SAMPLE MINE-SITE PERMIT APPLICATION (HYDROLOGIC ASSESSMENT)

By William J. Herb, Deborah E. Brown, Louis D. Carswell, and
Patricia L. Lietman

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FACTORS FOR CONVERTING INCH-POUND UNITS
TO INTERNATIONAL SYSTEM UNITS (SI)

Multiply inch-pound unit	By	To obtain SI unit
inch (in.)	25.4	millimeters (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1,609	kilometers (km)
square mile (mi^2)	2.590	square kilometers (km^2)
cubic yard (yd^3)	0.7646	cubic meter (m^3)
ton	0.9072	megagram (Mg)
cubic foot per second (ft^3/s)	0.2832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.06309	cubic decimeter per second (dm^3/s)
ton per square mile (ton/mi^2)	0.3503	megagrams per square kilometer (Mg/km^2)
micromho (μmho)	1	microsiemens (μS)

GLOSSARY

Adjacent area - land located outside the affected area where surface or ground water may be adversely impacted by surface coal mining and reclamation activities.[1]

Affected area - any land or water upon or in which surface mining activities are conducted or located.[1]

Benthic invertebrate - for the study, an animal without a backbone, living on or near the bottom of an aquatic environment, which is retained on a 210-μm mesh sieve.

General area - with respect to hydrology, the topographic and ground-water basin surrounding a mine plan area which is of sufficient size, including areal extent and depth, to include one or more watersheds containing perennial streams and ground-water zones and to allow assessment of the probable cumulative impacts on the quality and quantity of surface- and ground-water systems in the basin.[1]

Mine plan area - area of land and water within the boundaries of all permit areas during the entire life of the surface coal mining and reclamation activities. At a minimum, it includes all areas which are or will be affected during the entire life of those operations.[1]

Taxon (plural taxa) - any formal taxonomic unit or category of organisms; for example species, genus, family, order, and so forth.[2]

[1] Modified from Office of Surface Mining Reclamation and Enforcement Permanent Regulatory Program (1979).

[2] Pennak (1964).

ABSTRACT

Hydrologic data are presented that may be useful in the permit-application procedure required under current Office of Surface Mining regulations. The material is presented in a format which may serve as a guide for subsequent permit applications.

Data on the quality and quantity of surface water and ground water for the mine plan, adjacent, and general areas are presented. The data are presented in three general categories: measured and estimated current conditions, estimated annual variations, and predicted effects of mining and reclamation.

Current surface-water, ground-water, and biological conditions are the easiest to define. Seasonal variations in surface-water flow can be estimated with some confidence, but seasonal variations in surface-water quality, biological quality, and ground-water levels and quality are difficult to estimate with the insufficient field data available. The effects of mining and reclamation cannot be predicted through the use of the scant data collected and current predictive tools.

INTRODUCTION

An integral part of current Office of Surface Mining policies, as set forth in Public Law 95-87 and Part 741 of the Permanent Regulatory Program, is a permit requirement for surface mining. To receive a permit, an individual must submit an application which must contain, in part, a description of present hydrologic conditions, seasonal variations, and a prediction of the effects of mining. At this time (1980) there is no established format for the presentation of hydrologic data and no clear understanding of just what hydrologic data are available.

This report was prepared to serve as a guide for preparing the hydrologic section of a permit application and illustrates hydrologic information that can be collected or estimated rapidly for a mine-site-permit application. Field data for this report were collected over a 1-month period, and hydrologic data were collected for surface water and ground water. The material in this report can be categorized into three general groups. The first is a presentation of field measurements and laboratory determinations; the second is a generalization of possible annual variation in several hydrologic characteristics, and the third is an assessment of the potential effects of mining and reclamation on various hydrologic characteristics.

The hypothetical mining area discussed in this report is confined to part of Pennsylvania State Game Lands 50, Somerset County, Pa.

Parenthetical references to sections in the text refer to the pertinent sections of the Permanent Regulatory Program as spelled out by the Office of Surface Mining (1979).

ACKNOWLEDGMENTS

The authors are grateful to the Pennsylvania Department of Environmental Resources, Division of Water Quality, Aquatic Biology Section, for assistance in benthic invertebrate identification and the Pennsylvania Department of Environmental Resources, Bureau of Surface Mine Reclamation, for information on past coal mining in the study area.

STUDY AREA

The area investigated is in the Monongahela River basin in southwestern Pennsylvania (fig. 1). Pennsylvania State Game Lands 50, Somerset County, contains mineable reserves of the Lower Kittanning coal group that are representative of those in other parts of the Monongahela basin.

The area of Game Lands 50 that contains potentially mineable coal is in the drainage basin of Laurel Run, a tributary of Coxes Creek. The coal in Game Lands 50 covers 0.30 mi^2 in the Laurel Run basin (fig. 2) and averages 42 inches in thickness. The total coal volume of this coal seam in Game Lands 50 is about 1,000,000 yd^3.

To simplify location reference, basins in the study area are designated 1, 2, 2A, 3 . . . 10. These reference numbers are used throughout the report to identify sampling sites or the drainage basins above the sampling sites. Site 1 is in the affected area, sites 2-5 are in the adjacent area, and sites 2A and 6-10 are in the general area as defined in the glossary.

Climate

Annual precipitation in the area of investigation for 1941-70 averaged 45 inches (Flippo, 1979) and includes about 70 inches of snow. Precipitation averaged 4.5 inches per month for March-July, about 2.6 inches per month for October and November, and 3.5 inches per month for the remaining 5 months. There are 106 days per year when precipitation is greater than 0.10 inch, and 20 days when precipitation is greater than 0.50 inch.

The average annual temperature is 48°F, averaging 28°F from December through February and 67°F from June through August. Potential annual evapotranspiration is 24 inches (Flippo, 1979).

Table 1.--Location of surface-water sites

Site no.	Stream	Location
1	Laurel Run	About 1.5 miles upstream from confluence with Bromm Run and 0.5 mile upstream from unnamed tributary draining southern part of Game Lands 50.
2	Laurel Run	About 1.0 miles upstream from confluence with Bromm Run and immediately downstream from mouth of unnamed tributary not shown on Murdock quadrangle.
2A	Unnamed tributary to Laurel Run	About 1.0 miles southeast of Murdock, immediately downstream from culvert on dirt road.
3	Dempsey Run	On Bromm Road, 0.9 mile south of Roberts, and 250 feet upstream from mouth.
4	Bromm Run	Immediately upstream from confluence with Laurel Run at Murdock.
5	Laurel Run	Immediately upstream from confluence with Bromm Run, at Murdock.
6	Coxes Creek	Immediately upstream from mouth of Laurel Run, at Murdock.
7	Coxes Creek	Immediately downstream from mouth of Laurel Run, at Murdock.
8	Coxes Creek	About 0.8 mile southeast of Banio, 0.33 mile downstream from Rice Run, and immediately upstream from bridge on "Beagle Club" Road.
9	Coxes Creek	About 1.3 miles northeast of Rockwood, 0.26 mile upstream from mouth of Wilson Creek, and immediately upstream from bridge on dead-end road.
10	Coxes Creek	About 0.65 mile downstream from Wilson Creek, 0.5 mile upstream from mouth, and immediately upstream from bridge at north-west corporate boundary of Rockwood.

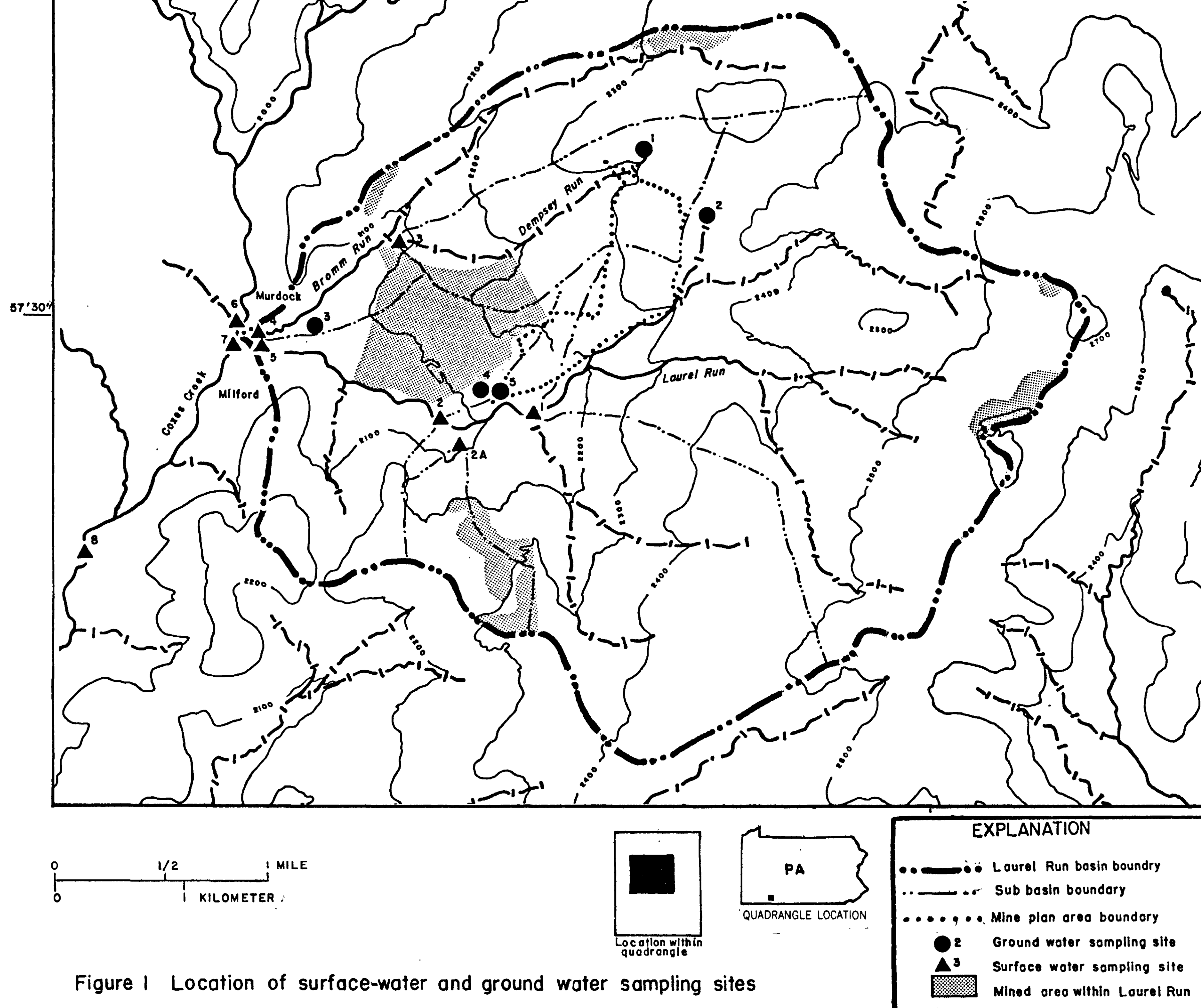


Figure 1 Location of surface-water and ground water sampling sites

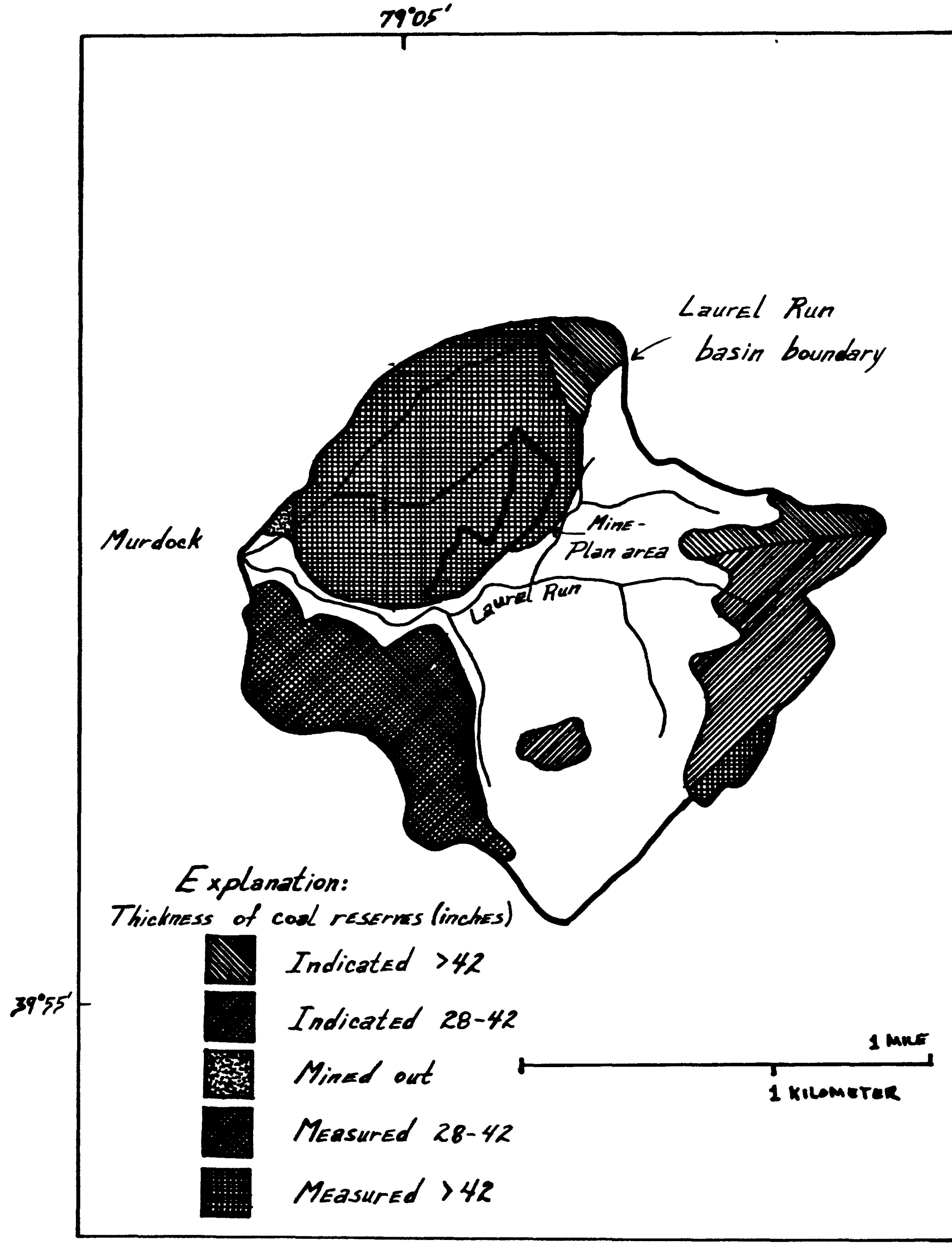


FIGURE 2.– Relation of Lower Kittanning coal to Laurel Run basin and mine-plan area.

Geology (Section 779.14)

Rocks of the Allegheny and Pottsville Groups of Pennsylvanian age form the bedrock in the proposed mine area (fig. 3). Younger rocks have been removed by erosion. Mississippian age and older rocks that underlie the Pottsville Group do not crop out and are almost entirely below the zone of fresh water circulation.

