. The amount of water in wells completed in spoils was inadequate to provide samples. Preliminary specific conductance measurements with a down-hole probe, however, indicated higher mineralization than in premining top aquifer water. This increase is likely a result of blasting and handling of the overburden, exposing more surface area of the rock and increasing its susceptibility to solution.

Table 1.--Chemical analyses of water collected from well W10-3 at C06 during mining.

Parameter	Unit	Concentration or value				
		3-16-77	6-17-77	9-15-77	12-27-77	7- 6-78
Alkalinity as $CaCO_3$	mg/L	112	116	115	115	125
Aluminum Dissolved	μg/L	-	-	-	-	20
Aluminum Total	μg/L	30	40	2900	20	-
Antimony Dissolved	μg/L	-	-	-	-	-
Antimony Total	μg/L	0	0	0	1	-
Arsenic Dissolved	μg/L	-	-	-	-	0
Arsenic Total	μg/L	0	1	0	2	-
Barium Dissolved	μg/L	-	-	-	-	0
Barium Total	μg/L	100	0	100	100	-
Bicarbonate	mg/L	136	141	140	140	152
Cadmium Dissolved	μg/L	-	-	-	-	0
Cadmium Total	μg/L	0	0	0	0	1
Calcium Dissolved	mg/L	25	26	27	-	26
Carbon Dioxide	mg/L	22	18	22	28	4.9
Carbon Dissolved Organic	mg/L	-	-	-	2.6	0.7
Carbon Total Organic	mg/L	8.1	6.3	11	-	-
Carbonate	mg/L	0	0	0	0	0
Chloride Dissolved	mg/L	1.3	1.8	1.1	1.1	1.5
Chromium Dissolved	μg/L	-	-	-	-	0
Chromium Total	μg/L	10	<10	<10	20	-
Color	Pt/Co	0	13	10	31	1
Copper Dissolved	μg/L	-	-	-	-	0
Copper Total	μg/L	2	5	5	8	-
Cyanide	mg/L	0.00	0.00	0.00	0.00	0.00
Fluoride Dissolved	mg/L	0.2	0.2	0.2	0.3	0.2
Hardness Noncarbonate	mg/L	13	3	6	-	0
Hardness Total	mg/L	120	120	120	-	120
Hydrogen Sulfide	mg/L	0.2	0.0	0.0	0.0	0.0
Iron Dissolved	μg/L	60	40	20	20	150
Iron Total	μg/L	5200	18,000	14,000	10,000	10,000
Lead Dissolved	μg/L	-	-	-	-	0
Lead Total	μg/L	4	10	13	8	-
Magnesium Dissolved	mg/L	15	13	13	-	14
Manganese Dissolved	μg/L	10	20	10	60	30
Manganese Total	μg/L	80	150	60	110	80
Mercury Dissolved	μg/L	-	-	-	<0.5	0.5
Mercury Total	μg/L	0.0	0.0	0.5	<0.5	-
Nickel Dissolved	μg/L	-	-	-	-	0
Nickel Total	μg/L	6	6	6	8	-
Nitrogen NH_4 as N Dissolved	mg/L	-	-	-	-	0.00
Nitrogen NH_4 as N Total	mg/L	0.00	0.01	0.01	0.01	-
Nitrogen Organic as N Dissolved	mg/L	-	-	-	-	0.04
NO_2+NO_3 as N Dissolved	mg/L	-	-	-	-	0.07
NO_2+NO_3 as N Total	mg/L	0.02	0.08	0.10	0.03	-
pH (field)		7.0	7.1	7.0	6.9	7.7
Phenols	μg/L	7	6	2	9	4
Phosphorus as P Dissolved	mg/L	-	-	-	-	0.00
Phosphorus as P Total	mg/L	0.00	0.01	0.01	0.01	-
Phosphorus as PO_4 Total	mg/L	0.00	0.03	0.03	-	-
Potassium Dissolved	mg/L	0.7	0.7	0.8	0.7	0.8
Residue Dissolved (calculated sum)	mg/L	151	146	147	-	153
Residue Dissolved	tons/acre-ft	0.21	0.20	0.20	-	0.21
Selenium Dissolved	μg/L	-	-	-	-	0
Selenium Total	μg/L	0	0	0	0	-
Silica Dissolved	mg/L	16	14	15	14	14
Silver Dissolved	μg/L	-	-	-	0	0
Silver Total	μg/L	0	0	0	0	-
Sodium adsorption ratio		0.2	0.2	0.2	-	0.1
Sodium Dissolved	mg/L	5.2	3.8	4.1	4.0	3.6
Sodium (percent)	%	8	6	7	0	6
Specific Conductance (field)	μmho /cm	250	245	250	290	246
Strontium Dissolved	μg/L	-	-	-	-	60
Strontium Total	μg/L	80	80	60	40	-
Sulfate Dissolved	mg/L	20	17	17	16	17
Water Temperature (°C)	°C	12.5	13.0	13.0	11.0	13.5
Zinc Dissolved	μg/L	-	-	-	50	10
Zinc Total	μg/L	50	40	60	60	-

WATERSHED M09

Summary of Premining Conditions

Premining conditions at M09, then a pastured 43-acre watershed, are described by U.S. Bureau of Mines (1978). Premining stratigraphy (fig. 9) consisted of nearly flat-lying shale, limestone, sandstone, coal, and clay of the Pennsylvanian System. As at C06, two major perched saturated zones were present above the regional flow system (fig. 10). The top aquifer was above the clay that underlaid the Meigs Creek (Sewickley) No. 9 coal bed. The middle aquifer was above the clay that underlies the Pittsburgh No. 8 coal bed. Ground-water flow, recharge, and discharge were similar to that at C06, except for the presence of flow in the north part of the middle aquifer across the watershed boundary. Water entered across the northwestern divide and left across the northeastern divide (flow arrow near the watershed divide in middle aquifer, fig. 10).

