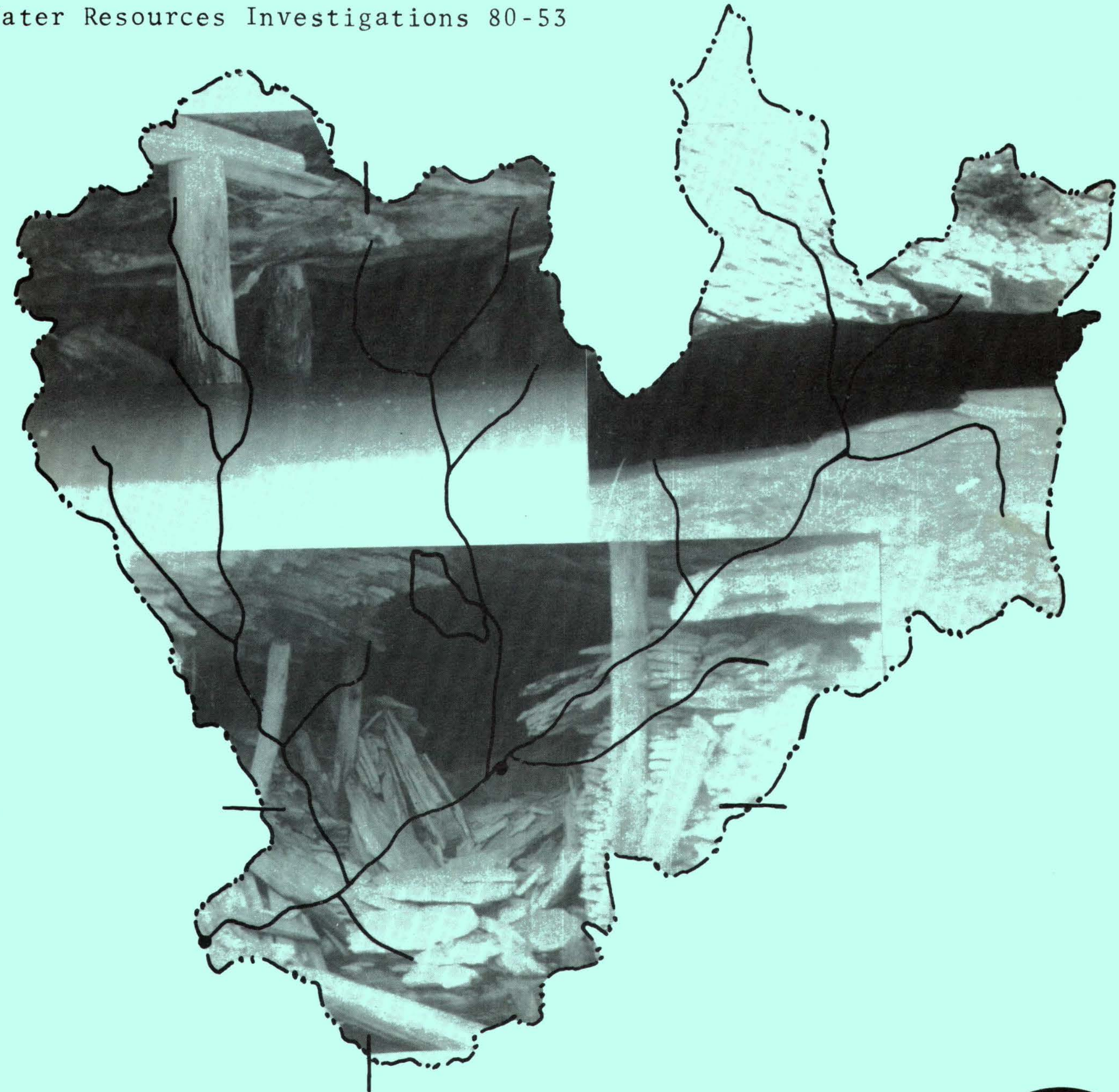
EFFECTS OF STRIP MINING THE ABANDONED DEEP ANNA S MINE ON THE HYDROLOGY OF BABB CREEK, TIOGA COUNTY, PENNSYLVANIA

U.S. GEOLOGICAL SURVEY

Water Resources Investigations 80-53



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Daylighting (strip mining of coal seams previously deep mined) operations are being conducted on the Anna S Mine, that underlies about 850 acres that are drained by three major discharges. The Hunter Drift drains an underground area of about 400 acres, the Anna S 1, main entry, an area of 330 acres, and Mitchel 2 discharge an area of about 120 acres. As of August 1, 1979, about 55 acres (15 percent) had been daylighted in the Hunter Drift basin, about 15 acres (5 percent) in the Anna S main entry basin and about 30 acres (25 percent) in the Mitchel basin.