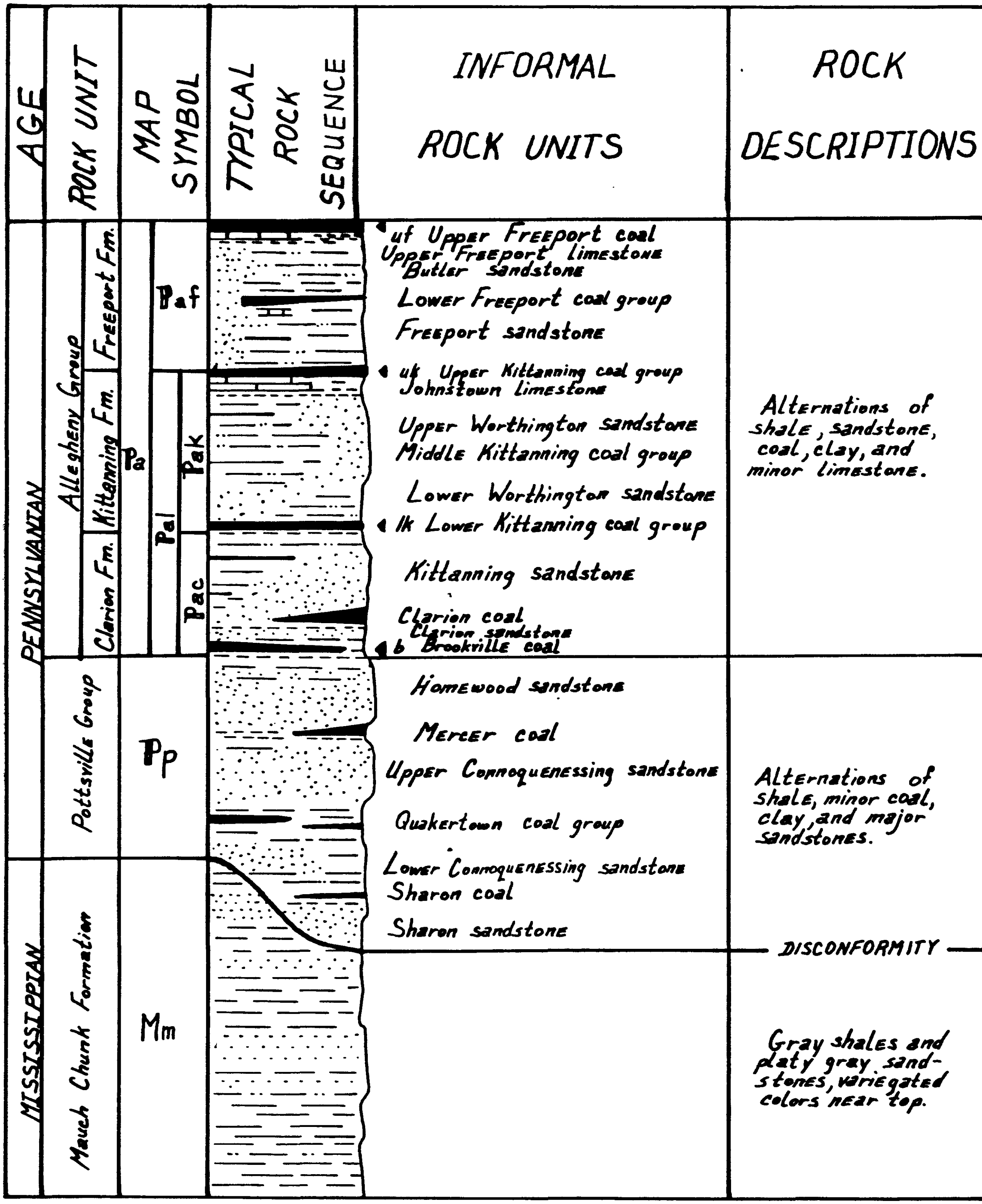
The Mauch Chunk Formation of Mississippian age underlies the Pottsville Group and is approximately 250 feet below the Lower Kittanning coal (fig. 3). The Mauch Chunk Formation was in part deposited in a marine environment and is characterized by shale and lesser amounts of sandstone, siltstone, and minor limestone. The shale is red; however, the unit contains much gray shale.

The Pennsylvanian age rocks are composed of sandstone, shale, and coal of continental origin and minor shale and limestone of marine origin. These rocks were deposited near sea level in a variety of rapidly changing environments, and, although the detrital sediments had a common source, rapid changes in the environment of deposition cause lateral and vertical changes in lithology. In general, the major coals and marine rocks are the most persistent units.

The Pottsville Group is characterized by fluvial sandstones. Four major sandstone units are separated by three minor shale and included coal units. The coals are not persistent laterally, vary in thickness and quality, and are not currently mined.

The Allegheny Group contains more shale than the Pottsville Group; four persistent economically mineable coal beds, and several nonpersistent coal beds. The Kittanning sandstone has been quarried a mile west of the proposed mine area.

The Allegheny Group is subdivided into the Clarion, Kittanning, and Freeport Formations. These units are not lithologically unique, but are intervals between the major coal beds (fig. 3). The Clarion extends from the base of the Brookville coal or its underclay to the base of the Lower Kittanning coal or its underclay. The Kittanning includes the interval between the base of the Lower Kittanning coal or its underclay to the top of the Upper Kittanning coal. The Freeport includes the interval between the top of the Upper Kittanning coal and the top of the Upper Freeport coal. Within 2 miles of the proposed mine area the Lower and Upper Kittanning coals and the Lower and Upper Freeport coals have been strip mined.



Vertical Scale: 1 inch equals 100 feet

Figure 3. - Generalized Stratigraphic section in proposed mine area.

The Kittanning Formation has been characterized by Flint (1965, p. 64) as complex due to variations in the coal beds and the irregular distribution of the sandstone beds. The Kittanning contains three coal groups, the Lower, Middle, and Upper. These groups each contain two or more coal beds that locally coalesce, forming one larger "bed." The Lower Kittanning coal bed is 5.5 to 6 feet thick and is in two benches, separated by an 8-inch clay or shale binder. An 18-inch "rider" coal bed occurs 15 to 25 feet above the Lower Kittanning coal. The beds overlying the Lower Kittanning coal contain considerable sandstone in the proposed mine area.

The proposed mine area is on the west flank of the Negro Mountain anticline. Beds dip to the west 6° to 7° or decrease in altitude to the west about 100 feet in every 1000 feet. Major joint sets dip at high angles to the horizontal and are probably parallel to the strike and dip of the rocks.

The areal distribution of outcropping rocks is shown in figure 4 and shown in section in figure 5.

Land use and land cover

General categories of land use and land cover for basins in the mine-plan and adjacent areas were determined from the Murdock, Pa., quadrangle (U.S. Geological Survey, 1973) and from mining records. Table 2 shows the predominant land use and land cover is forest, which ranges from 45 to 86 percent of the subbasins. The open-land category ranges from 11 to 22 percent. Much of this open land is fallow fields or pasture, although some is cultivated from row crops, and a small part is occupied by rural residences. Quarrying operations occupy less than 1 percent of the study area. Strip mines, active or abandoned, occupy less than 20 percent of the individual subbasins, except for 33 percent of basin 2A.

CURRENT WATER-RESOURCE CONDITIONS

Estimates of current water resource conditions are based on discharge measurements, water quality sampling, and biological sampling during April 23-25, 1979, and May 21-23, 1979. All measurements and samples for each site were collected in approximately the same location.

Surface Water (Section 779.16)

Streamflow (Section 779.16(a))

The hypothetical mining is confined to Laurel Run basin (fig. 1). Laurel Run drains 8.60 mi^2 and empties into Coxes Creek at Murdock. The Murdock, Pa., quadrangle (U.S. Geological Survey, 1973) shows 4.3 miles of perennial streams and 12.0 miles of intermittent streams in the Laurel Run basin. A few small ponds are in the basin near the eastern drainage divide.

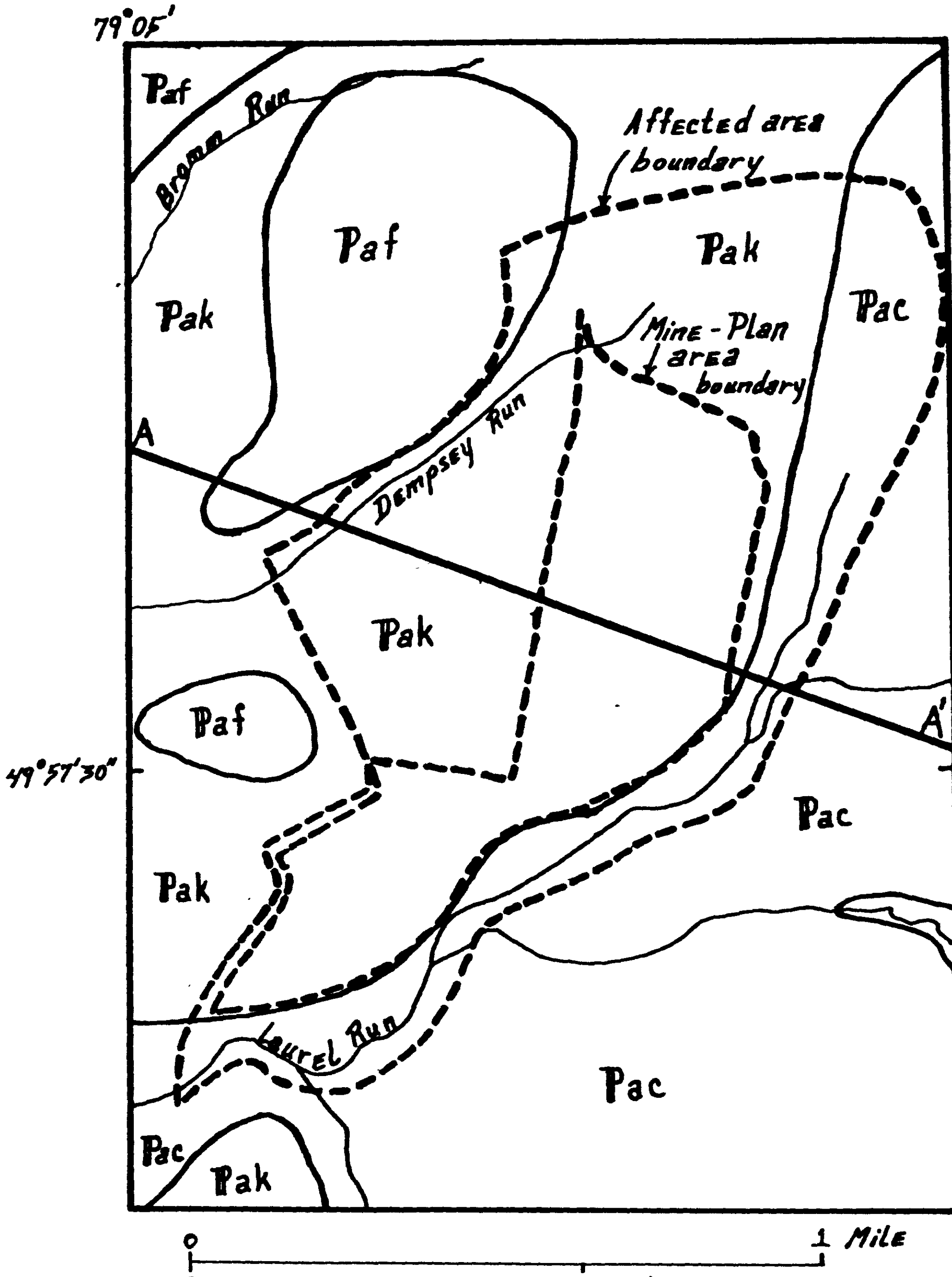


Figure 4.—Relation of mine-plan and affected areas to surficial geology. Geology keyed to figure 3.

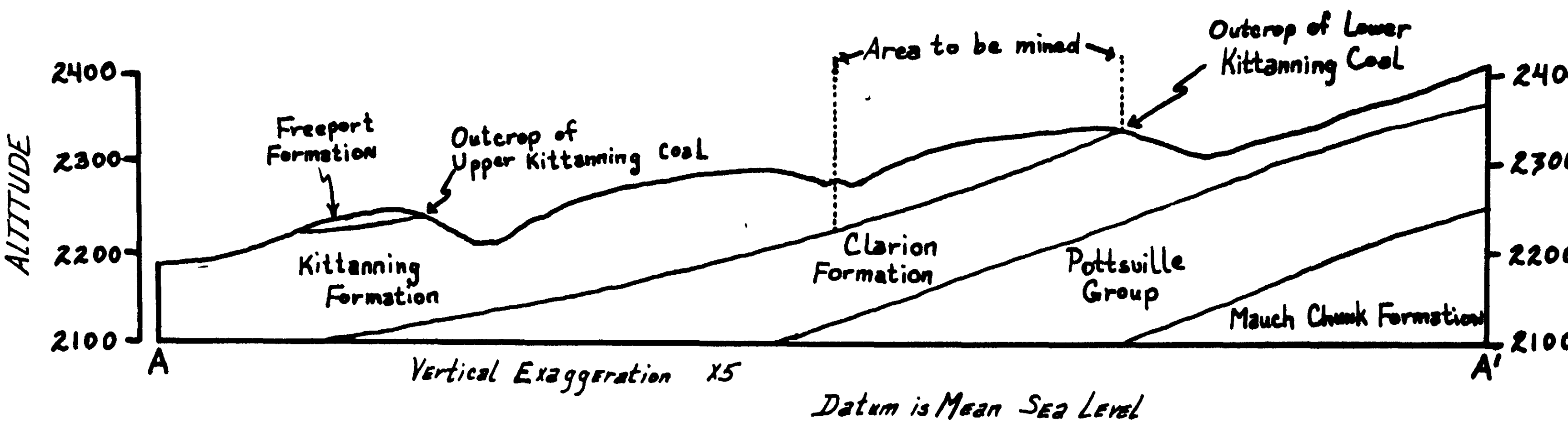


FIGURE 5.- Geologic cross section through the proposed mine area. Location of Section A-A' shown on figure 4.

Table 2.--Land use and land cover for basins within mine plan and adjacent areas

Basin	Percentage of basin in land-use and land cover class[1]			
	Forest	Open	Strip mine	Quarry
1	86	11	3	-
2	85	12	3	-
2A	45	22	33	-
3	68	15	17	-
4	75	15	9	1
5	76	18	6	<1

[1]From U.S. Geological Survey, 7 1/2-minute Murdock, Pa., quadrangle, photorevision of 1973, and Pennsylvania Department of Environmental Resources, Surface Mine records (written communication, 1979).

The surface-water sites for which discharge measurements and estimates of discharge statistics were made are all in Coxes Creek basin. Coxes Creek drains 65 mi^2 (including the Laurel Run drainage area) and empties into the Casselman River at Rockwood (fig. 6). All the sites (figs. 1 and 6) are in Somerset County and Hydrologic Unit 05020006.

Table 3 lists the drainage area at all surface-water sites and the length of perennial and intermittent streams for the Laurel Run basin sites. No municipal or large-scale private surface-water users are in the affected or adjacent areas.

Data and estimates in this and subsequent sections for site 1 are representative of the affected area. Data and estimates for sites 2-5 are representative of the adjacent area. Data presented for site 6 represent streamflow conditions into the general area, and sites 2A and 7-10 represent the general area. The measured discharges are given in table 4.

Sediment (Section 779.16(b)(2))

Sediment investigations in basins adjacent to the Monongahela River (Wark and Keller, 1963; Williams and George, 1968) found annual suspended-sediment yields of 0.03 tons per acre from forested watersheds. Therefore the premining suspended-sediment yield from the 190-acre forested mine plan area is estimated to be 6 tons per year. The mean suspended-sediment concentration, based upon an estimated mean runoff of 0.6 ft^3/s, is 10 mg/L (milligrams per liter).

Much of the 6 tons of suspended sediment probably moves during only a few storms, as shown by Yorke and Herb (1978) for the Maryland Piedmont. As a result, the median sediment concentration would be less than the 10 mg/L average. The suspended-sediment concentrations shown in table 4 illustrate base-flow conditions, except those samples for May 21, which were taken during a rainstorm.

Sediment yields of basins in the study area would probably range from 19 tons per mi^2 for forest land to the 40-100 tons per mi^2 given by Williams and Reed (1972) for Valley and Ridge streams in the Susquehanna River basin.