Ground water was commonly of the calcium magnesium bicarbonate type. The middle and deep aquifers included some water of the sodium bicarbonate and sodium chloride types. Specific conductance values ranged from 430 to 890 µmho/cm in the top aquifer, 560 to 12,400 in the middle aquifer, and 1,750 to 26,800 in the deep aquifer (U.S. Bureau of Mines,1978), revealing a general increase in dissolved-solids concentration with depth.

Data Collection During Mining

All wells except W5-2 and W10-3 (fig. 11) were destroyed within 2 months after the start of mining. Monthly water-level measurements continued at W5-2 until July 1977, after which an hourly record was obtained through August 1978. Monthly measurements were made at W10-3 throughout the period. Springflow was monitored by USDA-ARS at one location (fig. 11) until the site was destroyed during mining. Continuous stream-discharge data were collected by USDA-ARS at the mouth of the watershed throughout the mining phase.

Six water samples each from wells W5-2 and W10-3 and four baseline samples were collected and analyzed during the mining phase.

Ground-Water Hydrology During Mining

Conditions during mining of M09 resembled conditions during mining of C06, and much of the preceding discussion for C06 applies here also.

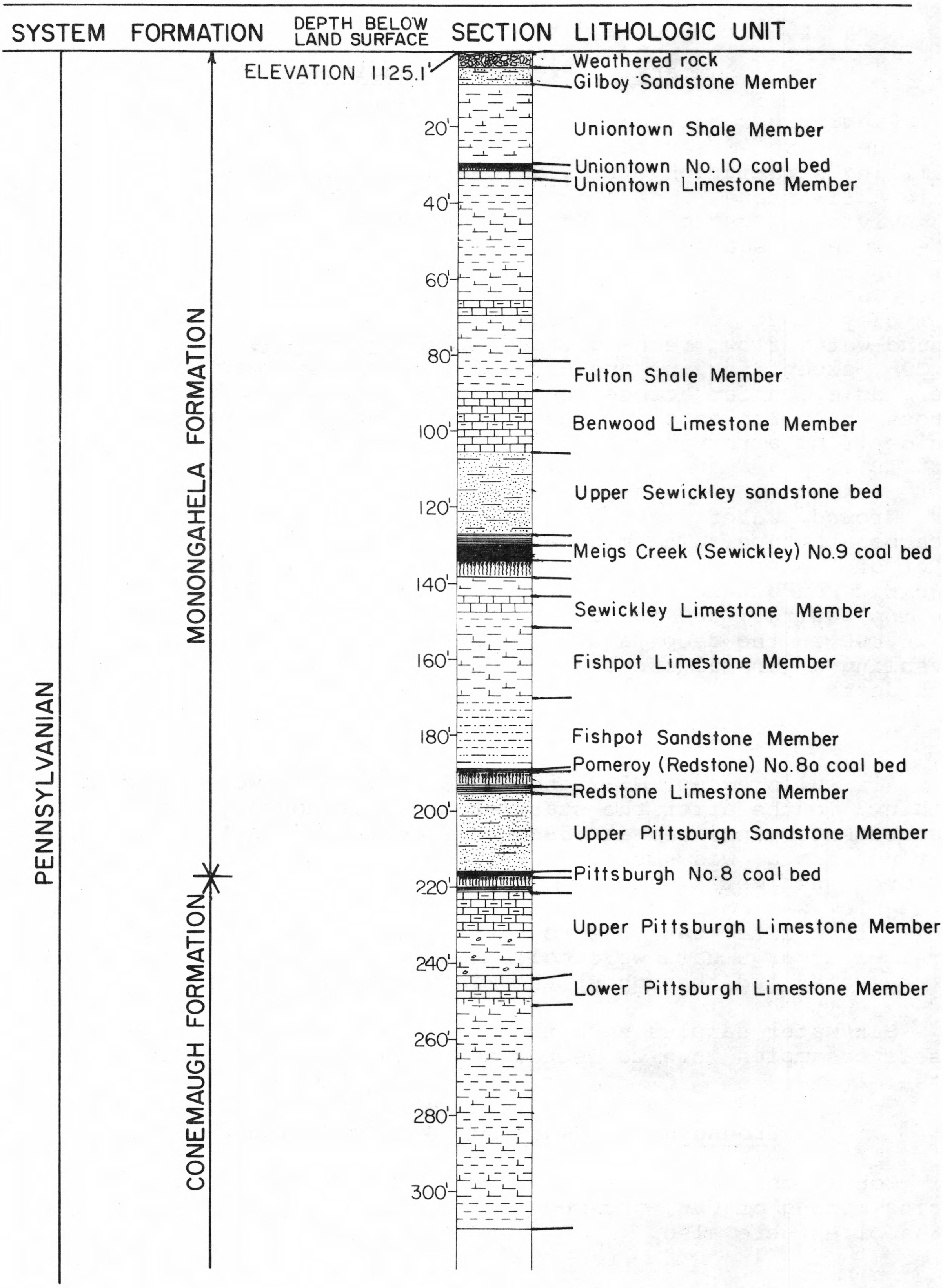


Figure 9.--Stratigraphic column for M09.