The acidity of the Mitchel 2 discharge changed the most, from 176 milligrams per liter (as $CaCO_3$) in 1975-76 to 1,190 in 1978-79, an increase of 580 percent. The acidity of the Hunter Drift discharge increased from 348 milligrams per liter during 1975-76 to 710 milligrams per liter during 1978-79, an increase of 100 percent. The acidity of Anna S 1 increased about 45 percent.

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August 1980

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

H. William Menard, Director

For additional information write to:

U.S. Geological Survey
Federal Building
P.O. Box 1107
Harrisburg, Pennsylvania 17108

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Multiply foot-pound units	By	To obtain (SI) units
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
acre	0.4047	hectare (ha)
pound (lb)	0.454	kilogram (kg)
ton (short)	0.9072	metric ton (t)
acre-foot	1233	cubic meter (m^3)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
degree Fahrenheit (°F)	-32 x 5/9	degree Celsius (°C)

EFFECTS OF STRIP MINING THE ABANDONED DEEP ANNA S MINE ON THE HYDROLOGY OF BABB CREEK, TIOGA COUNTY, PENNSYLVANIA

By Lloyd A. Reed

ABSTRACT

The Anna S mine, that underlies about 850 acres drained by three major discharges, is being daylighted. The Hunter Drift drains an underground area of about 400 acres, the Anna S 1 main entry, an area of 330 acres, and Mitchel 2 discharge, an area of about 120 acres. Daylighting began in the section drained by the Mitchel discharge in the fall of 1976 and in the area drained by the Hunter Drift discharge in the winter of 1978. As of August 1, 1979, about 55 acres (15 percent) had been daylighted in the Hunter Drift basin, about 15 acres (5 percent) in the Anna S main entry basin, and about 30 acres (25 percent) in the Mitchel basin. About 30 percent of the area daylighted in the Mitchel basin has been regraded and reseeded. Only about half the daylighted area has been backfilled to date, leaving toxic spoils exposed to the air. The area that has not been daylighted is forested, and some timber has been harvested ahead of the mining operations.

Data collected since November 1977 indicate that the acidity of discharges from Mitchel 2 and Hunter Drift has increased significantly and that the acidity of the Hunter Drift is still increasing. The acidity of the Mitchel 2 discharge changed the most, from 176 milligrams per liter (mg/L) in 1975-76 to 1,190 in 1978-79, an increase of 580 percent. The Hunter Drift discharge acidity increased from 348 mg/L during 1975-76 to 710 mg/L during 1978-79, an increase of 100 percent. Acidity of Anna S 1 increased from 212 mg/L during 1975-76 to 307 during 1978-79, an increase of 45 percent; and that of Bridge Run decreased about 10 percent, from 118 mg/L during 1975-76 to 106 mg/L during 1978-79.

When the percentage increase in acidity is compared to the percentage of the area that has been daylighted, a general trend can be noticed. At Anna S 1, 5 percent was daylighted and acidities increased 45 percent; at Hunter Drift, 15 percent was daylighted and acidities increased 100 percent; at Mitchel 2, 25 percent was daylighted and acidities increased 580 percent. At Bridge Run, daylighting was not done and acidities decreased 10 percent.

INTRODUCTION

Babb Creek drains 129 mi^2 in southern Tioga County and enters Pine Creek at Blackwell. Parts of the basin are underlain by significant coal deposits, that were partly removed by deep mining between 1870 and 1920. Acid discharge from the deep mines exceeds the neutralization potential of Babb Creek during most of the year, so that the resultant pH at Blackwell (fig. 1) is normally less than 6.0. To reduce the amount of acid discharged from the underground mines, a process called daylighting has been proposed. This technique would remove most of the acid-producing coal left as pillars, collapse the underground passageways, and reduce the amount of air circulating underground. Much of deep mined areas of the Babb Creek basin can be daylighted, as the major coal seam is generally less than 80 feet under the surface.

This report presents water-quality data collected from November 1977 to September 1979 as part of a study to determine the effects of daylighting the Anna S mine complex. Data collection is continuing to determine any changes in flow and water quality from the Anna S mine caused by daylighting and in the water quality of Babb Creek.

The study is being conducted by the U.S. Geological Survey in cooperation with the U.S. Environmental Protection Agency. The Pennsylvania Department of Environmental Resources, Bureau of Surface Mine Reclamation, is providing technical support.