Chemical quality (Section 779.16 (b)(2))

Chemical water quality samples were collected at all surface-water sites in April and May 1979. Field measurements included pH, alkalinity and acidity according to potentiometric standard methods, and dissolved oxygen by the Winkler method (Skougstad and others, 1979). Samples were also collected for specific conductance, total and dissolved iron, total manganese, sulfate, suspended sediment, and residue on evaporation at 180°C (ROE): prepared according to standard procedures; and sent to the laboratory for analysis (Skougstad and others, 1979). The results of these determinations are given in table 4.

Table 3.--Drainage areas and selected channel-length data for basins above surface-water sampling sites

Site	Drainage area (mi²)	Channel length[1] Perennial (mi)	Channel length[1] Intermittent (mi)
1	3.37	1.8	5.5
2	5.48	2.3	7.7
2A	.26	0	0
3	.67	0	1.4
4	1.86	.86	3.6
5	6.74	3.3	8.4
6[2]	38.3	---	---
7[2]	46.4	---	---
8[2]	50.2	---	---
9[2]	55.1	---	---
10[2]	64.6	---	---

[1]As shown on Murdock, Pa., quadrangle (U.S. Gelogical Survey, 1973 photorevision).

[2]Perennial and intermittent channel lengths not measured for main stem Coxes Creek.

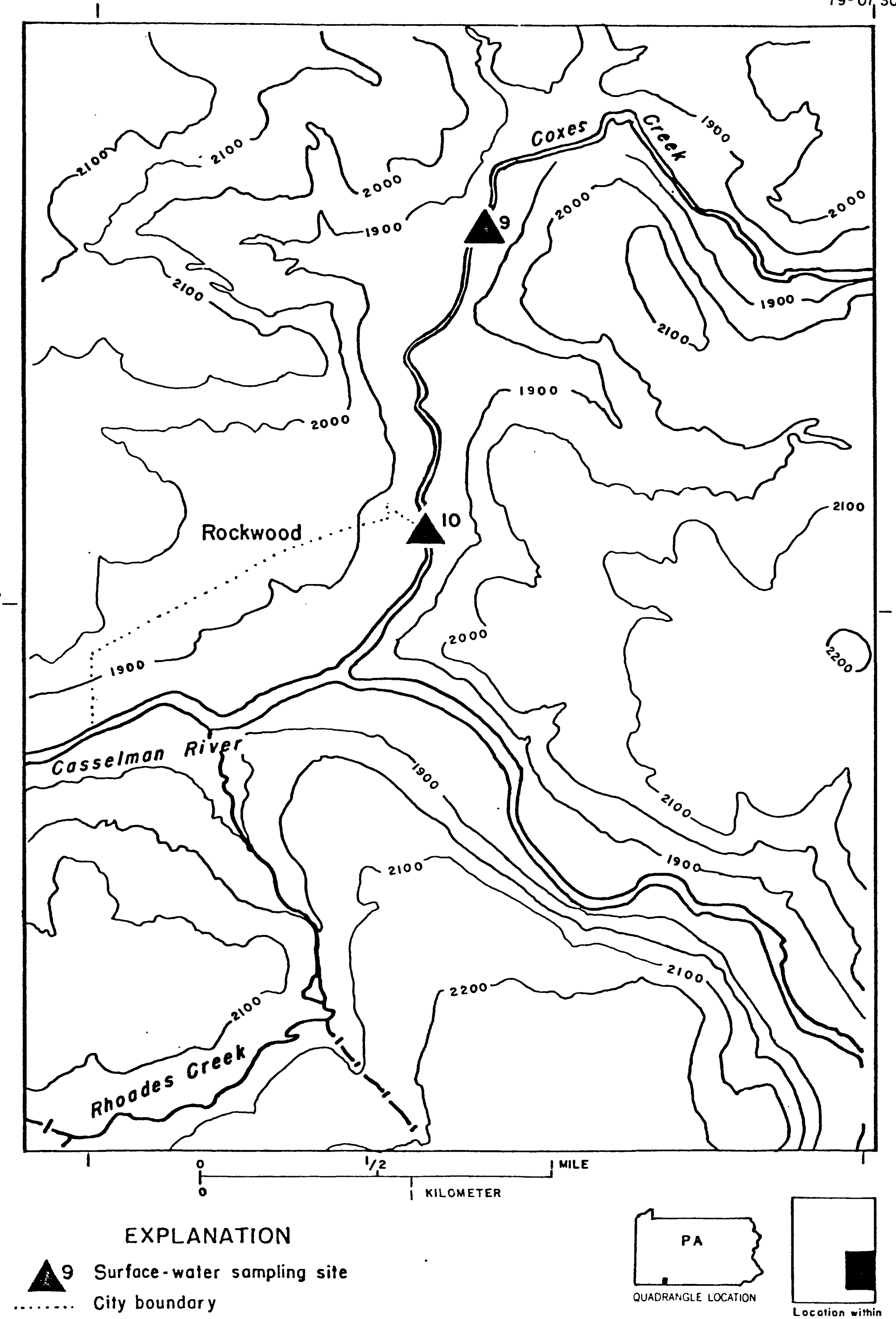


Figure 6 - Location of surface-water sampling sites 9 and 10

Table 4.--Discharge and water-quality constituents for surface-water sites

Site	Date	pH (units)	Acidity (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)	Specific conductance (µmho/cm at 25°)	Dissolved oxygen (mg/L)	Oxygen saturation (percent)	Temperature (°C)	Suspended sediment (mg/L)	Residue on evaporation	Dissolved Iron (Fe) (µg/L)	Total Iron (Fe) (µg/L)	Total manganese (Mn) (µg/L)	Dissolved sulfate (SO_4) (mg/L)	Instantaneous discharge (ft^3/s)
1	4-23-79	4.68	15	1	48	11.1	102	8.0	5	---	90	210	150	12	4.4
	5-22-70	4.30	10	0	44	10.4	100	10.5	8	35	30	300	150	12	2.6
2	4-23-79	4.76	9	1	50	11.2	99	7.0	4	---	80	380	160	12	7.4
	5-22-79	4.17	12	0	43	10.4	99	10.0	5	42	40	280	170	12	5.3
2A	4-25-79	4.33	34	0	161	10.2	97	10.2	2	---	160	200	520	55	.09
	5-22-79	3.85	42	0	160	10.2	99	10.2	3	127	160	210	510	57	.05
3	4-24-79	4.78	7	1	50	10.7	96	8.0	2	---	60	100	170	12	.21
	5-22-79	4.20	10	0	43	9.8	96	11.5	2	44	20	80	170	12	.11
4	4-24-79	5.70	6	3	58	10.6	98	9.0	6	---	250	530	300	16	1.8
	5-21-79	6.18	12	4	68	9.7	99	13.5	7	63	130	700	330	17	1.4
5	4-24-79	4.98	9	3	63	10.6	94	7.5	4	---	270	390	280	17	5.9
	5-21-79	4.23	23	0	56	9.8	97	12.5	5	50	250	440	220	17	7.6
6	4-24-79	7.45	2	34	372	10.7	108	13.0	8	---	90	680	260	79	35
	5-21-79	7.17	9	32	436	9.0	100	17.5	19	287	30	1900	380	100	23
7	4-24-79	7.55	3	28	311	10.8	106	11.5	8	---	70	600	250	65	39
	5-21-79	7.10	8	26	364	9.1	98	16.0	17	234	20	1200	300	89	33
8	4-25-79	6.75	8	28	318	10.6	103	11.5	8	---	110	700	300	68	40
	5-21-79	7.05	15	22	333	9.1	94	14.5	16	212	80	1200	330	82	29
9	4-25-79	6.77	5	18	336	10.1	100	12.0	10	---	150	1100	380	84	50
	5-21-79	6.82	23	18	360	9.2	95	14.5	9	233	110	830	400	100	31
10	4-25-79	6.60	6	8	315	10.2	103	13.0	10	---	270	1400	520	88	54
	5-21-79	6.15	30	9	332	9.8	103	15.0	11	216	150	1100	540	100	41

The Office of Surface Mining Reclamation and Enforcement (1979) defines acid drainage as "water with a pH less than 6.0 and in which total acidity exceeds total alkalinity, discharges from an active, inactive, or abandoned surface coal mine and reclamation operation or from an area affected by surface coal mining and reclamation operations" (Section 701.5). Other indicators of acid mine drainage (AMD) (U.S. Department of the Interior, 1968) are shown in table 5. Not all of these indicators must be present to indicate AMD. Figure 7 illustrates selected AMD indicators found at the surface-water sites.

East and West Branches of Coxes Creek converge 0.75 miles upstream from Laurel Run. West Branch Coxes Creek flows through rural areas having some mining, whereas the East Branch flows through the town of Somerset and is influenced by a sewage treatment plant along the creek. Immediately above its confluence with Laurel Run, Coxes Creek (site 6) is a moderately buffered alkaline stream having conductances ranging from 300-400 μmho/cm (micromhos per centimeter) at 25°C; dissolved and total iron concentration ranges of 30-90 μg/L and 680-1900 μg/L, respectively; total manganese concentrations of 260-380 μg/L; and dissolved sulfate concentrations of 70-100 mg/L during the period of sampling.

Analyses of samples collected on Bromm, Dempsey, and Laurel Runs (sites 1, 2, 3, 4, 5) (table 4) show these creeks to be poorly buffered acidic waters, having conductances ranging from 70-160 μmho/cm at 25°C, and concentration ranges of 30-270 μg/L (micrograms per liter), 80-700 μg/L, 150-520 μg/L, and 12-57 mg/L for dissolved iron, total iron, total manganese, and sulfates, respectively. Surface mines surround the proposed mining site (Pennsylvania Department Environmental Resources, Surface Mine Records, written communication, 1979) (fig. 1) and slightly influence the quality of water in Bromm, Dempsey, and Laurel Runs. Iron precipitates are visible in some reaches of these streams. One of the most heavily influenced basins, 2A, drains into Laurel Run and receives discharges directly from a surface mine. The conductance, dissolved iron, and total manganese values are 2-3 times higher than those at other sites, but total iron concentrations are comparable (table 4).

Figure 8 shows how various AMD indicators vary with downstream location in Coxes Creek. Coxes Creek shows a downstream decrease in pH and alkalinity ranging from pH 7.45 and 32.0 net alkalinity (mg/L as $CaCO_3$) above Laurel Run (site 6) to pH 6.0 and -2.0 net alkalinity (mg/L as $CaCO_3$) near the mouth (site 10) during the April sampling. This is due to surface mine drainage entering Coxes Creek from Laurel Run and other streams. Specific conductances in Coxes Creek ranged from 300-500 μmho/cm at 25°C, total iron from 600-1900 μg/L, total manganese from 250-550 μg/L, and sulfate from 60-100 mg/L.

Table 5.--Indicators of acid-mine drainage in a flowing body of water (modified from U.S. Department of the Interior, 1968)

Characteristic	AMD indicator
pH	Less than 6.0
Acidity	More than alkalinity
Alkalinity	Less than Acidity
Total iron	More than 0.5 ppm
Total manganese	More than 0.5 ppm
Sulfate	More than 75.0 ppm
Total aluminum	More than 0.3 ppm
Total hardness	More than 150 ppm
Calcium hardness	More than 75 ppm
Magnesium hardness	More than 50 ppm

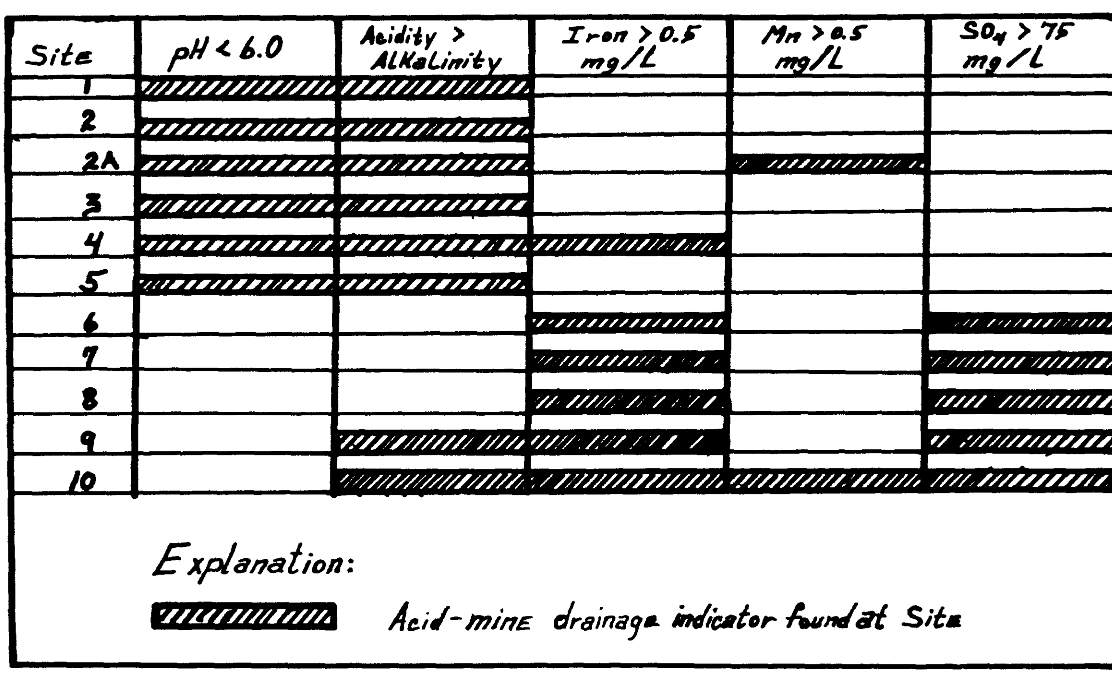


Figure 7.—Indicators of acid-mine drainage found at surface-water sampling sites.

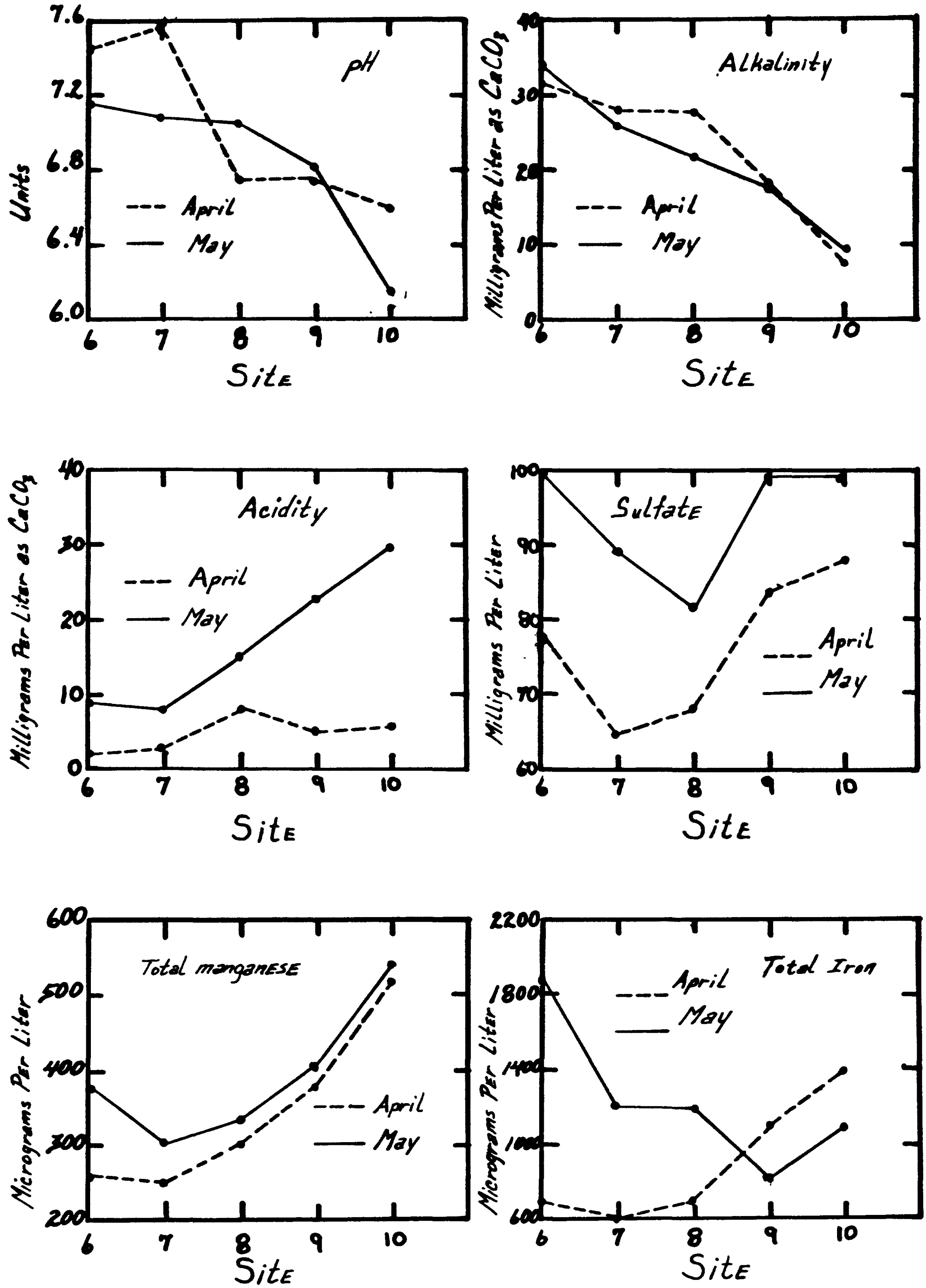


Figure 8.—Trends of selected water-quality constituents for Sampling Sites on Coxes Creek.