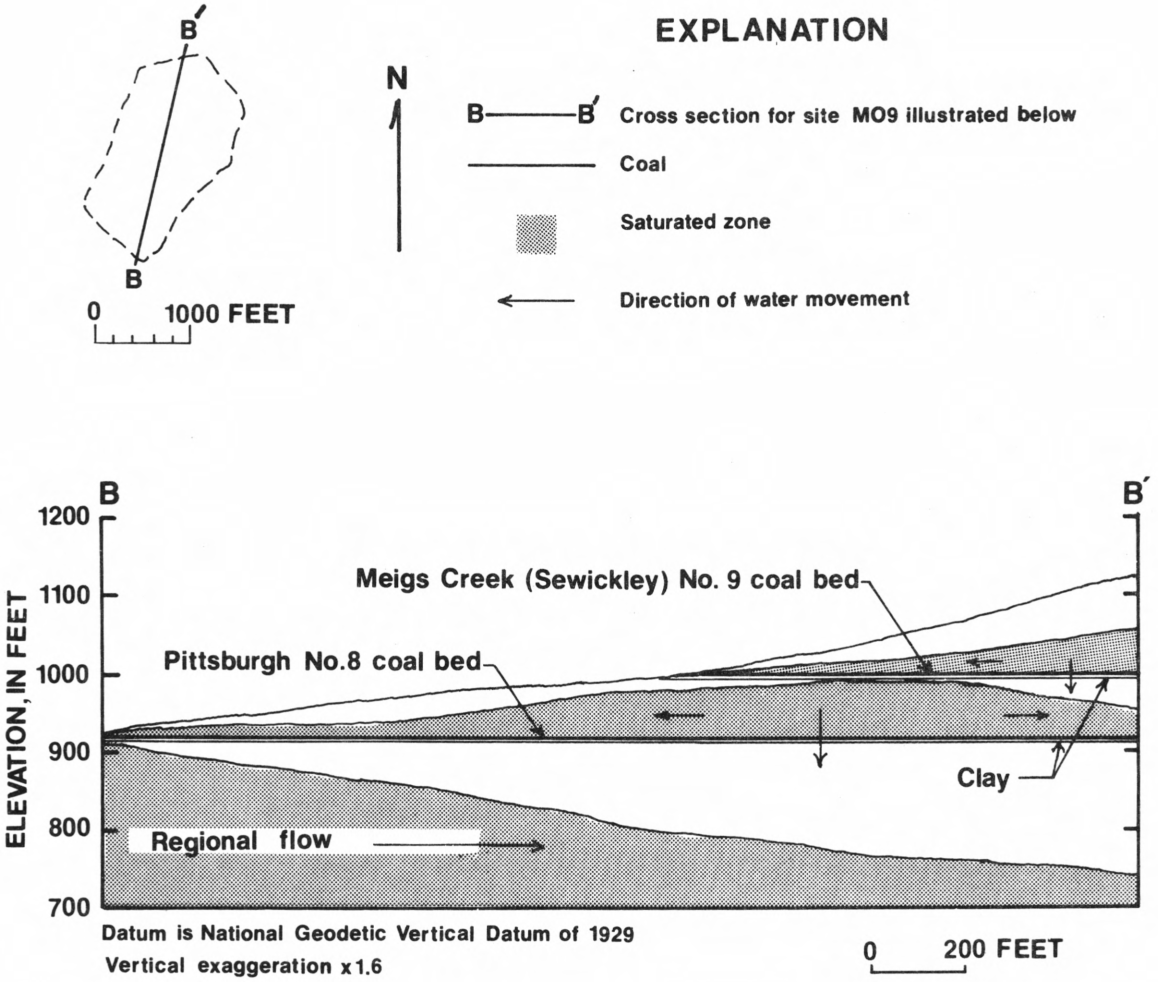


Figure 10.--Cross section for M09 illustrating premining ground-water occurrence and flow.