DESCRIPTION OF THE STUDY AREA

Babb Creek (fig. 1) drains a 129 mi^2 basin in north-central Pennsylvania. Altitudes range from 800 ft at the mouth of Babb Creek to 2,200 ft on some of the ridge tops. The basin is predominantly forest covered, except some areas along the north and southeast parts of the basin that are farmed. Most of the basin is underlain by shale and sandstone. Limestone is present along the north edge of the basin, and it is generally these areas that are being farmed. Only the northeast edge has been glaciated.

The climate is typical of interior northern Pennsylvania. Precipitation averages 37 inches per year and is fairly well distributed through the year. Temperatures range from 95°F during July or August to -20°F in January or February. About half of the precipitation in December, January, and February is snow.

COAL DEPOSITS

Several of the higher hills are underlain by coal deposits, and the larger, more accessible deposits have been deep mined. Figure 1 shows five areas that have been mined.

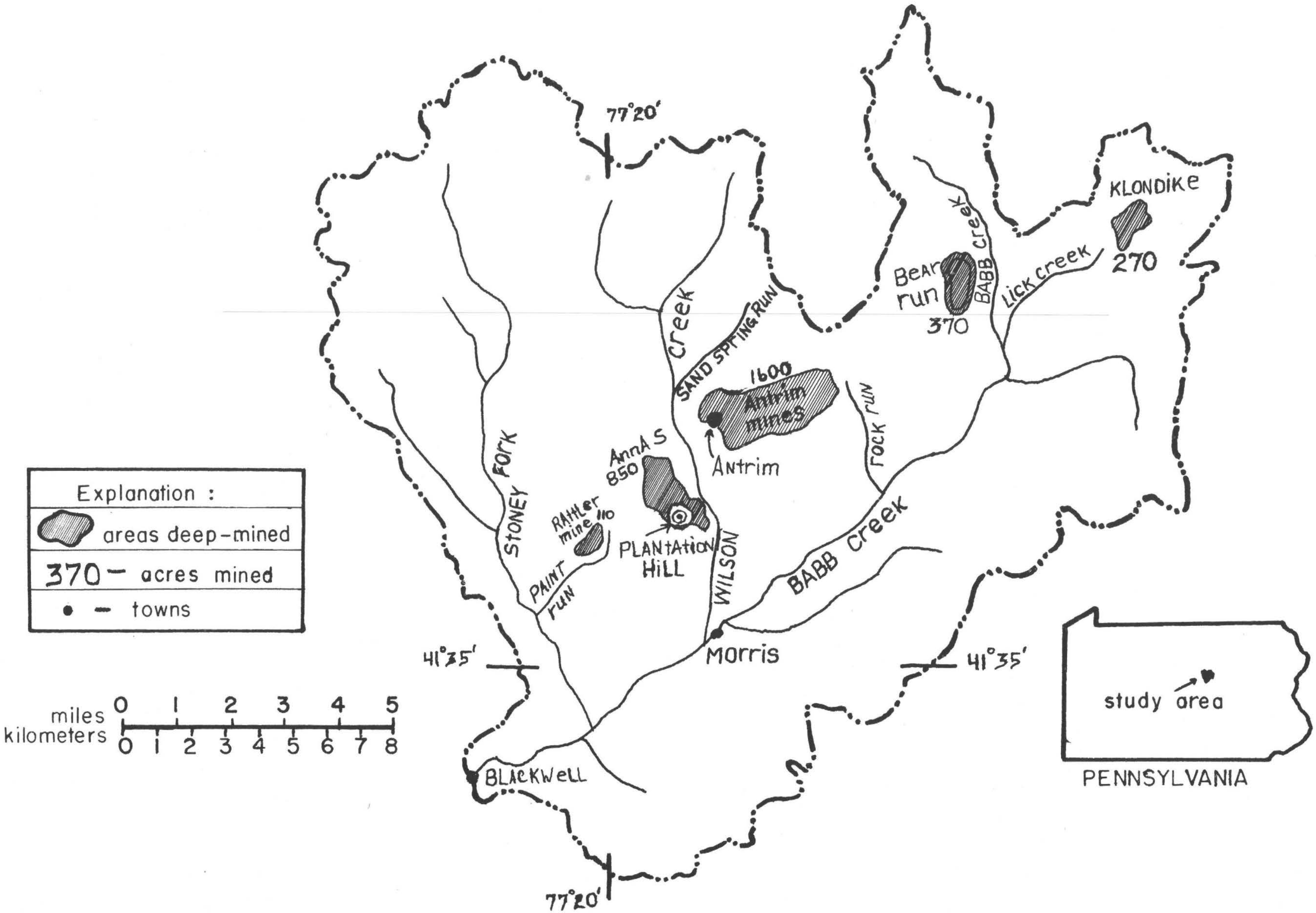

Figure 1.--Babb Creek basin showing the major streams and the areas that have been deep mined.