Scant data collected during 1971-76 for the streams sampled in the present study follow the same trends and are in approximately the same ranges as the current samples (Pennsylvania Department Environmental Resources, Surface Mining Records, written communication, 1979).

The variations in the constituent values between April and May are most likely due to the 30 percent streamflow decrease. At all sites, the total iron concentrations increase with increasing sediment concentrations, and the other constituent concentrations increase with decreasing discharges.

Biological Quality (Section 816.57)

The aquatic biological samples were collected from Laurel Run (sites 1, 2, 2A, 5), Dempsey Run (site 3), Bromm Run (site 4), and Coxes Creek (sites 6, 7, 8, 9, 10) (figs. 1 and 6). Dempsey Run is a tributary of Bromm Run; Bromm Run is a tributary of Laurel Run; and Laurel Run is a tributary of Coxes Creek. All biological sampling sites were close to the chemical quality sampling sites. Figure 9 illustrates the substrate composition at the biological sampling sites.

Of the 11 sites studied during this project, none were directly in the affected area. Section 816.57 (Office of Surface Mining Reclamation and Enforcement, 1979) specifies that, "No land within 100 feet of a perennial stream or a stream with a biological community . . . shall be disturbed by surface mining activities . . . ." This implies that stations 1 and 2, lying in State Game Land 50, will not be part of the mining permit unless specifically authorized, under Sections 816.43-816.44. According to Section 816.57, a biological stream community must consist of "two or more species (from the phylums) Arthropoda or Mollusca . . . ." For this study, we included the phylum Annelida in the definition of a biological stream community. Site 4 on both sampling trips and site 10 on the May visit did not meet the requirements for having a biological stream community. At four sites (2A, 4, 5, 6), some of the invertebrates collected could not be categorized as part of a biological stream community because they were terrestrial. These terrestrial invertebrates will not be discussed in this study.

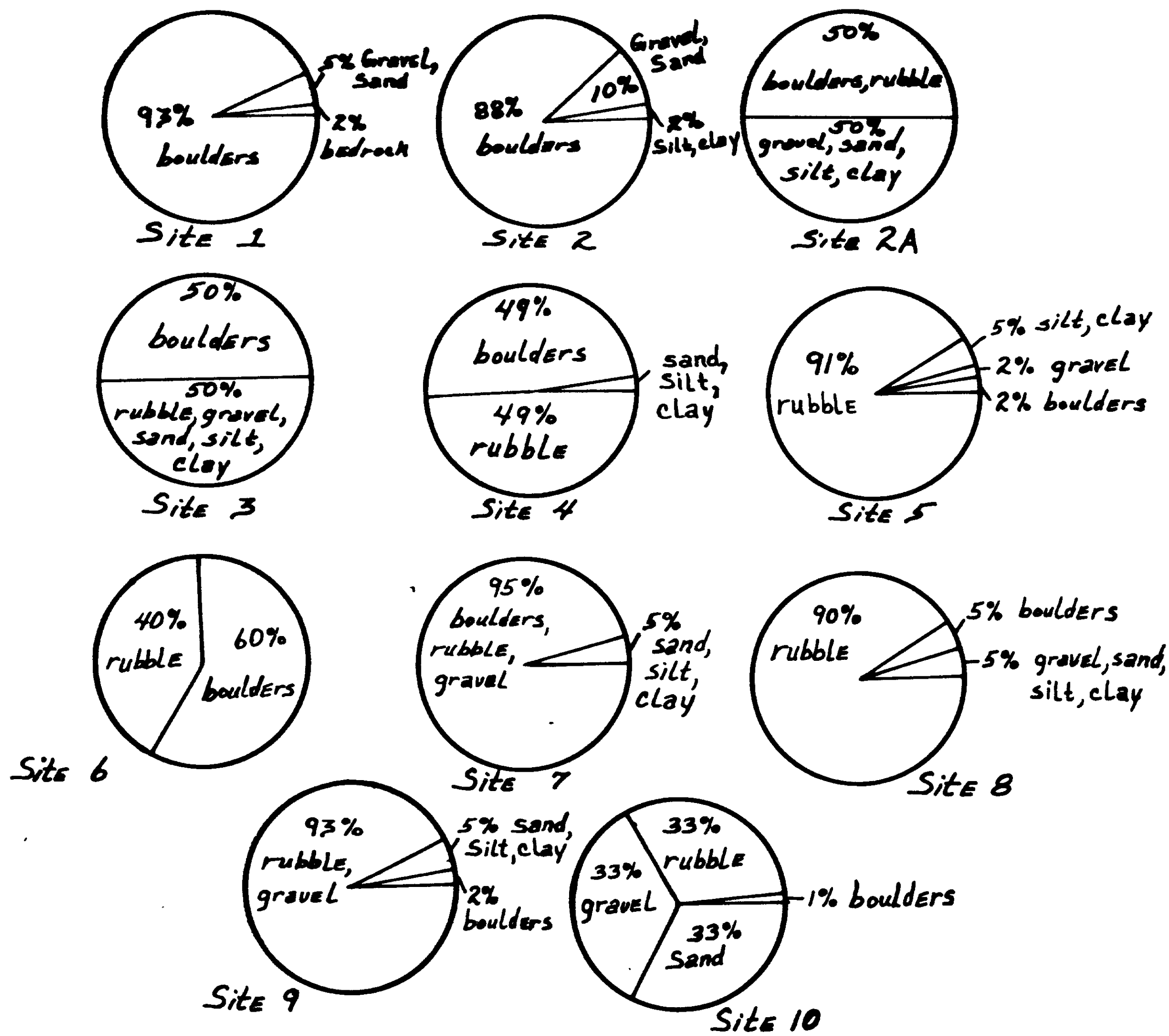


Figure 9. - Substrate composition at biological sampling sites. Substrate characteristics from National Environmental Research Center (1973).

The benthic invertebrates were collected with a 1-ft^2 Surber[1/] stream bottom sampler fitted with a 210-μm (micrometer) Nitex mesh. Streams were generally sampled for 15 minutes by scraping the bed material or stirring up the bottom and allowing the dislodged material to float into the Surber sampler. Some sites (2A, 3, 4) were sampled for only 10 minutes because of small size and sparse aquatic fauna. After collection the sample was placed in a 595-μm sieve with a 210-μm sieve attached beneath. Between periodic rinsings with stream water, the benthic invertebrates were removed from the sampled material on the sieves and placed in 70 percent ethyl alcohol. The benthic invertebrates were later identified to the genus level in the laboratory (table 6).

The numbers and kinds of genera were used in the computation of the Wilhm and Dorris diversity index values (table 7). A high diversity index, 3.0 or greater, normally indicates unpolluted or healthy stream conditions. A low diversity index, less than 2.0, usually indicates polluted or unhealthy stream conditions (Herrick, 1973).

This study examined benthic invertebrates because of their use as indicators of water quality within a given environment. Good water quality is generally characterized by large numbers of species and small populations within each species. Evidence of poor water quality would be small numbers of species and large populations of individual species (Herricks, 1973), whereas very poor water quality would be indicated by small numbers of species and small populations. This project utilized identification to the genus level, but because species within a genus can vary in tolerance to AMD and organic compounds, generalizations resulted in the tolerance inconsistencies found in table 6.

Measured water-quality constituents show that the Laurel Run basin is only slightly influenced by acidity. This can be demonstrated by the variety and numbers of benthic invertebrates there. Much of this acidity is probably natural, but some AMD may be present.

Isopoda and Decapoda are two crustacean orders collected and observed at sites 1, 2, and 3. Decapoda can survive in a variety of stream environments ranging from clean to AMD polluted, although it usually is not found in abundance in AMD waters (Karl Schaeffer, oral communication, 1979; Collier, 1964). Isopoda has been found in waters with a pH as low as 3.9 (Lackey 1938). As the environment of the area produces its own natural acidity, Isopoda and Decapoda may have adapted to water at sites 1, 2, and 3, where the average pH is 4.5.

[1/] The use of a brand name in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

Table 6.—Taxonomic distribution of benthic invertebrates collected at surface-water sampling sites

Taxonomic identification	Number of individuals in taxonomic classification — Site number — Month[1]: 1 A	1 M	2 A	2 M	2a A	2a M	3 A	3 M	4 A	4 M	5 A	5 M	6 A	6 M	7 A	7 M	8 A	8 M	9 A	9 M	10 A	10 M	AMD tolerance[2] T	AMD tolerance[2] ST	AMD tolerance[2] I	Organic tolerance[2] T	Organic tolerance[2] ST	Organic tolerance[2] I
Arthropoda																												
Insects																												
Diptera (true flies)																												
Simuliidae (black flies)																												
Prosimulium	22	16	4	17	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Simulium	-	-	7	4	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-
Tipulidae (crane flies)																												
Limonia	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dicranota	-	3	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Limnophila	-	1	-	-	-	-	1	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tipula	-	-	1	-	-	-	-	1	-	-	-	-	-	-	1	1	-	-	-	-	1	-	-	-	-	-	*	*
Erioptera	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-
Ceratopogonidae (biting midges)																												
Palpomyia (group)	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	*	*	-
Chironomidae (midges)																												
Unidentified genera	-	-	-	-	-	-	-	-	-	-	1	-	-	6[3]	-	9	6[3]	5[3]	-	-	-	-	*	-	-	*	*	-
Orthocladiinae																												
Orthocladius or Cricotopus	1	-	-	-	-	-	-	-	-	-	-	3	8	39	20	26	66	57	7	17	-	-	-	-	-	*	*	*
Eukiefferiella	-	-	3	1	1	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Cardiocladius	-	-	-	-	-	-	-	-	-	-	-	-	2	3	7	-	6	-	-	-	-	-	-	-	-	-	-	-
Psectrocladius	-	-	-	-	2	15	-	-	-	-	1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diplocladius	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parametriocnemus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Brillia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Chironominae																							*	*	*	-	-	-
Tribelos	-	-	-	-	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*
Polypedilum	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	2	-	-	-	-	-	-	-	-	-	-	*	*
Rheotanytarsus	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*	*
Diamesinae																												
Diamesa	-	-	-	-	-	-	-	-	-	-	-	-	2	1	1	42	2	1	-	1	-	-	-	-	-	-	-	*
Tanypodinae																												
Pentaneurini (tribe)	-	2	-	4	5	6	4	4	-	-	5	3	1	2	-	1	-	1	1	-	-	2	-	-	-	*	*	*
Ephemeroptera (mayflies)																							-	-	*	-	-	*
Ephemerellidae																												
Ephemerella	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	*	-	-	-
Baetidae																												
Baetis	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	-	3	-	1	-	-	-	-	*	-	-	*
Plecoptera (stoneflies)																							-	-	*	-	-	*
Nemouridae																												
Amphinemura	-	9	-	5	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-
Ostrocerca	-	-	-	-	-	-	2	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leuctridae																												
Leuctra	9	5	6	11	2	3	41	10	-	-	9	10	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-
Peltoperlidae																												
Peltoperla	1	-	-	-	-	-	5	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-
Perlodidae																												
Isoperla	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*
Trichoptera (caddis flies)																							-	-	*	*	-	-
Philopotamidae																												
Dolophilodes	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhyacophilidae																												
Rhyacophila	8	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	*

Table 6.—Taxonomic distribution of benthic invertebrates collected at surface-water sampling sites—(Continued)

	Number of individuals in taxonomic classification																											
	Site number																											
	1		2		2A		3		4		5		6		7		8		9		10		AMD tolerance[2]			Organic tolerance[2]		
	Month[1]																											
Taxonomic identification	A	M	A	M	A	M	A	M	A	M	A	M	A	M	A	M	A	M	A	M	A	M	T	ST	I	T	ST	I
Arthropoda (continued)																												
Insecta (continued)																												
Trichoptera (continued)																												
Hydropsychidae																												
Hydropsyche	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	28	3	1	-	-	-	*	*	-	-	*	*
Cheumetopsyche	-	-	-	-	-	-	-	-	-	-	-	-	1	3	1	1	1	1	1	-	1	-	-	*	-	-	*	-
Aphropsyche	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parapsyche	1	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diplectrona	-	-	1	1	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Limnephilidae																												
Neophylax	1	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ironoquia	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydatophylax	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Polycentropidae																												
Polycentropus	-	-	-	-	-	2	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*
Hydroptilidae																												
Leucotrichia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Megaloptera (dobsonflies, etc)																							*	-	-	-	-	-
Corydolidae (fishflies)																												
Nigronia	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-
Sialidae (alderflies)																												
Sialis	-	-	-	-	2	4	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	*	-	*	*
Coleoptera (beetles)																							-	-	*	*	-	-
Psphenidae (water pennies)																												
Ectopria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	-	4	1	-	-	-	-	*	-	-	*
Elmidae (riffle beetles)																							-	-	*	-	-	*
Optioservus (larvae)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	*	-
Odonata (dragon and damselflies)																							-	-	-	-	-	*
Cordulegastridae																							-	-	-	-	-	*
Cordulegaster	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Crustacea (shelled animal)																												
Isopoda																							*	-	-	-	-	-
Asellidae (aquatic sowbugs)																												
Asellus	7	6	7	3	-	-	14	3	-	-	-	-	7	18^3	1	4	-	-	4	1	-	-	-	-	-	*	-	-
Decapoda																												
Astacidae (crayfish)	1^4	-	2^4	-	-	-	3^4	3^4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*	-	*	*	-
Annelida																												
Oligochaeta	-	-	3	1	-	-	-	1	-	-	-	-	4	1	-	-	1	-	2	1	3	-	-	-	*	-	-	-
Hirudinea (leeches)																							-	-	*	*	-	-
Pharyngobdellida																												
Erpobdellidae	-	-	-	-	-	-	-	-	-	-	-	-	4^3	3^3	2	-	-	-	-	2	-	-	-	-	-	*	-	-
Mollusca																												
Gastropoda																							-	-	*	-	-	-
Basommatophora																												
Planorbidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Helisoma	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	*	*	-
Physidae																												
Physa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	*	*	*	*

[1]Column headings of A and M indicate sampling in April and May, respectively.
[2]Column headings of T, ST, and I indicate tolerant, semitolerant, and intolerant, respectively. Different sources may indicate different tolerance levels for a single genus as indicated by an *.
[3]Too many specimens captured to collect and preserve.
[4]More were collected than preserved.