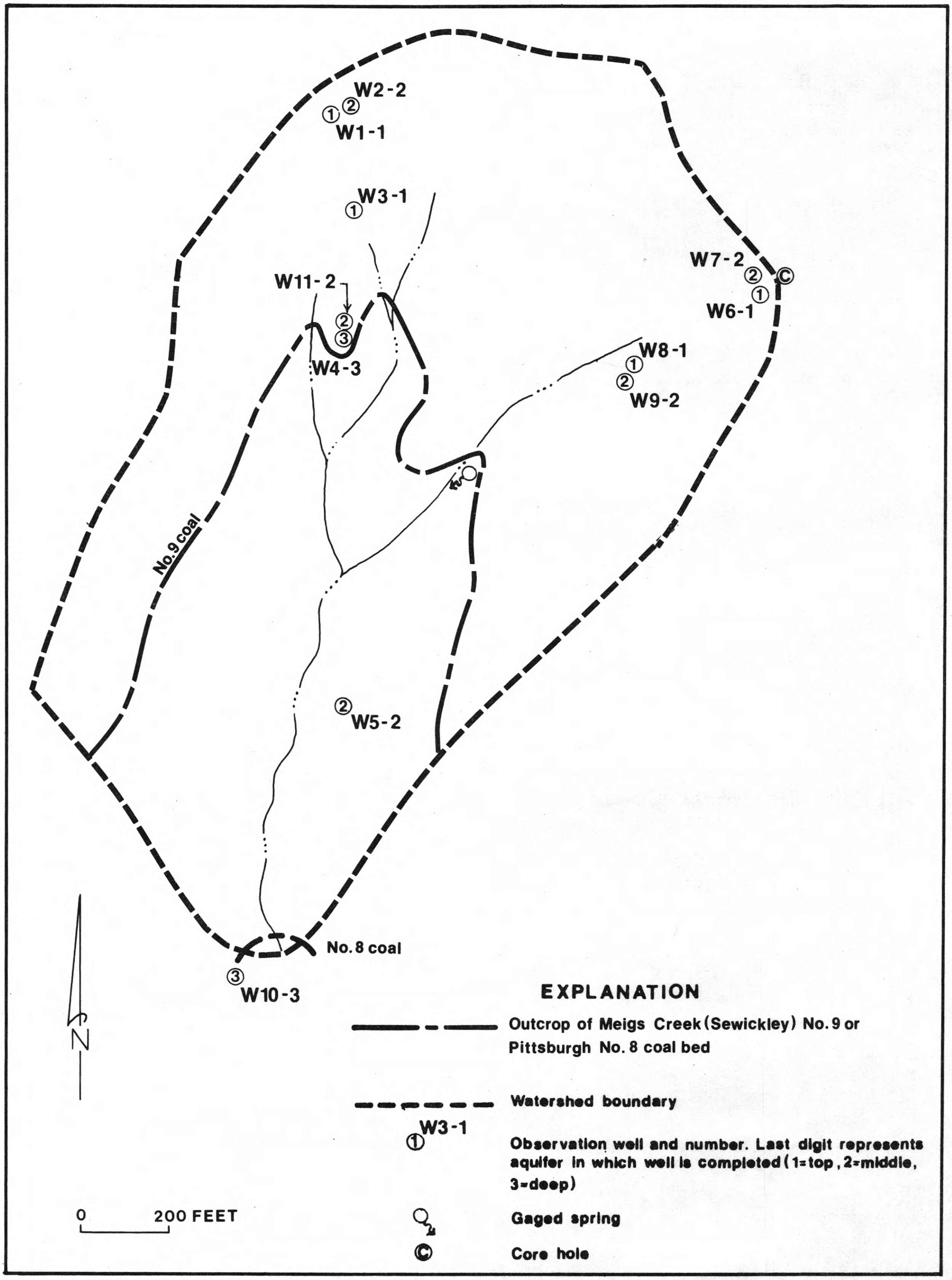


Figure 11.--Premining locations of observation wells, gaged spring, and coal outcrops at M09.

Top aquifer water-table decline in response to mining just north of M09 began about May 1976 (fig. 12; well locations shown in fig. 11). Dewatering was greatest near the divide (wells W1-1 and W6-1). Flow at the spring (fig. 11) gradually decreased and ceased on November 8, 1976.

The low-flow part of the streamflow hydrograph (fig. 13) reflects ground-water conditions during the mining phase. Precipitation during this period was not abnormally high or low, based on data collected by USDA-ARS. Relatively low flow during June to November 1977, after destruction of the top aquifer, consisted chiefly of water discharging from the middle aquifer. Small increases in base flow that developed later were probably caused by discharge from overburden spoils after infiltration of precipitation.

Water-level data collected at wells W5-2 and W10-3 (fig. 14) throughout the mining phase do not show effects of mining except possibly for a water-level rise in well W5-2 about the end of April 1977. The rise seems larger than might be expected from the amount of rainfall during this period, though no conclusive explanation is evident.

As at C06, initial data from postmining observation wells indicate little saturation of the spoils; three wells were dry and one well contained 1 foot of water. Water levels of the middle and deep aquifers did not change substantially during the mining phase.

Ground-Water Quality During Mining

Chemical analyses of water from wells W5-2 and W10-3 during the mining phase of M09 (table 2) show no definitive trends, although some constituent values varied from sample to sample.

Base-flow samples collected at the mouth of the watershed had dissolved-solids concentrations as follows:

February 1, 1977 ------------ 149 mg/L
June 7, 1977 ---------------- 359
November 1, 1977 ------------ 445
March 7, 1978 --------------- 308

Premining base-flow samples had dissolved-solids concentration range of 129 to 281 mg/L (U.S. Bureau of Mines, 1978), reflecting primary contribution from the top aquifer. Shortly after mining began, base flow still consisted mainly of top aquifer discharge (February 1977 sample). Higher mineralization of later base-flow samples reflects depletion of the top aquifer, leaving the middle aquifer and the overburden spoils as the predominant sources.