Most of the coal seams belong to the Allegheny Formation of Pennsylvanian age. They include the Rock (E Vein), Seymour, Morgan, Cushing, Bloss, and possibly the Bear Creek coal seam. There is some indication that the Bear Creek coal seam belongs to the underlying Pottsville Formation (Kantz and Associates, 1976). A schematic drawing of the coal seams found in the area is shown in figure 2. Not all seams are found in all areas. The Bloss coal, which has been the most extensively mined, was about 3 ft thick in most areas. Some was left in place as roof support pillars; however, extensive pillar removal was undertaken before the deep mines closed. The Seymour coal has been mined in some locations, mostly at the Antrim mine. The Morgan coal has been extensively mined at Antrim, but is not found in the Anna S mine. The Cushing coal, which lies below the Seymour coal, has also been mined at Antrim. The Bear Creek coal is generally 1 to 2 ft thick and is about 15 ft beneath the Bloss coal. The remaining Bloss pillars plus the Bear Creek coal make daylighting economically feasible in parts of the study area.

The rock above the Bloss coal and between the Bloss and Bear Creek coals is mostly shale containing pyrite. The soils are sandy loams of the Dekalb-Clymer group and are generally 2 to 6 ft thick. They have a low fertility. (See Higbee, 1967.)

DEEP MINES

The Anna S mine (fig. 1) is on a mountain 1 mi west of Antrim and includes about 850 acres. Nearly all the drainage from the Anna S mine enters Wilson Creek. The Antrim mine, just east of Antrim, is the largest. It includes about 1,600 acres, and most of its drainage enters Wilson Creek. The eastern areas of the Antrim mine drain into Rock Run, a tributary to Babb Creek.

The Rattler mine, west of the Anna S mine, includes 110 acres and drains into Paint Run, a tributary to Stony Fork. The Bear Run mine includes 370 acres and drains directly into Babb Creek. The Klondike mine includes about 270 acres and drains into Lick Creek, a tributary of Babb Creek. The Bear Run and Klondike mines are about 10 miles northeast of Antrim.

HISTORICAL WATER-QUALITY DATA

The water-quality survey at 12 sites on Babb Creek and its tributaries was made by the Pennsylvania Fish Commission on October 23-24, 1947, (Trembley written communication, 1948).

Babb Creek at Blackwell was sampled on July 22, 1970, (Barker 1972). Samples were also collected monthly, from all known mine discharges and the major streams, during 1975-76 as part of a study called Operation Scarlift (Kantz, 1976).

The recorded data (table 1) indicate that Wilson Creek at Morris and Babb Creek at Blackwell have been affected by acid discharges of about the same magnitude for an extended period. The pH of Babb Creek at Blackwell was approximately the same each time samples were collected. Acidity and alkalinity were determined on the samples collected in 1947 and 1975. The pH and acidity of Wilson Creek at Morris were determined in 1947 and 1975, and only slight differences were noted.