Table 7.--Wilhm and Dorris diversity indices[1] of benthic invertebrates at surface-water sampling sites.

	Sampling site										
	1	2A	2	3	4	5	6	7	8	9	10
April	2.3	2.3	3.2	2.4	0	2.4	2.6	2.0	1.3	3.0	1.4
May	2.8	2.1	2.9	3.1	0	2.4	1.4	2.3	.6	1.9	0
April and May[2]	2.7	2.4	3.3	2.9	0	2.7	1.6	2.7	1.0	2.8	1.8

[1]Diversity indices for sites 6 and 8 were computed using estimated numbers of those taxa which were too plentiful to enumerate. The estimates were based on the surface area of the 210 μm sieve used in sampling and the number of taxa observed per unit area.

[2]The diversity indices for April and May were computed as though the samples were collected at the same time.

Sites 1, 2, and 5 on Laurel Run had two Dipteran families in common, black flies (Simulidae) and midges (Chironomidae). Chironomidae is generally characterized as having AMD tolerant larvae (Letterman and Mitsch, 1978). Pentaneurini, a tribe within the Chironomidae family, was found at all sites except 4. The greatest numbers of this tribe were found in the Laurel Run basin, where acidity was always greater than alkalinity. One stonefly family (Plecoptera), Leuctridae, and one caddis fly family (Trichoptera), Hydropsychidae, were also found at Sites 1, 2, and 5. When sites 2A and 3, on tributaries to Laurel Run, were included with the above sites to define common families, only Chironmidae and Leuctridae were found with Leuctridae being the more dominant family. Generally speaking, Plecoptera is an AMD intolerant order, and only Laurel Run and its tributaries carried genera in this order. The dominant genera of Plecoptera were Leuctra and Amphinemura.

One Plecopteran genus which is an exception to the AMD intolerant classification is Nemoura. In recent years Nemoura has been reclassified into Amphinemura and Ostrocerca, both of which were found in the Laurel Run basin. According to Koryak (1972), the larvae of Nemoura in Europe are most abundant in waters having low pH and a high iron content. The Laurel Run basin had a slightly higher dissolved iron content in its waters than Coxes Creek. Waters of the Laurel Run basin had an average pH of 4.7 during both sampling trips, whereas waters of Coxes Creek basin had an average pH of 6.9. Rhyacophila, which is sensitive to AMD, was found only at site 1. This further supports the theory that acidity in Laurel Run is mainly due to geology and not AMD (Letterman, 1978).

Because the Laurel Run basin sites support Plecoptera, an AMD intolerant order, and their diversity index values (table 7) were slightly higher than Coxes Creek, Laurel Run seems to be the healthier stream. The exception is site 4, where aquatic life was virtually nonexistent. On both visits to site 4, oil was observed on the surface and along the edges of the stream. Regularly used railroad tracks traverse the right bank at site 4. Before the April trip, several trains had recently been derailed, which might account for the oil in the stream. The effects of the oil may also have diminished the number of benthic invertebrates found. Site 4 is also below an abandoned quarry where a variety of refractory products are now manufactured. Runoff from raw materials in the area may have affected the stream fauna. (Refer to the ground-water section on chemical quality, site 3, for further information.)

Laurel Run and its tributaries had 50 percent more caddis fly (Trichopteran) genera than Coxes Creek but had 47 percent fewer caddis fly individuals. According to the diversity index criteria given at the beginning of this section, Laurel Run is the healthier stream because of smaller populations within each genera and the greater variety of genera. Laurel Run and Coxes Creek could be compared because of similarities in substrate (fig. 9) and unit flow rates. The Laurel Run basin averaged 0.85 $(ft^3/s)/mi^2$ for April and 0.66 $(ft^3/s)/mi^2$ for May. Coxes Creek averaged 0.85 $(ft^3/s)/mi^2$ for April and 0.61 $(ft^3/s)/mi^2$ for May.

Sites 2A and 3 in the Laurel Run basin supported some Megaloptera an order that has been found by others in streams with AMD (Collier, 1964; Winger, 1977). Kimmel and Hales (1973) found Nigronia to be able to survive in waters having a pH as low as 1.5. This Megalopteran genus was collected at site 2A. Sialis was found at sites 2A and 3 in the Laurel Run basin, and is generally considered as AMD semitolerant by Koryak (1972), but Nichols and Bulow (1973) classify it as AMD tolerant. The National Environmental Research Center (1973) indicates Sialis as semitolerant to organic wastes. Both Laurel Run and Coxes Creek have scant invertebrate communities. Figure 10 shows the Arthropoda taxa found in Coxes Creek and Laurel Run. Coxes Creek is slightly influenced by AMD.

AMD harmfully affects benthic invertebrates in streams and can indirectly injure other life. Koryak (1972) found that the biomass of benthic invertebrates was lowest where deposits of ferric hydroxide were found, although large populations within a few species resulted in a low diversity index. Winger (1977) found the same to be true for the biomass of benthic invertebrates in AMD waters, but the low diversity values he obtained from the streams were from small numbers of taxa in small populations. Starvation of benthic invertebrates, indirectly caused by AMD pollution, occurs when food sources are eliminated (Napier, 1976).

Herrick (1973) reported that benthic invertebrates will use drift to recolonize if AMD enters a stream temporarily. Some benthic invertebrates are also able to move upstream or laterally to avoid stress (Luedtke, 1976). Koryak (1972) was able to show that genera decreased in numbers when iron concentrations increased, but this trend was not evident in the current data.

The midges (Chironomidae) and biting midges (Ceratopagonidae) are two families within the Dipteran (true fly) order that are AMD tolerant or semitolerant (Letterman, 1978). Coxes Creek above and below its confluence with Laurel Run had the most genera and greatest numbers in these two families. Sites 6-10 on Coxes Creek had two families in common, the Dipteran family Chironomidae and the caddis fly (Trichopteran) family Hydropsychidae. Hydropsyche, a genus in Hydropsychidae that is AMD tolerant, was found in greatest numbers at sites 7 and 8. Orange deposits of ferric hydroxide could be seen on the left bank and on the stream bed at sites 6, 7, and 10.

The Crustacean, Ispoda, can be tolerant or semitolerant of AMD (Lackey, 1938). The largest numbers of these were collected and observed at site 6, though some were found at sites 7 and 9. As mentioned previously, large numbers of a single genus or species can be an indicator of poor water quality. This was illustrated by site 6 in May, where many aquatic sowbugs (Asellus) were found.

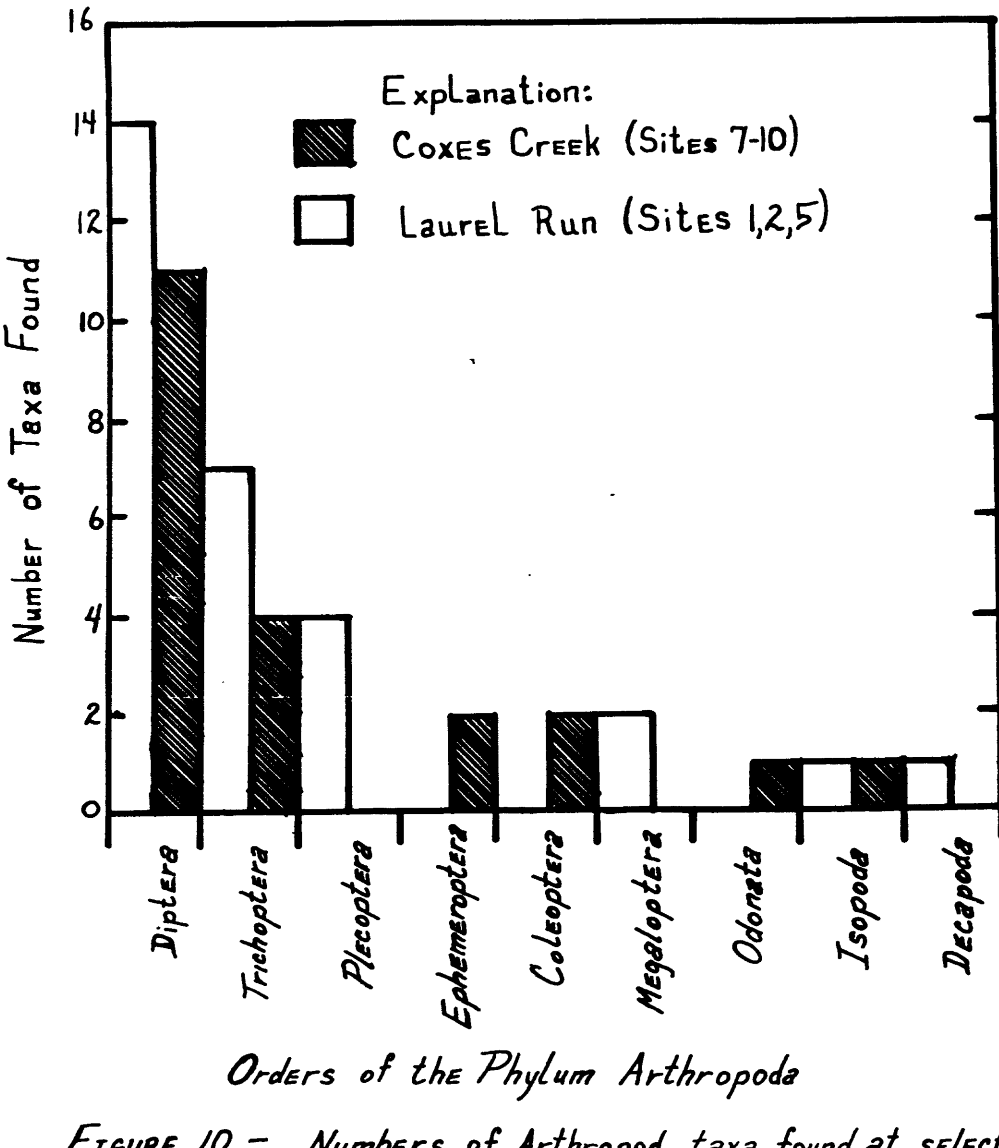


Figure 10.— Numbers of Arthropod taxa found at selected sampling sites on Coxes Creek and Laurel Run.

Site 10, near the mouth of Coxes Creek, showed a decrease in the kinds and numbers of benthic invertebrate genera found in other sections of the creek. This depressed community may be due to the effect of Wilson Creek, which enters just above site 10. Wilson Creek has several abandoned strip and deep mines that drain directly into it. The increase in acidity in May and consistently high values in total iron, dissolved manganese, and sulfate during April and May indicate the influence of AMD (table 4). The midge tribe, Pentaneurini, seems to exhibit an AMD tolerance because it was the only benthic invertebrate found in the May sampling at site 10.

Mayflies (Ephemeroptera) are AMD intolerant. Some aquatic beetles (Coleoptera) have been known to exist in waters with AMD (Letterman, 1978; Collier, 1964), but Coleoptera is generally considered an AMD intolerant order (Nichols and Bulow, 1973). However, Herrick (1973) found a specie in the Elmidae family to be dominant in AMD stressed waters. Elmidae was found in Coxes Creek at site 9. Mayflies were found at sites 6, 7, 8 and 9 and aquatic beetles at sites 7, 8, and 9.

Although some biological indicators hint that Coxes Creek is not as healthy as Laurel Run, Ephemeroptera, a healthy stream indicator organism, is found there. Therefore, more environmental factors are at work within the Coxes Creek basin than accounted for by this study.

Sedimentation can adversely effect stream flora and fauna. If the food that supports the benthic invertebrates is transported with the sediment or smothered below it, the benthic invertebrates may starve. Additionally, as the habitat of benthic invertebrates is the stream bottom, they can be buried in sediment. If mining increases peak flow rates, the stream bottom may scour. Scour due to high flow may physically remove organisms and alter these streams, reducing habitat and food supply (Branson, 1972; Herricks, 1973). Recovery from high flow scour and deposition can be slow or fast depending on the season (Herricks, 1973). High summer water temperatures increase the growth rate of diatoms and algae (Herricks, 1973). This rapid increase in food restoration for benthic invertebrates decreases their recovery time (Herricks, 1973).

An unstable substrate such as sand can contribute to the inability of benthic invertebrates to colonize successfully (Luedtke, 1976). Benthic invertebrates usually live on, or under, more stable substrates such as gravel and rubble. Station 10 had the sandiest substrate and the second smallest biological community.

Coxes Creek has the additional influence of an alkaline discharge from the East branch. The alkaline discharge may be caused by organic pollution from a sewage treatment plant. This is also indicated by the fact that two genera of freshwater snails (Helisoma and Physa), generally known to be organic pollution tolerant, were found there (National Environmental Research Center, 1973). Snails need calcium carbonate for shell construction and will not survive in an area where calcium carbonate is tied up in AMD (Karl Schaeffer, oral communication; Pennak, 1953). Helisoma and Physa were found at sites 6, 8, and 9. Aquatic earthworms (Oligochaeta) were found at sites 6, 7, and 9; and site 6 had fairly large numbers of leeches (Erpodellidae) along the edges of the stream. Generally speaking, aquatic earthworms and leeches are indicators of organic pollution (National Environmental Research Center, 1973; Karl Schaeffer, oral communication). Site 6 had large numbers of leeches, giving support to the belief that there is organic pollution entering Coxes Creek from the East branch.

The midges (Chironomidae) and caddis fly (Trichopteran) larvae are organic pollution tolerant. Sites 6, 7, and 8 held the largest populations. At stations more distant from the treatment plant and closer to the mouth of Coxes Creek, the numbers of these organic-tolerant benthic invertebrates decreased. The largest numbers of aquatic sowbugs, Asellus, an organic pollution tolerant genus, were found at site 6. Asellus is also tolerant of low pH and high dissolved solids.

Coleoptera, generally known as an organic pollution tolerant order, (National Environmental Research Center, 1973) was found at only three sites. Riffle beetles (Elmidae) are Coleopterans which are usually intolerant of organic pollution. Riffle beetles were most abundant at site 9, though a few were found at sites 7 and 8.

The chemical constituents examined in our investigations do not fully explain the reasons for the low diversity indices at sites 4, 6, 8, and 10, or the high diversity indices at sites 2, 3, and 9, but they do indicate the general water quality of the streams. Herricks' (1973) guidelines for interpreting Wilhm and Dorris diversity index values show that Coxes Creek had 60 percent of its biological samples fall in the unhealthy stream category, whereas Laurel Run basin had only 17 percent of its biological samples fall into the same category.

Ground Water (Section 779.15)

Levels and Yield (Section 779.15 (a))

The fresh-water flow system is 300 to 500 feet thick and is underlain by salty water. The sole source of the fresh ground water is precipitation which averages 45 inches annually. Approximately 24 inches of this water is returned to the atmosphere by evaporation and transpiration, 9 inches is direct runoff, and 12-13 inches infiltrates to the ground-water reservoir. The infiltrate to the ground-water reservoir generally moves laterally and downward along a flow path to discharge as springs or to streams, sustaining their flow between intervals of precipitation. Water moves downgradient through joints and fractures in the rock. Intergranular openings in the rocks of the area are not significant because of the small grain size of the detrital sediments and the low solubility of the intergranular cementing material.

Major recharge areas are in the uplands and discharge areas are mainly in the valleys. Water, as it moves from recharge to discharge areas, flows down a gradient that expresses the loss of potential energy in the system in overcoming the frictional resistance to flow.

The altitude of the top of the zone of saturation and direction of flow on that surface is shown on figure 11. This is based on the assumption that the water table follows the topography. Flow at depth depends on gradients and the hydraulic conductivities of the rocks and may differ significantly in direction from flow at the top of the zone of saturation.