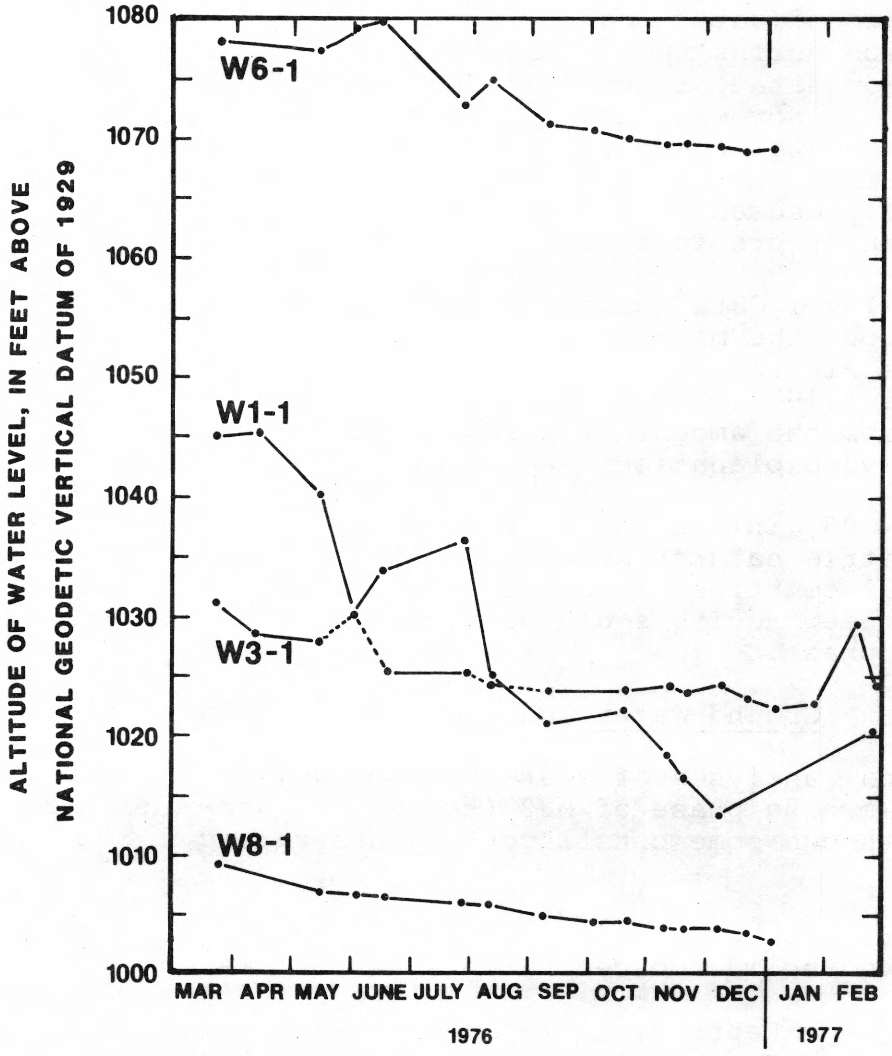


Figure 12.--Hydrographs for observation wells completed in top aquifer at M09.