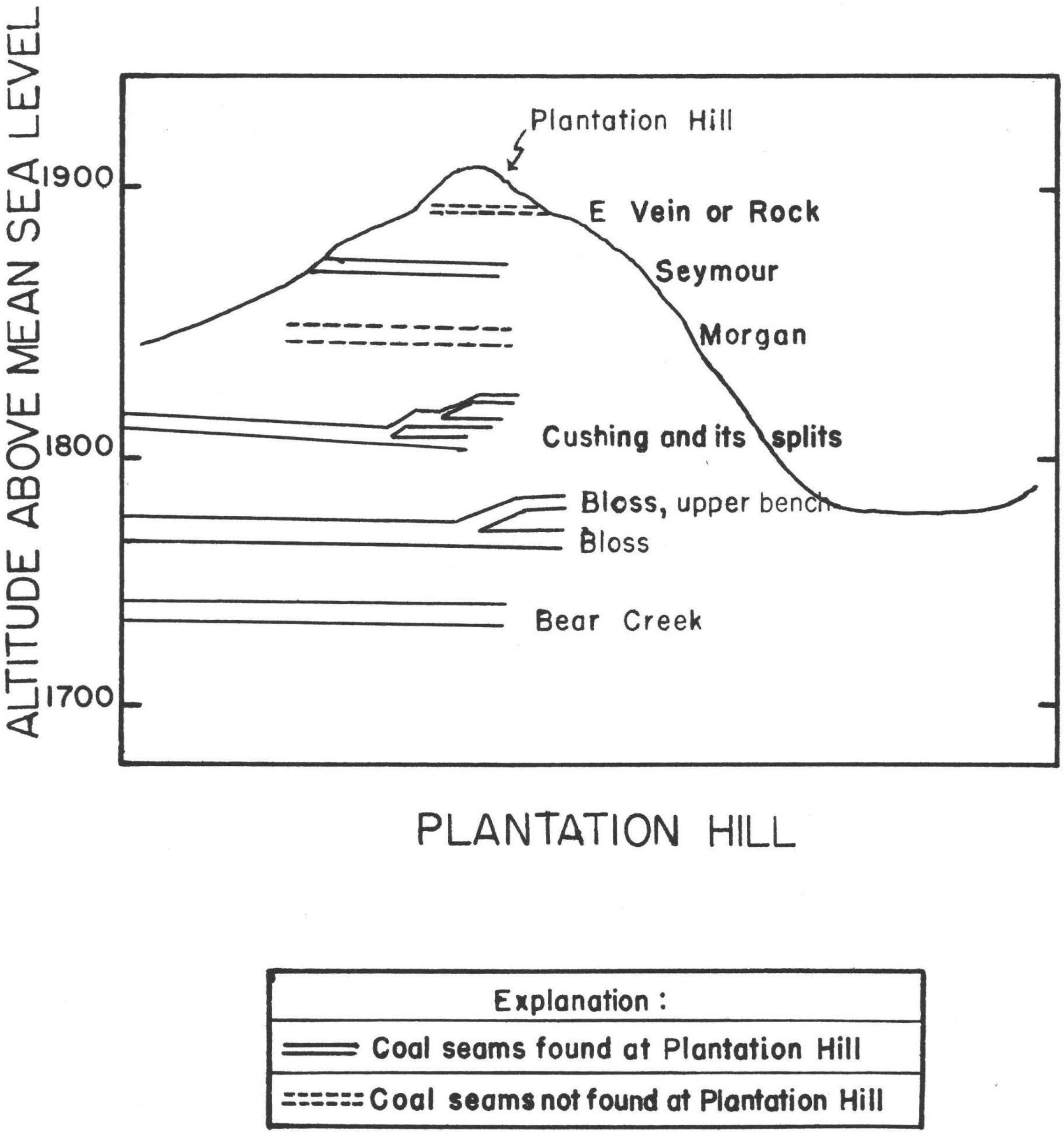

Figure 2.--Coal seams at Plantation Hill. Sketch also shows stratigraphic position of coal seams absent here, but present elsewhere in Babb Creek basin.

Table 1.--Summary of historical water-quality data for the Babb Creek basin, October 23, 1947, to August 5, 1975

Date	pH (units)	Acidity (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)
Babb Creek at Blackwell			
October 23, 1947	4.8	12	7
July 22, 1970	5.2	--	--
August 5, 1975	5.0	20	6
Wilson Creek at Morris			
October 23, 1947	3.2	100	
August 5, 1975	3.5	88	

DAYLIGHTING OPERATIONS

The Anna S mine, that underlies about 850 acres and has three major discharges (fig. 3) is being daylighted. Daylighting is the removal by surface mining of coal pillars and associated coal measures left in place during deep mining. The Hunter Drift drains an underground area of about 400 acres, the Anna S 1 main entry drains an area of 330 acres, and the Mitchel 2 discharge drains an area of about 120 acres. Daylighting (fig. 4) began in the section drained by the Mitchel discharge in the fall of 1976, and the area drained by the Hunter Drift discharge in the winter of 1978. From April to August 1979, neither site was mined. As of August 1, 1979, 55 acres (15 percent) had been daylighted in the Hunter Drift basin; 15 acres (5 percent) in the Anna S main entry basin; and 30 acres (25 percent) in the Mitchel basin. About 30 percent of the area daylighted in the Mitchel basin has been regraded and reseeded. As of August 1, 1979, only half the daylighted area in each of the basins had been backfilled, leaving toxic spoils exposed to the air. The area that has not been daylighted is forested, and some timber has been harvested ahead of the mining operations.

DATA COLLECTION

From November 2, 1977, until July 30, 1979, streamflow and water-quality data were collected from 16 sites in the Babb Creek basin. Figure 5 shows the data-collection points; types of data and frequency of collection are given in table 2.

Figure 6 is a sketch map of the Anna S mine, showing data-collection stations and the outcrop of the Bloss coal. The map also shows the extent of deep mining and the elevation of the coal.