At present, the ground-water reservoir is essentially unused in the mine area. Water is chiefly used for domestic purposes and is largely derived from shallow dug wells and springs. An insignificant quantity of water is temporarily withdrawn from the top of the system and returned in the form of on-lot sewage.

Records of drilled domestic wells in Somerset and Black Townships show that the median yield is 8 gal/min, median depth 100 feet, median depth to water about 60 feet, and a median casing length of 30 feet. The range in yield is 0 to 60 gal/min, depth of well 75 to 300 feet, and depth to water 45 to 250 feet. Four wells were drilled deeper than 200 feet and yielded 3 gal/min or less. The 12 wells that yielded 20 gal/min or more averaged 77 feet in depth, and major producing zones in these wells were reported to average 53 feet in depth. The well data indicate that more water is available in the shallower parts of the flow system, and that water producing fractures become fewer and tighter with increasing depth.

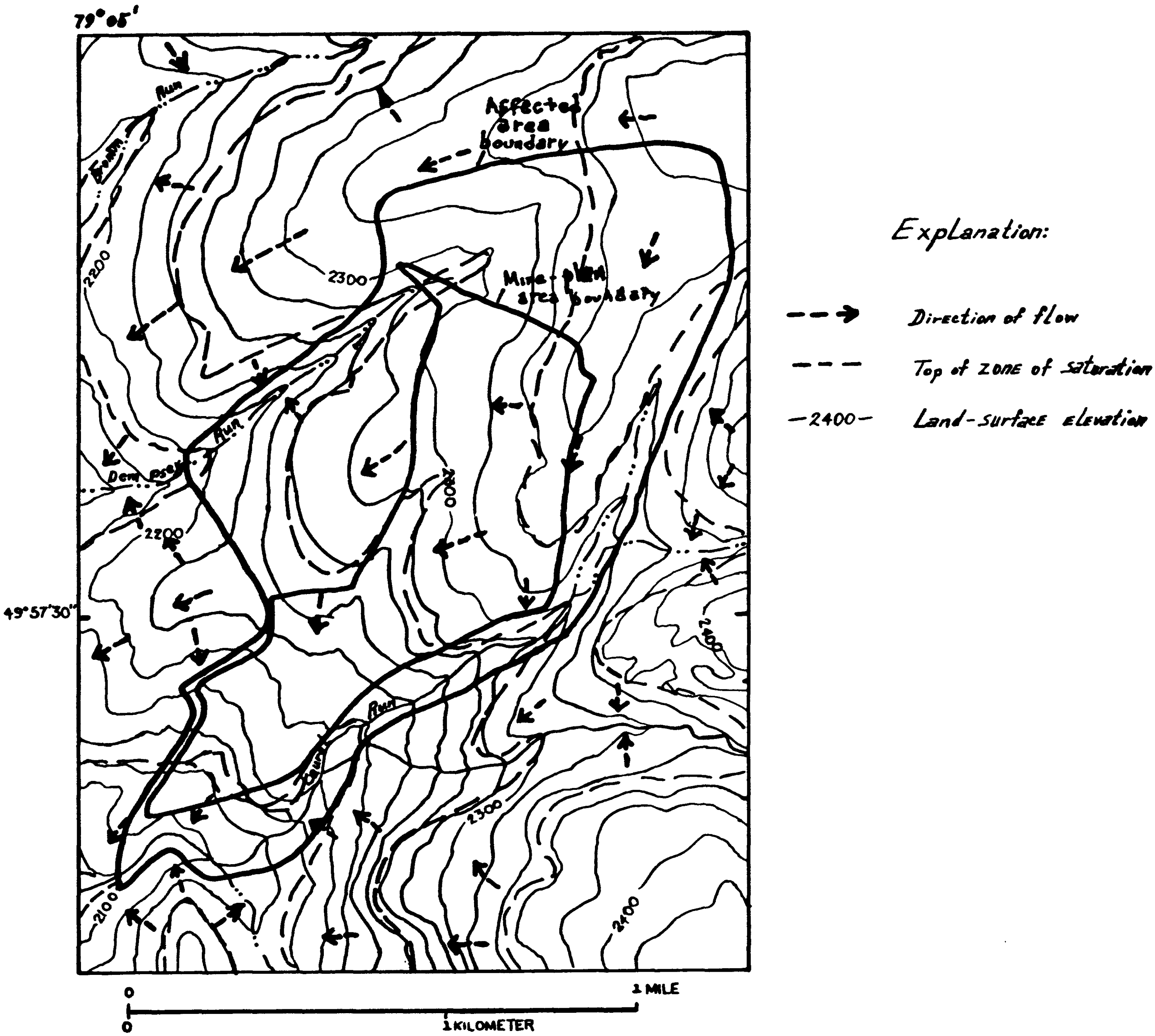


Figure 11.– Location of top of zone of saturation and direction of flow. (Constructed from altitude of peremial streams and reported average depth to water. Flow direction from surface land slope.)

Chemical Quality (Section 779.15 (b))

The quality of ground water in the area was characterized by Lohman (1938) as hard and to contain excess amounts of dissolved iron. The ideal procedure for determination of ground-water quality would be the collection of samples at various depths in many locations to define the chemical quality of the system and describe variations in water quality as it moves through the system. However, locations where ground water could be sampled near the study area were limited to several domestic wells.

Most residences use water from shallow dug wells or springs. The largest user is a farm on the central west edge of the proposed mining area.

Sample locations are shown on figure 1. Locations 1 and 2 are dug wells less than 20 feet deep on the north edge of the proposed mine area at an altitude of 2300 feet. Sample location 4 is a 12-foot-deep dug well, and location 5 is a 65-foot-deep drilled well, which yields water from a depth of 50 feet. Locations 4 and 5 are just south of the proposed mine area at an altitude of about 2120 feet. Location 3 is a drilled well, 8 inches in diameter, of unknown depth, used for industrial purposes at Murdock, 1 mile west of the southern limit of the proposed mine area at an altitude of about 2000 feet.

The present owner of location 3 manufactures a variety of refractory products. Raw materials from a variety of sources (none local) are stored in partly covered and uncovered locations at the plant site (an abandoned quarry in the Lower Kittanning sandstone). Some of the imported raw materials, may be leaching with subsequent effect on the chemical quality of the well water. The well is reported to have the highest yield in the vicinity of the mine site.

Ground-water samples collected at all 5 sample locations were acidic; pH ranged from 4.6 to 6.1. (table 8). A lower pH limit of 5.0 for domestic water supplies is recommended by the U.S. Environmental Protection Agency (1976). This lower limit is a consideration of needs for subsequent treatment rather than an inherent health consideration; therefore, the pH values of 4.6 and 4.8 measured at site locations 1 and 2 should not be injurious to human health.

Acidity of the ground-water samples was not measured; however, alkalinity was found to range from 2-8 mg/L (as $CaCO_3$) except for sample location 4, where the water which had an alkalinity of 21 mg/L (as $CaCO_3$), (table 8). All alkalinities were far below the 400 mg/L level, where problems may occur in domestic water supplies (U.S. Environmental Protection Agency, 1976).

Table 8.--Summary of water quality at ground-water sampling sites

Site 1						
ALK,TOT (AS CACO3)	MG/L	2	NITR. NO3 AS NO3 DIS	MG/L	7.5
ALUMINUM DISSOLVED	UG/L	250	NITROGEN DIS ORG ASN	MG/L	0.26
ANALYZING AGENCY		80010	NITROGEN DISS AS N	MG/L	2.0
ARSENIC DISSOLVED	UG/L	0	NITROGEN DISS KJD	MG/L	0.27
BARIUM DISSOLVED	UG/L	90	NITROGEN NH4 ASN DIS	MG/L	0.01
BICARBONATE	MG/L	2	NITROGEN NO2 ASN DIS	MG/L	0.00
BORON DISSOLVED	UG/L	20	NITROGEN NO3 ASN DIS	MG/L	1.7
CADMIUM DISSOLVED	UG/L	0	NO2+NO3 AS N DISS	MG/L	1.7
CALCIUM DISS	MG/L	3.8	PH FIELD		4.6
CARBON DIOXIDE	MG/L	80	PH LAB		5.0
CARBONATE	MG/L	0	PHOS ORTHO DIS AS P	MG/L	0.00
CHLORIDE DISS	MG/L	2.5	PHOSPHATE DIS ORTHO	MG/L	0.00
CHROMIUM DISSOLVED	UG/L	0	POTASSIUM DISS	MG/L	0.9
COBALT DISSOLVED	UG/L	2	POTASSIUM 40,D.PCI/L		0.7
COPPER DISSOLVED	UG/L	10	RESIDUE DIS CALC SUM	MG/L	32
FLUORIDE DISS	MG/L	0.0	RESIDUE DIS TON/AFT		0.06
HARDNESS NONCARB	MG/L	13	RESIDUE DIS 180C	MG/L	42
HARDNESS TOTAL	MG/L	15	SAR		0.1
IRON DISSOLVED	UG/L	0	SELENIUM DISSOLVED	UG/L	0
LEAD DISSOLVED	UG/L	15	SILICA DISSOLVED	MG/L	5.1
LITHIUM DISSOLVED	UG/L	3	SILVER DISSOLVED	UG/L	0
MAGNESIUM DISS	MG/L	1.2	SODIUM DISS	MG/L	0.9
MANGANESE DISSOLVED	UG/L	100	SODIUM PERCENT		11
MERCURY DISSOLVED	UG/L	< 0.5	SP. CONDUCTANCE FLD		50
NICKEL DISSOLVED	UG/L	3	SP. CONDUCTANCE LAB		50
NITR. NH4 AS NH4 DIS	MG/L	0.01	SULFATE DISS	MG/L	8.9
NITR. NO2 AS NO2 DIS	MG/L	0.00	WATER TEMP (DEG C)		11.0

Table 8.--Summary of water quality at ground-water sampling sites--(Continued)

Site 2					
ALK.TOT (AS CACO3)	MG/L	4	NITR. NO3 AS NO3 DIS	MG/L	5.7
ALUMINUM DISSOLVED	UG/L	160	NITROGEN DIS ORG ASN	MG/L	0.01
ANALYZING AGENCY		80010	NITROGEN DISS AS N	MG/L	1.3
ARSENIC DISSOLVED	UG/L	0	NITROGEN DISS KJD	MG/L	0.03
BARIUM DISSOLVED	UG/L	100	NITROGEN NH4 ASN DIS	MG/L	0.02
BICARBONATE	MG/L	5	NITROGEN NO2 ASN DIS	MG/L	0.01
BORON DISSOLVED	UG/L	8	NITROGEN NO3 ASN DIS	MG/L	1.3
CADMIUM DISSOLVED	UG/L	0	NO2+NO3 AS N DISS	MG/L	1.3
CALCIUM DISS	MG/L	8.3	PH FIELD		4.9
CARBON DIOXIDE	MG/L	101	PH LAB		5.0
CARBONATE	MG/L	0	PHOS ORTHO DIS AS P	MG/L	0.00
CHLORIDE DISS	MG/L	3.4	PHOSPHATE DIS ORTHO	MG/L	0.00
CHROMIUM DISSOLVED	UG/L	1	POTASSIUM DISS	MG/L	1.1
COBALT DISSOLVED	UG/L	6	POTASSIUM 40,D.PCI/L		0.8
COPPER DISSOLVED	UG/L	660	RESIDUE DIS CALC SUM	MG/L	49
FLUORIDE DISS	MG/L	0.0	RESIDUE DIS TON/AFT		0.07
HARDNESS NONCARB	MG/L	22	RESIDUE DIS 180C	MG/L	54
HARDNESS TOTAL	MG/L	27	SAR		0.1
IRON DISSOLVED	UG/L	30	SELENIUM DISSOLVED	UG/L	0
LEAD DISSOLVED	UG/L	11	SILICA DISSOLVED	MG/L	4.3
LITHIUM DISSOLVED	UG/L	4	SILVER DISSOLVED	UG/L	0
MAGNESIUM DISS	MG/L	1.4	SODIUM DISS	MG/L	0.9
MANGANESE DISSOLVED	UG/L	60	SODIUM PERCENT		7
MERCURY DISSOLVED	UG/L	< 0.5	SP. CONDUCTANCE FLD		82
NICKEL DISSOLVED	UG/L	6	SP. CONDUCTANCE LAB		77
NITR. NH4 AS NH4 DIS	MG/L	0.03	SULFATE DISS	MG/L	20
NITR. NO2 AS NO2 DIS	MG/L	0.03	WATER TEMP (DEG C)		16.5

Table 8.--Summary of water quality at ground-water sampling sites--(Continued)

Site 3							
ALK,TOT (AS CACO3)	MG/L		8	NITR. NO3 AS NO3 DIS	MG/L	0.00
ALUMINUM DISSOLVED	UG/L		100	NITROGEN DIS ORG ASN	MG/L	0.00
ANALYZING AGENCY			80010	NITROGEN DISS AS N	MG/L	0.09
ARSENIC DISSOLVED	UG/L		1	NITROGEN DISS KJD	MG/L	0.09
BARIUM DISSOLVED	UG/L		50	NITROGEN NH4 ASN DIS	MG/L	0.09
BICARBONATE	MG/L		10	NITROGEN NO2 ASN DIS	MG/L	0.00
BORON DISSOLVED	UG/L		50	NITROGEN NO3 ASN DIS	MG/L	0.00
CADMIUM DISSOLVED	UG/L		5	NO2+NO3 AS N DISS	MG/L	0.00
CALCIUM DISS	MG/L		6.6	PH FIELD		5.9
CARBON DIOXIDE	MG/L		20	PH LAB		5.4
CARBONATE	MG/L		0	PHOS ORTHO DIS AS P	MG/L	0.00
CHLORIDE DISS	MG/L		3.8	PHOSPHATE DIS ORTHO	MG/L	0.00
CHROMIUM DISSOLVED	UG/L		0	POTASSIUM DISS	MG/L	4.6
COBALT DISSOLVED	UG/L		36	POTASSIUM 40,D.PCI/L		3.4
COPPER DISSOLVED	UG/L		5	RESIDUE DIS CALC SUM	MG/L	214
FLUORIDE DISS	MG/L		0.1	RESIDUE DIS TON/AFT		0.29
HARDNESS NONCARB	MG/L		38	RESIDUE DIS 180C	MG/L	216
HARDNESS TOTAL	MG/L		47	SAR		2.4
IRON DISSOLVED	UG/L		18000	SELENIUM DISSOLVED	UG/L	0
LEAD DISSOLVED	UG/L		0	SILICA DISSOLVED	MG/L	9.9
LITHIUM DISSOLVED	UG/L		50	SILVER DISSOLVED	UG/L	0
MAGNESIUM DISS	MG/L		7.3	SODIUM DISS	MG/L	37
MANGANESE DISSOLVED	UG/L		990	SODIUM PERCENT		61
MERCURY DISSOLVED	UG/L	<	0.5	SP. CONDUCTANCE FLD		335
NICKEL DISSOLVED	UG/L		24	SP. CONDUCTANCE LAB		333
NITR. NH4 AS NH4 DIS	MG/L		0.12	SULFATE DISS	MG/L	120
NITR. NO2 AS NO2 DIS	MG/L		0.00	WATER TEMP (DEG C)		11.0

Table 8.--Summary of water quality at ground-water sampling sites--(Continued)