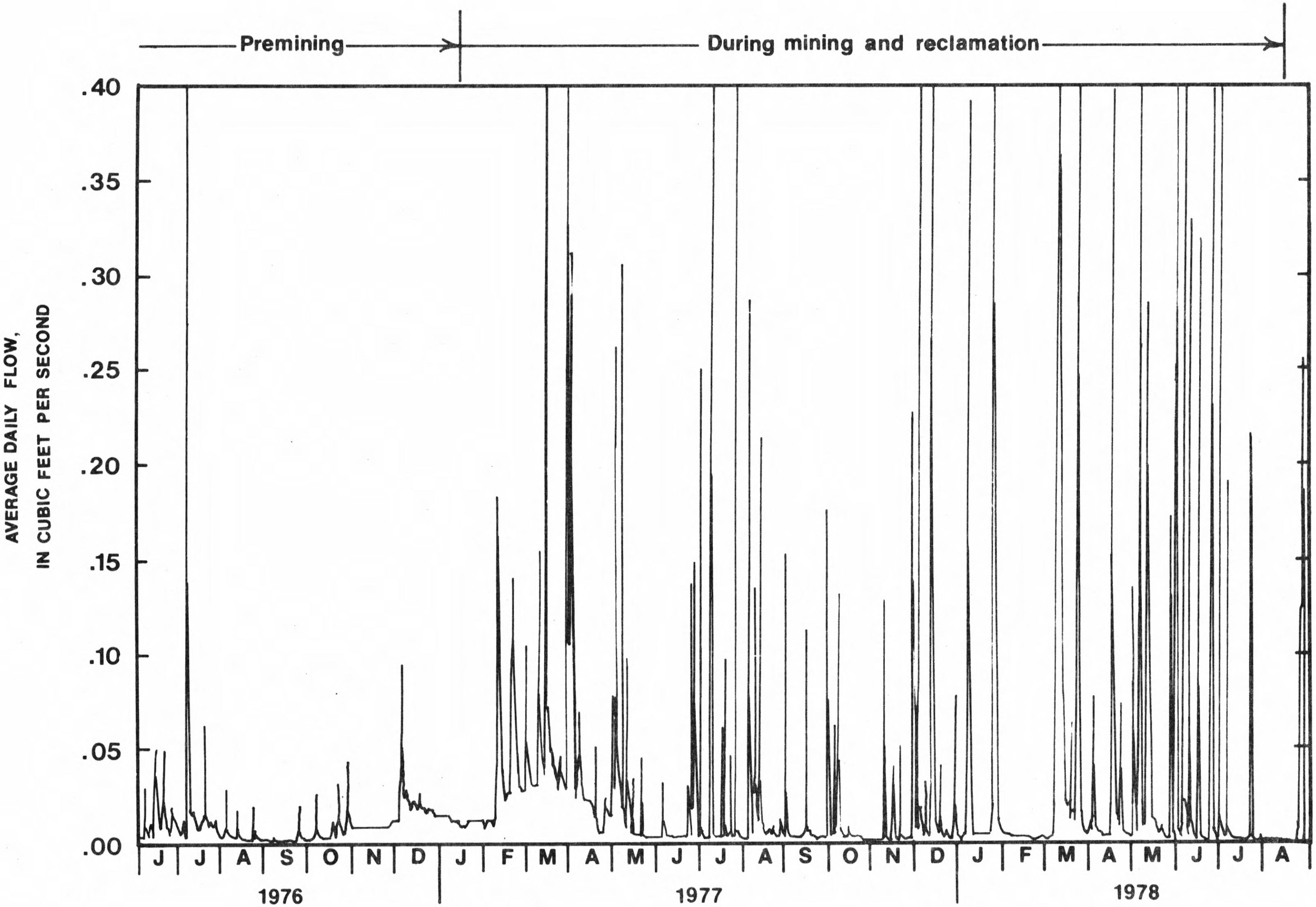


Figure 13.--Hydrograph of streamflow at mouth of M09 (based on preliminary data from U.S. Department of Agriculture, Agricultural Research Service).