The three largest discharges from the Anna S mine (Mitchel 2, Anna S 1, and Hunter Drift) were measured continuously with v-notch weirs and stage recorders, and water samples were collected monthly. At the remaining 11 sites, water discharge was measured according to techniques described in Corbett and others (1962) at the time of sample collection. The samples were analyzed immediately upon collection for pH, water temperature, specific conductance, alkalinity, and acidity (Brown and others, 1970). Alkalinity and acidity titration curves were plotted from the titration data so that alkalinity and acidity could be determined to any selected endpoints between 4.5 and 8.3. Monthly samples were analyzed in the USGS central laboratory for dissolved iron, manganese, and sulfate. Samples collected quarterly were analyzed for total iron and manganese and dissolved and total aluminum and zinc. Suspended sediment was analyzed in the Survey laboratory in Harrisburg, Pa.

A portable water-quality monitor was used for 3 months at one mine-discharge site and for 1 month at another. The data showed changes in water quality associated with changes in water discharges and storms.

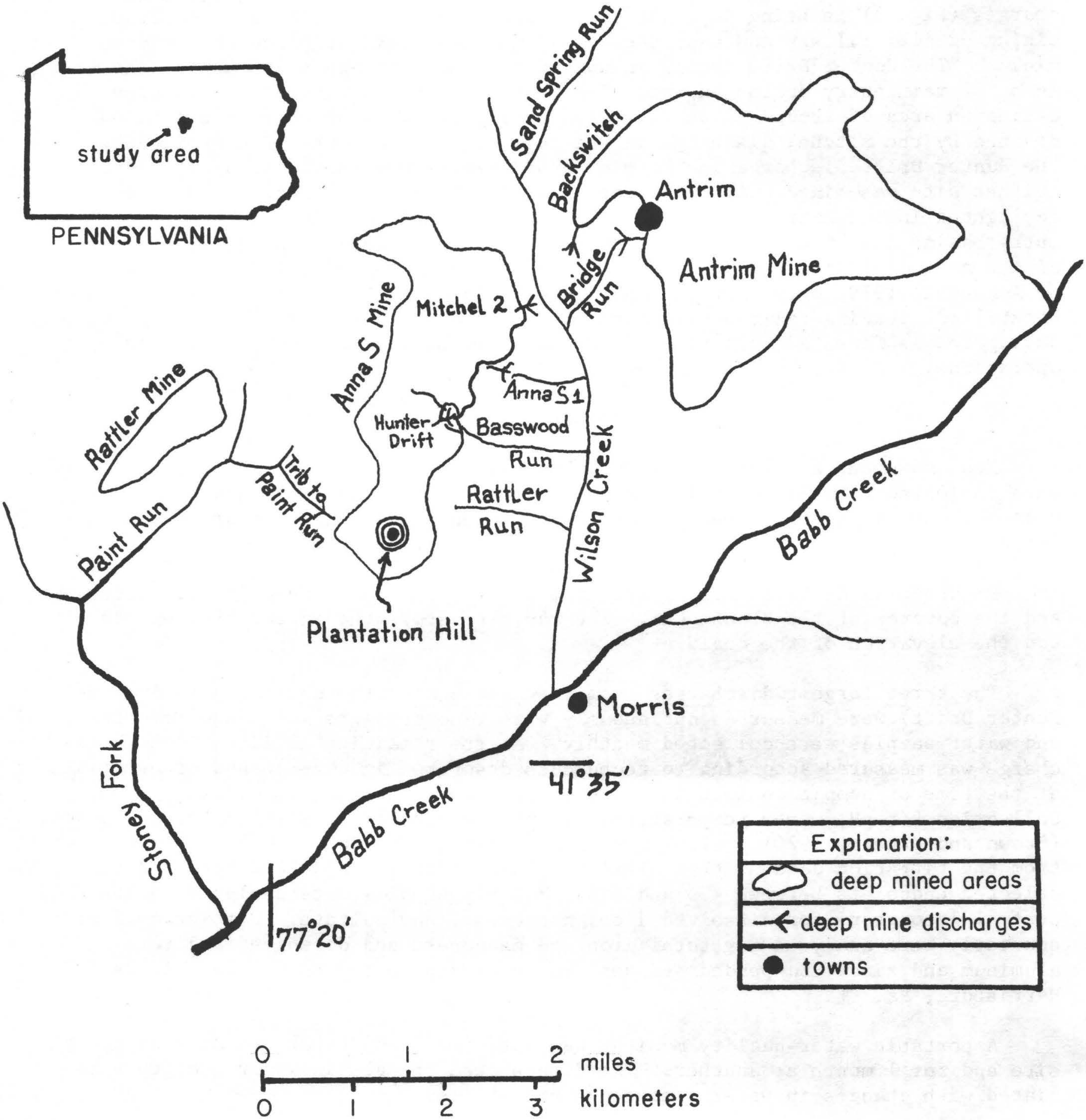

Figure 3.--Lower Wilson Creek basin showing the mined areas and the mine discharges.