Site 4

ALK.TOT (AS CACO3)	MG/L	21	NITR. NO3 AS NO3 DIS	MG/L	1.0
ALUMINUM DISSOLVED	UG/L	30	NITROGEN DIS ORG ASN	MG/L	0.01
ANALYZING AGENCY		80010	NITROGEN DISS AS N	MG/L	0.25
ARSENIC DISSOLVED	UG/L	0	NITROGEN DISS KJD	MG/L	0.02
BARIUM DISSOLVED	UG/L	20	NITROGEN NH4 ASN DIS	MG/L	0.01
BICARBONATE	MG/L	26	NITROGEN NO2 ASN DIS	MG/L	0.00
BORON DISSOLVED	UG/L	2	NITROGEN NO3 ASN DIS	MG/L	0.23
CADMIUM DISSOLVED	UG/L	0	NO2+NO3 AS N DISS	MG/L	0.23
CALCIUM DISS	MG/L	9.2	PH FIELD		6.1
CARBON DIOXIDE	MG/L	32	PH LAB		6.3
CARBONATE	MG/L	0	PHOS ORTHO DIS AS P	MG/L	0.00
CHLORIDE DISS	MG/L	1.7	PHOSPHATE DIS ORTHO	MG/L	0.00
CHROMIUM DISSOLVED	UG/L	0	POTASSIUM DISS	MG/L	0.6
COBALT DISSOLVED	UG/L	0	POTASSIUM 40,D.PCI/L		0.4
COPPER DISSOLVED	UG/L	61	RESIDUE DIS CALC SUM	MG/L	38
FLUORIDE DISS	MG/L	0.0	RESIDUE DIS TON/AFT		0.06
HARDNESS NONCARB	MG/L	5	RESIDUE DIS 180C	MG/L	43
HARDNESS TOTAL	MG/L	27	SAR		0.1
IRON DISSOLVED	UG/L	50	SELENIUM DISSOLVED	UG/L	0
LEAD DISSOLVED	UG/L	0	SILICA DISSOLVED	MG/L	8.0
LITHIUM DISSOLVED	UG/L	4	SILVER DISSOLVED	UG/L	0
MAGNESIUM DISS	MG/L	0.9	SODIUM DISS	MG/L	0.9
MANGANESE DISSOLVED	UG/L	8	SODIUM PERCENT		7
MERCURY DISSOLVED	UG/L	< 0.5	SP. CONDUCTANCE FLD		56
NICKEL DISSOLVED	UG/L	2	SP. CONDUCTANCE LAB		57
NITR. NH4 AS NH4 DIS	MG/L	0.01	SULFATE DISS	MG/L	2.3
NITR. NO2 AS NO2 DIS	MG/L	0.00	WATER TEMP (DEG C)		15.0

Table 8.--Summary of water quality at ground-water sampling sites--(Continued)

Site 5					
ALK,TOT (AS CACO3)	MG/L	3	NITR. NO3 AS NO3 DIS	MG/L	0.66
ALUMINUM DISSOLVED	UG/L	20	NITROGEN DIS ORG ASN	MG/L	0.03
ANALYZING AGENCY		80010	NITROGEN DISS AS N	MG/L	0.18
ARSENIC DISSOLVED	UG/L	0	NITROGEN DISS KJD	MG/L	0.03
BARIUM DISSOLVED	UG/L	10	NITROGEN NH4 ASN DIS	MG/L	0.00
BICARBONATE	MG/L	4	NITROGEN NO2 ASN DIS	MG/L	0.00
BORON DISSOLVED	UG/L	4	NITROGEN NO3 ASN DIS	MG/L	0.15
CADMIUM DISSOLVED	UG/L	0	NO2+NO3 AS N DISS	MG/L	0.15
CALCIUM DISS	MG/L	0.7	PH FIELD		5.2
CARBON DIOXIDE	MG/L	40	PH LAB		5.3
CARBONATE	MG/L	0	PHOS ORTHO DIS AS P	MG/L	0.00
CHLORIDE DISS	MG/L	1.6	PHOSPHATE DIS ORTHO	MG/L	0.00
CHROMIUM DISSOLVED	UG/L	0	POTASSIUM DISS	MG/L	0.3
COBALT DISSOLVED	UG/L	3	POTASSIUM 40,D.PCI/L		0.2
COPPER DISSOLVED	UG/L	31	RESIDUE DIS CALC SUM	MG/L	15
FLUORIDE DISS	MG/L	0.0	RESIDUE DIS TON/AFT		0.02
HARDNESS NONCARB	MG/L	1	RESIDUE DIS 180C	MG/L	18
HARDNESS TOTAL	MG/L	4	SAR		0.3
IRON DISSOLVED	UG/L	340	SELENIUM DISSOLVED	UG/L	0
LEAD DISSOLVED	UG/L	0	SILICA DISSOLVED	MG/L	7.5
LITHIUM DISSOLVED	UG/L	0	SILVER DISSOLVED	UG/L	0
MAGNESIUM DISS	MG/L	0.5	SODIUM DISS	MG/L	1.2
MANGANESE DISSOLVED	UG/L	20	SODIUM PERCENT		38
MERCURY DISSOLVED	UG/L	< 0.5	SP. CONDUCTANCE FLD		17
NICKEL DISSOLVED	UG/L	0	SP. CONDUCTANCE LAB		18
NITR. NH4 AS NH4 DIS	MG/L	0.00	SULFATE DISS	MG/L	0.1
NITR. NO2 AS NO2 DIS	MG/L	0.00	WATER TEMP (DEG C)		16.5

All ground-water samples had a total hardness from 447 mg/L and would be classified as soft, according to the U.S. Environmental Protection Agency (1976), (table 8). The residue on evaporation at 180°C ranged from 18-216 mg/L (table 8), which falls below the upper limit of 250 mg/L for dissolved solids (U.S. Environmental Protection Agency, 1976).

Dissolved iron in the ground-water samples was generally below the U.S. Environmental Protection Agency (1976) limit of 300 µg/L for domestic water supplies. However, water at location 5 had a concentration of 340 µg/L, and water at location 3 had a concentration of 18,000 µg/L (table 8).

Water at locations 4 and 5 had dissolved manganese below the 50 µg/L limit as set forth by the Environmental Protection Agency (1976). Locations 1, 2, and 3 had water having dissolved manganese concentrations of 100, 60, and 990 µg/L, respectively (table 8).

The specific conductance of the ground-water samples ranged from 17 to 82 µmho/cm at 25°C, except for location 3, where a specific conductance of 335 µmho/cm at 25°C was measured.

A dissolved sulfate concentration of 120 mg/L was found at location 3. At the remaining locations, the range was from 0.1 to 20 mg/L.

The tendency for constituent values to be greatest at sampling location 3 may be an indication of ground-water contamination from the refactory-product raw materials stored at the sampling location.

Table 8 lists total results of the chemical analyses of the ground-water samples. Concentrations of such constituents as arsenic, lead, mercury, and selenium were well within U.S. Environmental Protection Agency (1976) limits for domestic water supplies.

ESTIMATED ANNUAL TRENDS (SECTION 779)

Streamflow (Section 779.16(b) (1))

The shortness of this investigation precluded direct measurement of annual flow variation at the surface-water sites. Note also that, even if daily streamflow data were collected for a full year, it would do little more than define the flow variation for that particular year. Several generalization techniques were used to estimate mean-monthly and mean-annual flows, peak discharges at selected exceedance probabilities, and the 7-day, 0.10 probability low flows for various periods.

Mean-annual and mean-monthly flow estimates were made through the use of regression equations developed by Herb (1979):

Equation	Standard error percent	
$Q_A = 0.1174\ DA^{0.9872}\ APX^{0.9137}$	11	(1)
$Q_1 = 0.1501\ DA^{1.0306}\ APX^{0.8931}$	13	(2)
$Q_2 = 0.3198\ DA^{0.9980}\ APX^{0.7233}$	11	(3)
$Q_3 = 0.8224\ DA^{0.9804}\ E^{0.3825}\ APX^{0.4382}$	11	(4)
$Q_4 = 0.3399\ DA^{1.0044}\ E^{0.2070}\ APX^{0.6706}$	10	(5)
$Q_5 = 0.5608\ DA^{1.0000}\ E^{0.4776}\ APX^{0.3082}$	16	(6)
$Q_6 = 0.8046\ DA^{0.9903}\ E^{0.5534}$	26	(7)
$Q_7 = 0.0123\ DA^{1.0151}\ E^{-0.5440}\ APX^{1.4179}$	32	(8)
$Q_8 = 0.0203\ DA^{1.0460}\ APX^{1.0703}$	22	(9)
$Q_9 = 0.0083\ DA^{1.1161}\ APX^{1.1245}$	41	(10)
$Q_{10} = 0.0222\ DA^{1.0442}\ APX^{1.0321}$	33	(11)
$Q_{11} = 0.0216\ DA^{0.9952}\ APX^{1.3344}$	23	(12)
$Q_{12} = 0.0937\ DA^{0.9506}\ APX^{1.1389}$	14	(13)

Where Q_A, 1-12 = mean or mean-monthly discharge, in cubic feet per second, (subscript A refers to annual, 1 refers to January, 2 to February, and so forth);

DA = drainage area, in square miles;

E = mean basin elevation, in thousands of feet; and

APX = annual precipitation excess, in inches.

Drainage areas are given in table 3, the average precipitation excess (computed by subtracting annual potential evapotranspiration from mean annual precipitation (Herb, 1979)) was 21 inches for all sites, and mean basin elevations are given in the following table:

Basin	Mean elevation (feet x 10^3)
1	2.43
2	2.33
2A	2.21
3	2.24
4	2.20
5	2.33
6	2.25
7	2.28
8	2.23
9	2.17
10	2.18

Estimates of mean and mean-monthly discharges are given in table 9. The standard errors of the estimate given for regression equations 1-13 are an indication of the potential errors of the tabulated mean discharges. Regression equations 1-13 are only applicable in a small part of Pennsylvania, and the reliability for drainage areas less than 5 mi^2 is unknown.

Peak discharge estimates were made through the use of regression procedures outlined by Flippo (1977) and alternate regression procedures outlined by Herb (1977).

Estimates of peak discharges for flood frequency Region 5 (Flippo, 1977) were made through the use of the following basin characteristic regression equations:

	Standard error percent	
$P_{43} = 39.4\ DA^{0.827}\ APX^{0.222}$	28	(14)
$P_{10} = 45.4\ DA^{0.789}\ APX^{0.445}$	25	(15)
$P_{04} = 45.3\ DA^{0.772}\ APX^{0.566}$	26	(16)
$P_{02} = 44.5\ DA^{0.759}\ APX^{0.656}$	29	(17)
$P_{01} = 42.2\ DA^{0.751}\ APX^{0.744}$	31	(18)

Where P_{43-01} = Peak discharge, in cubic feet per second, for flood with specified exceedance probability (subscript 43 means a 43 percent chance of being exceeded in a given year, 10 means a 10 percent chance of being exceeded in a given year, and so forth; the reciprocal of exceedance probability is the recurrence interval); and DA and APX are as defined for the mean flow equations.

Table 9.--Estimated mean-annual and mean-monthly discharge[1] at surface-water sites

	Mean discharge (ft^3/s)												
	Period												
Site	Annual	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	6.3	8.0	9.7	14	11	7.4	4.4	2.0	1.9	.99	1.8	4.2	9.5
2	10	13	16	23	17	12	6.9	3.3	3.1	1.7	3.1	6.9	15
2A	.52	.57	.74	1.1	.80	.54	.33	.15	.13	.06	.13	.33	.83
3	1.3	1.5	2.0	2.9	2.1	1.4	.85	.40	.36	.17	.36	.85	2.1
4	3.7	4.4	5.4	7.8	5.8	3.9	2.3	1.1	1.0	.52	1.0	2.4	5.4
5	13	16	20	23	21	14	8.5	4.0	3.8	2.2	3.8	8.5	18
6	71	100	110	150	120	81	47	24	22	14	22	48	96
7	85	120	140	180	150	99	57	29	28	18	28	58	120
8	93	130	150	200	160	110	61	32	30	19	30	63	120
9	100	140	160	210	170	110	66	35	33	21	33	68	130
10	120	180	190	250	200	130	77	42	38	26	38	80	160

[1]Estimated discharges based on regression techniques outlined by Herb (1977).

Drainage area and precipitation excess data were determined as explained for mean flow estimates. Table 10 presents the peak discharges estimated by using equations 14-18. The interpretation of the standard error is the same as that given for mean flow estimates. Table 10 also presents alternate peak discharge estimates computed from channel characteristic regression equations presented by Herb (1977). The alternate estimating equations are:

	Standard error percent	
$P_{10} = 7.079\ CWIDE^{1.473}$	50	(19)
$P_{04} = 10.641\ CWIDE^{1.451}$	50	(20)
$P_{02} = 14.028\ CWIDE^{1.437}$	50	(21)

Where P_{10-02} are as previously defined, and

CWIDE = top width of bankfull channel, in feet.

The bankfull channel dimensions are the surface-water sites are:

Site	Channel width[1] (ft)	Mean channel depth[1] (ft)	Cross-sectional[1] area (ft^2)
1	17.5	1.68	29.5
2	24.2	1.71	41.4
2a	4.5	1.52	6.8
3[2]	--	--	--
4	9.5	1.54	14.6
5	29	2.57	74.6
6	69	4.36	301
7	75	2.51	188
8	70	3.12	218
9	70	3.70	259
10	82	3.97	326

[1]Based on single representative cross section.

[2]No defined channel.

The interpretation of error potential for both the basin and channel characteristic methods is the same as for mean flows. The closeness of estimates using the independent techniques of Flippo (1977) and Herb (1977) tend to support the estimates, although the reliability of both estimation procedures for drainage areas less than 2 mi^2 is unknown.

Table 10.--Estimates of peak discharge[1] at selected exceedance probabilities for surface-water sites

Site	Percent exceedance probability				
	43	10	4	2	1
	Estimated peak discharge (ft^3/s)				
1	211	460	650	820	1010
	(----)	(480)	(680)	(860)	(----)
2	320	770	910	1180	1450
	(----)	(670)	(1080)	(1370)	(----)
2A	25	59	89	110	140
	(----)	(65)	(94)	(120)	(----)
3	56	120	180	240	300
	(----)	(----)	(----)	(----)	(----)
4	130	280	400	510	630
	(----)	(200)	(280)	(360)	(----)
5	380	780	1060	1380	1660
	(----)	(1010)	(1410)	(1770)	(----)
6	1650	3150	4000	5300	6200
	(----)	(3620)	(4960)	(6160)	(----)
7	1900	3600	4700	6100	7200
	(----)	(4090)	(5590)	(6940)	(----)
8	2050	3900	5000	6500	7600
	(----)	(3700)	(5060)	(6290)	(----)
9	2250	4200	5400	7100	8300
	(----)	(3700)	(5060)	(6290)	(----)
10	2550	4700	6000	7900	9300
	(----)	(4670)	(6370)	(7890)	(----)

[1]Estimated discharges based on regression techniques outlined by Flippo (1977). Alternate estimates based on regression techniques outlined by Herb (1977) are shown in parentheses.

Regression techniques by Flippo (1979) were used to estimate 7-day, 0.10 probability (7-day, 10-year) low flows. When a 7-day, 0.10 probability low flow is specified for a period such as a month or year there is a 10 percent chance that the lowest average flow for 7 consecutive days during that period will be smaller. The 7-day, 0.10 probability low flows were estimated for annual periods and also for the individual months from May through October.

The regression equations used in the estimate, modified from Flippo (1979), were:

	Standard error percent	
$Q_A\ 7,.1 = 0.00168\ DA^{1.110}\ G^{2.380}$	34	(22)
$Q_5\ 7,.1 = 0.10257\ DA^{0.924}\ G^{1.419}$	29	(23)
$Q_6\ 7,.1 = 0.00780\ DA^{1.089}\ G^{2.643}$	29	(24)
$Q_7\ 7,.1 = 0.00277\ DA^{1.112}\ G^{2.579}$	30	(25)
$Q_8\ 7,.1 = 0.00179\ DA^{1.131}\ G^{2.581}$	34	(26)
$Q_9\ 7,.1 = 0.00316\ DA^{1.123}\ G^{1.888}$	38	(27)
$Q_{10}\ 7,.1 = 0.03990\ DA^{1.033}$	41	(28)

Where $Q_x\ 7,.1$ = 7-day, 0.10 probability low flow for period indicated by subscript (A = annual, 5 = May, 6 = June, and so forth), in cubic feet per second,

G = weighted geologic index determined from areal geology, as outlined by Flippo (1979), and

DA is as previously defined.