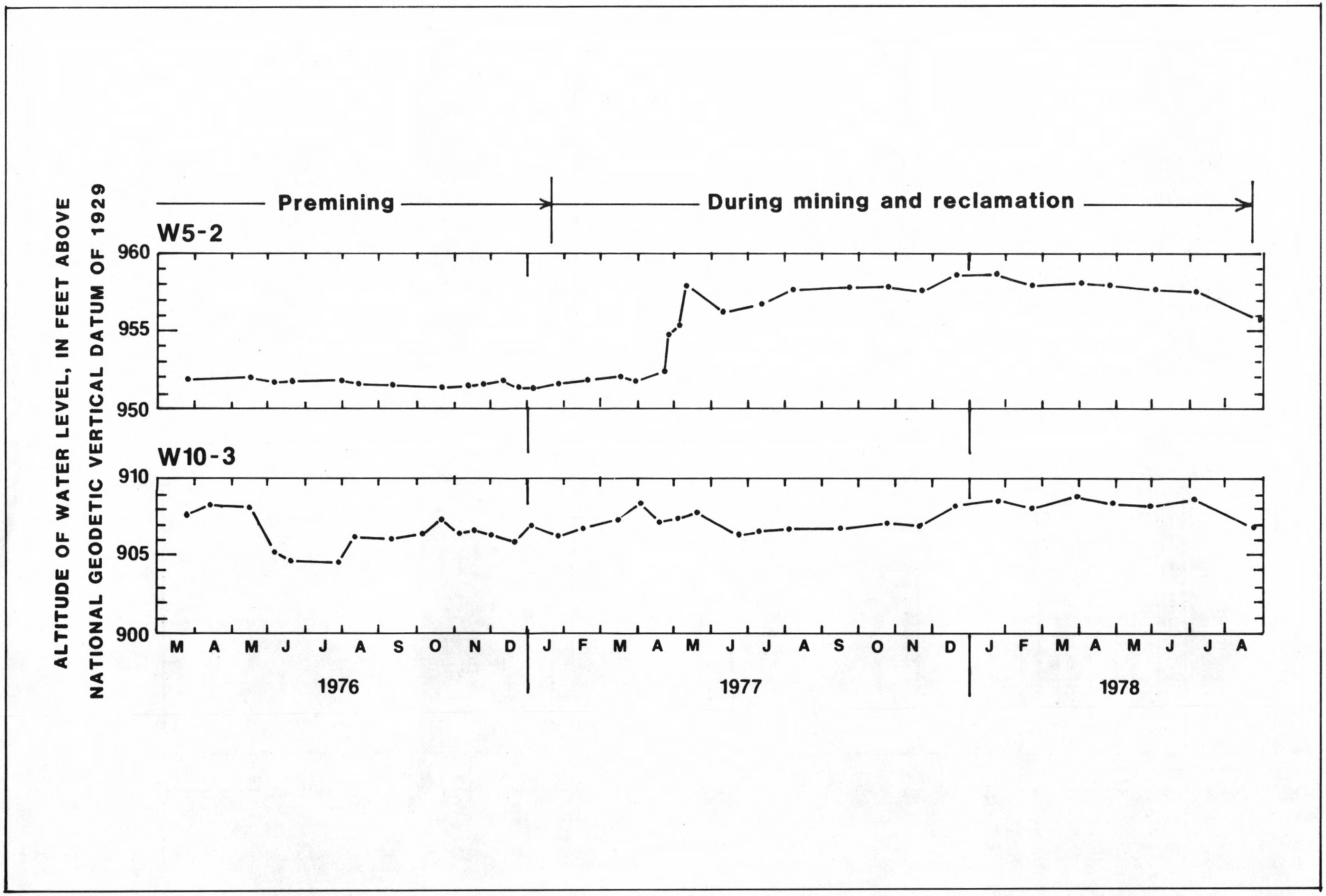


Figure 14.--Hydrographs for wells W5-2 and W10-3 at M09.

Table 2.--Chemical analyses of water collected from wells W5-2 and W10-3 at M09 during mining.

Parameter	Unit	Concentration or value											
		W5-2						W10-3					
		3-16-77	6-23-77	9-15-77	12-20-77	3-30-78	7- 6-78	3-16-77	6-23-77	9-15-77	12-20-77	3-30-78	7-6-78
Alkalinity as CaCO$_3$	mg/L	408	450	466	449	420	430	292	445	450	515	368	405
Aluminum Dissolved	µg/L	-	-	-	-	40	30	-	-	-	-	110	290
Aluminum Total	µg/L	830	40	100	400	-	-	2500	40	710	440	-	-
Antimony Dissolved	µg/L	-	-	-	-	0	-	-	-	-	-	1	0
Antimony Total	µg/L	0	0	0	0	-	-	0	0	0	0	-	-
Arsenic Dissolved	µg/L	-	-	-	-	1	1						
Arsenic Total	µg/L	2	3	0	4	-	-	6	3	1	1	0	0
Barium Dissolved	µg/L	-	-	-	-	200	200	-	-	-	-	0	0
Barium Total	µg/L	200	300	100	200	-	-	200	100	0	0	0	0
Bicarbonate	mg/L	498	549	568	547	512	524	324	459	474	524	357	412
Cadmium Dissolved	µg/L		-	-	-	1	3	-	-	-	-	1	0
Cadmium Total	µg/L	0	0	0	0	-	-	0	0	0	0	-	-
Calcium Dissolved	mg/L	5.7	2.3	6.2	6.1	5.2	6.7	15	0.3	1.0	1.3	1.9	1.4
Carbon Dioxide	mg/L	6.3	7.0	9.1	8.8	6.5	6.7	1.1	0.9	1.1	1.6	0.6	1.0
Carbon Dissolved Organic	mg/L	-	-	-	1.6	3.2	6.0						
Carbon Total Organic	mg/L	2.4	7.8	12	6.6	4.2	6.2	8.7	5.8	-	5.8	5.3	11
Carbonate	mg/L	0	0	0	0	0	0	16	41	37	51	45	40
Chloride Dissolved	mg/L	7.6	4.4	4.2	4.3	4.5	4.2	30	160	140	130	23	39
Chromium Dissolved	µg/L	-	-	-	0	0	0	-	-	-	0	1	0
Chromium Total	µg/L	10	10	<10	20	-	-	20	20	10	30	-	-
Color	Pt/Co	5	40	35	35	40	1	15	250	180	70	400	120
Copper Dissolved	µg/L	-	-	-	-	1	0	-	-	-	-	3	9
Copper Total	µg/L	7	8	8	15	-	-	12	10	9	9	-	-
Cyanide	mg/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fluoride Dissolved	mg/L	1.9	1.8	1.9	1.9	1.7	1.7	1.0	4.9	4.2	4.6	1.7	2.7
Hardness Noncarbonate	mg/L	0	0	0	0	0	0	0	0	0	0	0	0
Hardness Total	mg/L	21	14	24	24	21	27	100	2	4	5	11	8
Hydrogen Sulfide	mg/L	0.2	0.0	0.2	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.2	0.3
Iron Dissolved	µg/L	20	10	10	940	20	380	10	340	420	-	430	1900
Iron Total	µg/L	3500	10,000	6200	6100	6400	15,000	17,000	14,000	7800	5600	12,000	16,000
Lead Dissolved	µg/L	-	-	-	-	1	16	-	-	-	-	5	0
Lead Total	µg/L	8	42	18	25	-	-	13	11	10	7	-	-
Magnesium Dissolved	mg/L	1.6	2.0	2.0	2.0	1.8	2.4	16	0.4	0.3	0.4	1.5	1.0
Manganese Dissolved	µg/L	10	10	10	20	10	20	20	10	0	10	10	10
Manganese Total	µg/L	40	40	40	50	30	60	130	40	30	30	60	70
Mercury Dissolved	µg/L	-	-	-	<0.5	<0.5	0.5	-	-	-	<0.5	<0.5	0.5
Mercury Total	µg/L	0.0	0.0	0.5	<0.5	-	-	0.0	0.0	0.5	<0.5	-	-
Nickel Dissolved	µg/L	-	-	-	-	3	3	-	-	-	-	1	4
Nickel Total	µg/L	7	6	8	5	-	-	20	7	10	3	-	-
Nitrogen NH$_4$ as N Dissolved	mg/L	-	-	-	-	0.20	0.13	-	-	-	-	0.02	0.00
Nitrogen NH$_4$ as N Total	mg/L	0.20	0.19	0.23	0.22	-	-	0.01	0.18	0.20	0.18	-	-
Nitrogen Organic as N Dissolved	mg/L	-	-	-	-	0.15	0.28	-	-	-	-	0.38	1.0
NO$_2$+NO$_3$ as N Dissolved	mg/L	-	-	-	-	0.01	0.05	-	-	-	-	0.28	0.04
NO$_2$+NO$_3$ as N Total	mg/L	0.20	0.04	0.00	0.01	-	-	0.23	0.00	0.00	0.02	-	-
pH (field)		8.1	8.1	8.0	8.0	8.1	8.1	8.7	9.0	8.9	8.8	9.1	8.9
Phenols	µg/L	3	14	0	13	0	6	3	10	10	10	0	11
Phosphorus as P Dissolved	mg/L	-	-	-	-	0.02	0.01	-	-	-	-	0.03	0.06
Phosphorus as P Total	mg/L	0.03	0.02	0.01	0.03	-	-	0.12	0.11	0.10	0.07	-	-
Phosphorus as PO$_4$ Total	mg/L	0.09	0.06	0.03	-	-	-	0.37	0.34	0.31	-	-	-
Potassium Dissolved	mg/L	1.5	1.4	1.5	1.7	1.4	1.6	2.3	0.9	1.0	1.3	1.7	1.4
Residue Dissolved (calculated sum)	mg/L	526	548	572	562	-	520	418	800	779	814	-	555
Residue Dissolved	tons/acre-ft	0.72	0.75	0.78	0.76	-	0.71	0.57	1.09	1.06	1.11	-	0.75
Selenium Dissolved	µg/L	-	-	-	-	0	0	-	-	-	-	0	0
Selenium Total	µg/L	0	0	0	0	-	-	0	0	0	0	-	-
Silica Dissolved	mg/L	7.4	6.4	7.1	7.8	6.7	6.3	6.9	3.6	3.4	3.1	3.8	4.6
Silver Dissolved	µg/L	-	-	-	0	0	0	-	-	-	0	0	0
Silver Total	µg/L	0	0	0	0	-	-	0	0	0	0	-	-
Sodium adsorption ratio		20	26	21	21	18	17	5.6	90	72	65	24	33
Sodium Dissolved	mg/L	210	220	230	230	190	200	130	320	320	330	180	210
Sodium (percent)	%	95	97	95	95	95	94	73	100	99	99	97	98
Specific Conductance (field)	µmhos/cm	860	880	890	860	750	830	705	1350	1130	1420	850	920
Strontium Dissolved	µg/L	-	-	-	340	330	350	-	-	-	70	70	100
Strontium Total	µg/L	340	350	310	360	-	-	580	90	70	70	-	-
Sulfate Dissolved	mg/L	45	39	39	37	-	38	41	42	38	34	-	49
Water Temperature (°C)	°C	12.5	14.5	14.5	10.5	12.5	15.5	12.0	14.0	13.5	11.5	13.0	13.0
Zinc Dissolved	µg/L	-	-	-	50	10	0	-	-	-	-	10	10
Zinc Total	µg/L	50	30	50	50	-	-	40	30	40	30	-	-