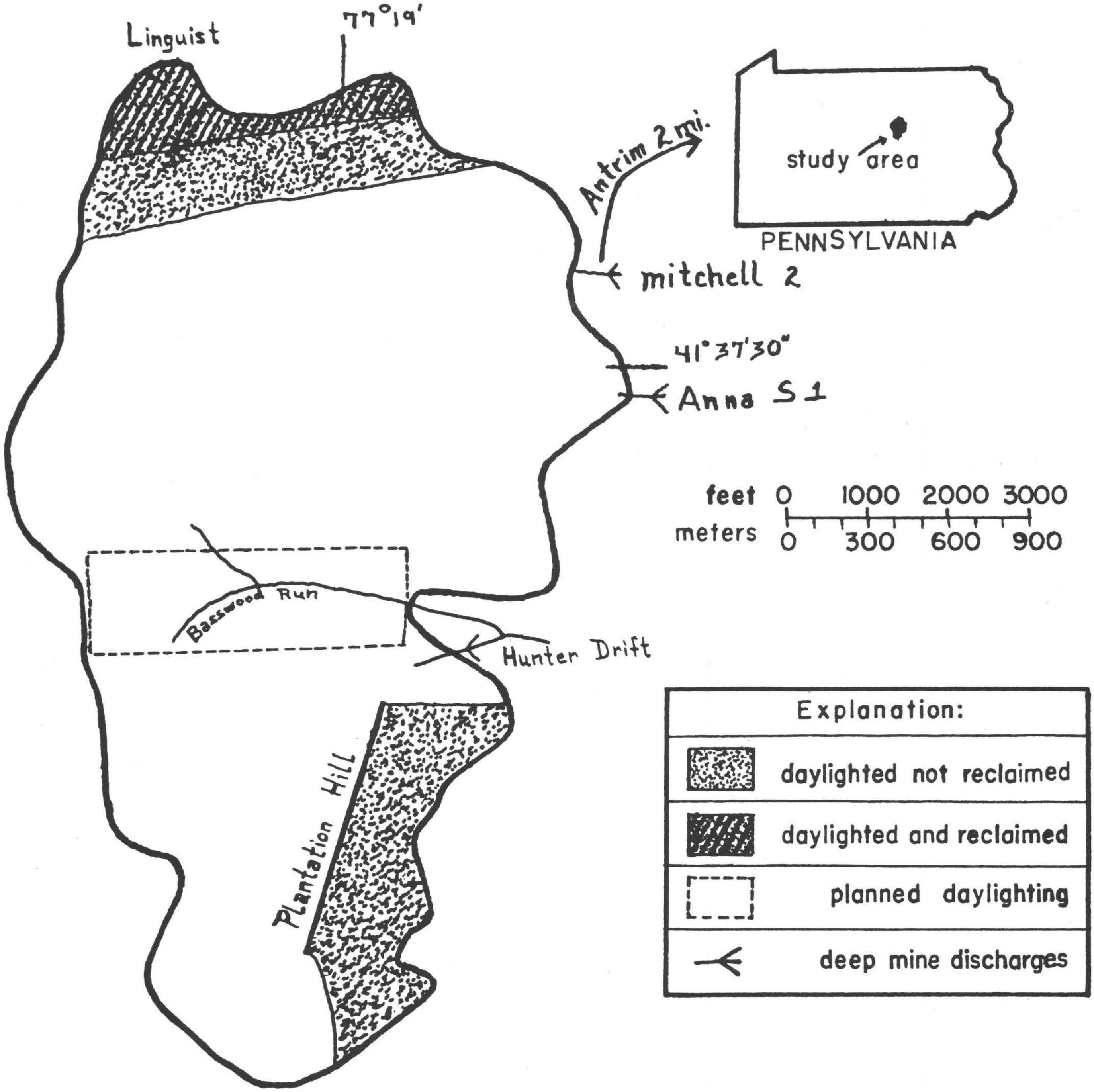

Figure 4.--Daylighted areas of the Anna S mine near Antrim, Pa., on August 1, 1979.