Drainage areas at each of the surface-water sites are obtained from table 3 and weighted geologic index was computed as shown in table 11.

The estimated low flows are presented in table 12. The standard errors of the estimate associated with regression equations 22-28 give some indication of the potential errors in the tabulated low flows. Regression equations 22-28 are applicable only in a specific area of the State, and Flippo (1979) cautions that they may not be reliable for drainage areas of less than 10 mi^2.

Table 11.--Computation[1] of weighted geologic index used in low-flow regression models

	Areal geology classification			
	Conemaugh Formation	Allegheny Group	Pottsville Group	
	Individual geologic index			
	0.50	0.30	1.00	Weighted geologic index
Site	Fraction of basin in areal geology classification			
1	0.00	1.00	0.00	0.30
2	0	.85	.15	.41
2A	0	1.00	0	.30
3	0	1.00	0	.30
4	0	1.00	0	.30
5	0	.95	.05	.34
6	.50	.50	0	.40
7	.45	.55	0	.39
8	.45	.55	0	.39
9	.40	.60	0	.38
10	.40	.60	0	.38

[1]The weighted geologic index is computed by taking the sum of the products of the individual geologic indices of the geology classification times the corresponding fraction of the basin within each classification. For example, the index for basin 7 is (.45)(.5) + (.55)(.3) + (0)(1.0) = 0.39

Table 12.--Estimated 7-day, 0.10 probability low flows[1] for surface-water sites

	7-day, 0.10 probability low flow (ft^3/s)						
Site	Annual	May	June	July	Aug.	Sept.	Oct.
1	0.01	0.06	0.01	0.01	0.01	0.01	0.14
2	.01	.14	.01	.01	.01	.01	.23
2A	.01	.01	.01	.01	.01	.01	.01
3	.01	.01	.01	.01	.01	.01	.03
4	.01	.03	.01	.01	.01	.01	.08
5	.01	.13	.01	.01	.01	.01	.29
6	.01	.81	.04	.02	.01	.03	1.7
7	.01	.93	.04	.02	.01	.04	2.1
8	.01	1.0	.05	.02	.01	.04	2.3
9	.01	1.1	.05	.02	.01	.05	2.5
10	.02	1.2	.05	.02	.02	.02	3.0

[1]Estimated through the use of regression procedures outlined by Flippo (1979).

Surface-Water Quality (Section 779.16 (b) (2))

The scant sediment data collected during this study precludes any site-specific generalization of the possible annual variation of sediment loads. Yorke and Herb (1978) show, that for an urbanizing basin in Maryland's Piedmont, monthly suspended-sediment loads are highest during February-August and lowest during September - January. Yorke and Herb also indicate that certain storm-period variables, notably total storm runoff and peak discharge, are closely correlated with storm sediment loads.

The data from 2-months sampling are insufficient to construct any seasonal chemical-quality trends. Other streams in Pennsylvania of comparable physiology and land use show that dissolved constituent concentrations vary inversely with water discharge. Based on estimated monthly mean discharges at all sampling sites, the lowest dissolved constituent concentrations would be found in March during high base flows, and the highest concentrations would be found in September during very low base flows.

Because of insufficient data and the nature of living organisms, a statistical chart showing seasonal trends of benthic invertebrates would be virtually impossible to compile.

Attempts to model various water-quality constituents have not met with unqualified success. Lystrom and Rinella (1978) estimated average annual sediment and dissolved solids yields for Susquehanna River basin streams. Their regression equations used various basin characteristics as the independent variables. One shortcoming in their procedure was that only average annual values were estimated, and monthly variation was ignored. Another shortcoming was the quality of the independent variables. A significant variable in the dissolved solids model was the percentage of the basin underlain by coal, but the amount of mining was not considered. The only significant land-use variable in the sediment-yield model was the percentage of the basin urbanized; this ignores other sediment-producing activity in the basin.

Other modeling efforts that have attempted to predict water-quality constituents on a daily basis have found that much data is required, and little is generally available. Herricks and others (1975) attempted to predict sulfate concentrations for Pennsylvania's Indian Creek basin. Their model used 1 year of continuous-record streamflow data from a sub-basin, hourly precipitation data, and 29 additional variables for calibration simply to generate the streamflow component. Sulfate modeling required background concentration and known acid loadings.

At the present, a simple, direct method for estimation of annual variation in water-quality parameters for unmonitored streams does not seem to exist.

Ground Water (Section 779.15)

Ground-water levels at the sites investigated were all within 10 feet of land surface in June 1979. All well sites visited were in valleys or adjacent to streams, where shallow water levels are expected. Most of the wells (sample sites) were dug and were less than 20 feet deep. The one drilled well sampled produced water from 50 feet below land surface, and, other than its method of construction, is similar to the dug wells in that it samples the same shallow zone of water circulation and has a depth to water of 8 to 10 feet below land surface. There are no records of fluctuations of the water levels on a seasonal basis. One well owner reported that his dug well went dry occasionally during the summer during long dry periods.

The wells in the immediate vicinity of the mine site all have shallow water levels, but they are similar in their topographic settings. Well records supplied to the State Geological Survey by well drillers show much greater depths to water in many wells. The median depth to water reported for 20 wells in Black and Somerset Townships is 65 feet. These wells had a median depth of 100 feet and are presumed to be located in a variety of topographic locations.

The chemical quality of the ground water in the proposed mine area is difficult to define from the few samples collected. Three of the four samples were from shallow dug wells in unconsolidated materials near streams. The drilled well was only a few tens of feet deeper, but derived its water from bedrock. In general, the samples taken from the northern end of the proposed strip area have a lower pH and contain less iron and silica than the samples taken at the south end of the area, several hundred feet lower in altitude. Compared with the samples from the north, those from wells in the southern part of the area showed a decrease in dissolved Al, Ba, CO_2, Mn, nitrogen as NO_3 and sulfate.

The samples (except for site 4) have a pH and acidity to alkalinity ratios similar to the surface-water samples.

PREDICTED EFFECTS OF MINING AND RECLAMATION (SECTION 780.21 (c))

Surface Water

Streamflow

Previous investigators have found that mined areas produce larger floods than similar areas that are undisturbed. Collier and others (1970) report that for floods with exceedance probabilities of 90 to 10 percent, unit flood flows are greater in mined areas in Kentucky. Curtis (1972) found that mining in Kentucky increased peak flow by 3 to 5 times if 30 to 50 percent of the watershed was disturbed. He attributes this to a decrease in interception and transpiration and surface sealing of shale soils. Collier and others (1964) show a shorter time to peak in a mined basin in Kentucky. These conclusions may not be applicable in Pennsylvania.

The effects of mining on low flows are not as definitive as those on peak flows. Collier and others (1964) found that low flows of 50 and 84 percent duration were 1.5 and 3.0 times larger in an unmined basin than for a mined basin. They attributed this to relatively impervious spoil piles reducing infiltration. On the other hand, Grubb and Ryder (1972) found that low flows increased in mined basins because of the effects of storage in abandoned underground mines, strip pits, and spoil piles.

Sediment

To estimate effects of mining on downstream suspended-sediment loads, some assumptions concerning the effectiveness of treatment operations are necessary. The first assumption is that sedimentation ponds will keep average sediment concentrations at or below the 30-day average of 35 mg/L, as required by the Office of Surface Mining. The second assumption is no increase in the average flow from the mine plan area.

A "worst-possible case," while still meeting effluent requirements, would be a year-round average concentration of 35 mg/L of suspended sediment (Section 816.42 (a)(7)). Such a concentration level would increase the sediment yield from the mine plan area to 21 tons per year, or by a factor of 3.5. However, if a normal annual sediment yield of 40 tons/mi^2 (Williams and Reed, 1972) at the mouth of Laurel Run is assumed, an increase of 15 tons would be only a 4 percent increase. The average suspended-sediment concentration at the mouth of Laurel Run would be raised from 21 to 22 mg/L. Guy (1979) indicates that sedimentation ponds increase the amount of time that downstream flows would be turbid because very fine sediment particles will not be removed, and detention time requirements extend the outflow hydrograph to almost three times the length of the inflow hydrograph.

If releases result from a storm larger than a 10-year, 24-hour precipitation event, effluent standards are not enforced (Section 816.42 (b)(1)), and high concentrations and large load may result. Collier and others (1964) report maximum storm suspended-sediment concentrations of 75,000 ppm (parts per million) in a mined Kentucky basin. Collier and others (1970) report that during 8 years the maximum suspended-sediment concentration exceeded 20,000 ppm, 68 times and 30,000 ppm, 37 times in Cone Branch, Kentucky. Maximum suspended-sediment concentrations observed in the mined Leatherwood Creek basin, Kentucky, were 46,400; 26,900; and 9,600 ppm (Curtis, 1971).

Guy (1979) points out that construction of sedimentation ponds will expose a relatively small area to erosion and sediment movement prior to stabilization. He also indicates that if construction is done during periods when revegetation is difficult the potential for adverse effects (large sediment loss) will be high. Guy also indicates that after the mined area is stabilized removal of the pond may cause adverse effects because no pond will be available to collect sediment while final stablization is awaited.

After reclamation, if the land is returned to forest cover, sediment yields should gradually return to premining levels. Curtis (1974) indicates that in untreated mining areas the sediment yield is highest the first 6 months after mining and decreases to "fairly low" levels in 3 years. Curtis found that factors affecting sediment yields were method of mining, method of spoil handling, and speed of establishing vegetal cover.

Chemical Quality

The discharge from the proposed mine will probably enter Laurel Run between sites 1 and 2. An assumption has previously been made that the mine discharge will be an average flow of 0.6 ft^3/s. Compared to the mean monthly discharge projected for site 2, the mine discharge will contribute from 3 percent of the flow in March to 35 percent of the flow in September.

Deep mine records for Lower Kittanning coal (Roger Hornberger, oral communication, 1979) shows untreated mine discharges having pH ranges of 3-5, sulfate values of 300 mg/L, and total iron values of 30 mg/L. As the coal to be mined at the proposed site is also Lower Kittanning coal, it will most likely have acid-producing characteristics.

According to the Office of Surface Mining Reclamation and Enforcement (1979) any acid discharge must be treated so that the "average of daily values for 30 consecutive discharge days" is 3.5 mg/L total iron and 2.0 mg/L total manganese and must have a pH within the range of 6.0 to 9.0 (Section 816.42 (a)(7)). If it is assumed that these limitations are met, then the discharge will have changed with treatment from a moderately buffered acid discharge containing approximately 15-30 mg/L total iron and manganese and 200-300 mg/L sulfate to a well-buffered alkaline discharge with iron and manganese concentrations within regulation guidelines. However, the sulfate concentrations will not be significantly affected by treatment.

Under treatment producing average allowable daily concentrations as stated above and with a mean flow of 10 ft^3/s and an estimated 0.6 ft^3/s mine discharge, Laurel Run, which is poorly buffered, will have significantly increased pH and alkalinity values. Total iron at site 2 may range from 0.4 to 0.5 mg/L, total manganese from 0.2 to 0.3 mg/L, and sulfate from 25 to 35 mg/L.

Laurel Run will be most affected during low flow, when up to 35 percent of the streamflow may be contributed to site 2 by mine discharge. Assuming that the treated discharge is at the maximum allowable limits of 7.0 mg/L iron, 4.0 mg/L manganese, and pH in the range of 6.0 to 9.0, the conductance, iron and manganese concentrations at site 2 may be increased up to ten times that of premining conditions.

Violations of the regulations, such as direct addition of untreated discharge to Laurel Run, may produce pH as low as 3, acidity above 100 mg/L as $CaCO_3$, iron and manganese of more than 5 mg/L, sulfate above 100 mg/L, and conductances above 1000 μmho/cm at 25°C at site 2.

Sites 1 and 3 will probably show some effects of mining. However, this will only be contributed by runoff from spoil piles. As site 3 contributes 35 percent of site 4's discharge, some minor effects of surface runoff will also appear at site 4.

Site 2A, a tributary to Laurel Run, will be unaffected by this additional mining. Site 6 will also be unaffected, as it is upstream from the confluence of Coxes Creek with Laurel Run.

The general area (Sites 7-10) will be influenced by the acid mine drainage from Laurel Run, which contributes approximately 30 percent of the discharge to Coxes Creek. The actual mining discharge contributes only 0.3 to 3.0 percent to Coxes Creek at these sites and is diluted by water from Laurel and Bromm Runs. Therefore, the net effect of these contributing waters will be dilution of Coxes Creek, where constituent concentrations already far exceed those of any controlled contribution from the proposed mining site.

During reclamation, pyritic material (the overburden nearest the coal) will be placed in the bottom of the pit. Sandstone, the rest of the overburden, will be used to fill the pit. The subsoil will be moderately compacted on top of the sandstone, and then the topsoil will be put into place. This will help to seal the pyrite from air and water, agents that may combine to cause acidity. A cover will help to reduce infiltration of rainfall. Because of these procedures, major surface discharge into Laurel Run from the mine site will cease, and the impact of previous mining will be greatly reduced.

Biological Quality

If chemical water quality guidelines are adhered to (Office of Surface Mining Reclamation and Enforcement, 1979) during the premining, mining, and post-mining phases, they will prevent adverse effects on the biological communities found in the adjacent and general areas.

Suspended sediment from mining could last for a prolonged period, slowing down or possibly preventing the biological recovery of the adjacent and general areas, unless sediment ponds are built. Even before the affected area is cleared, a pond would probably be built in the lower southwest corner of the mine plan area. This pond and others will collect the sediment as it erodes during clearing and mining; thereby preventing prolonged damage to the biological system.

Ground Water

Levels

Ground-water levels near the mine would be lowered, resulting in destruction of the present water supply for residents north and west of the area.

The consequences of mining would be a progressive change in infiltration characteristics and ground water gradients. This change would occur as soil and weathered rock were removed during mining, exposing bare rock, and increasing runoff. Eventually, as the area was backfilled, infiltration rates would be increased. The material used to backfill the mine would probably transmit water to lower altitudes to discharge much more rapidly than the natural system, and water levels in the area would remain lowered.

Quality

The long-run effect of the mine would be a minor reduction in chemical quality of ground water downdip from the mine. Mining and backfilling would greatly increase the surface area of the disturbed rock and thereby increase "weathering," accelerating oxidation and solution of pyrite. Presumably, most of the subsurface movement of water would be through the backfilled material to discharge in Laurel Run at the south end of the mine, probably at a higher temperature than the present discharge to the Run.

SUMMARY AND CONCLUSIONS

The simplest and easiest part of the hydrologic information presentation for a mine permit is acquisition of current surface-water data. Measurements can be made in the field and samples collected for laboratory analysis at many locations. However, such data are useful only as an indicator of conditions at a single time.

Unless funds are available for test-well drilling, acquisition of current ground-water data is more difficult. Domestic and industrial wells in an area may be so scarce that an adequate data base is not available.

Techniques are available that allow generalization of surface-water flow. However, most of the techniques have not been tested for applicability to small areas, such as the mine-plan area common in Pennsylvania.

Techniques for generalizing and estimating seasonal variation in chemical and biological quality of surface waters and levels and quality for ground water are not sufficiently developed to be useful.

Similarly, techniques for predicting the effects of mining allow only general statements, and conflicting results of earlier studies make the validity of such predictions suspect.

The final regulations promulgated by the Office of Surface Mining contain such general terms as "seasonal variation" and "general area," which are difficult to quantify.

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