As at C06, no immediate large changes in middle and deep aquifer water quality are evident. Initial down-hole specific-conductance data indicate that water in the replaced spoils is more highly mineralized than premining top aquifer water.

SUMMARY

Five small watersheds associated with coal seams in eastern Ohio are being studied to assess the hydrologic effects of strip mining. This report describes ground-water conditions during the mining phase in two of the watersheds, C06 and M09. Mining removed the Middle Kittanning No. 6 coal bed at C06 and the Meigs Creek (Sewickley) No. 9 coal bed at M09. At both places, the removed coal was the top major seam and cropped out in the watershed.

The premining watersheds were characterized by nearly flat-lying sedimentary rocks of the Pennsylvanian System. Clay beds below the two major coal seams in each watershed formed bases for perched saturated zones (aquifers). Generally, water in the perched aquifers constituted local flow systems, although some flow across the watershed boundary occurred in the middle aquifer at M09. Premining ground-water quality showed considerable spatial variability and generally higher mineralization with depth.

As mining neared the watersheds, water levels declined in the top aquifer near the divide of each watershed. Destruction of wells prevented documentation of any continued dewatering during mining. Reduced and more mineralized base flow resulted from destruction of the top aquifer, reflecting a change to the middle aquifer and the overburden spoils as the predominant sources of base flow.

Most wells completed in recontoured overburden spoils were initially dry, although a few feet of saturated spoils were present in some areas. The little water that accumulated in the spoils during the mining phase is more highly mineralized than premining top aquifer water. No significant effects of mining are evident on middle or deep aquifers.

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