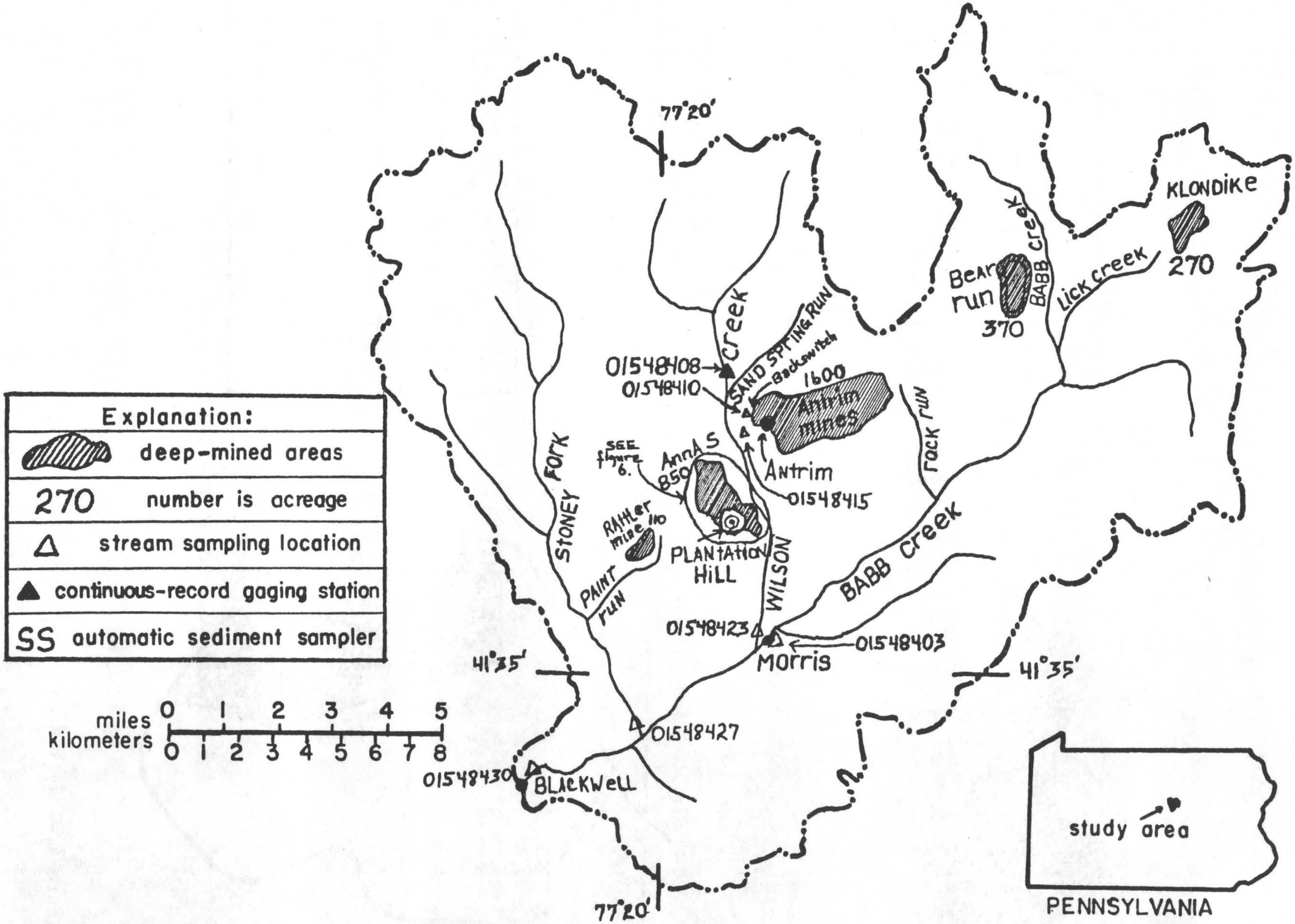

Figure 5.--Data-collection sites in the Babb Creek basin.

Table 2.--Mine discharge and stream sites where water-quality samples were collected

USGS Station Number	Station name	Drainage area (square miles)	Mine complex drained	Tributary to	Type of measurement: Monthly water quality	Continuous streamflow	Continuous suspended sediment
01548403	Babb Creek at Morris	53.0		Babb Creek at Blackwell	x		
01548408	Wilson Creek above Sand Spring Run	12.6		Wilson Creek at Morris	x	x	x
01548410	Backswitch Mine near Antrim		Antrim	do	x		
01548412	Mitchel 1 near Antrim		Anna S	do	x		
01548413	Mitchel 2 near Antrim	About 0.19	Anna S	do	x	x	
01548415	Bridge Run near Antrim	1.41	Antrim	do	x		
01548416	Anna S 1 near Antrim	About 0.52	Anna S	do	x	x	
01548417	Basswood Run above Hunter Drift near Antrim	0.57	Anna S	do		x	x
01548418	Hunter Drift near Antrim	About 0.63	Anna S	Basswood Run	x	x	
01548419	Anna S 2 near Antrim		Anna S	Basswood Run	x		
01548421	Basswood Run at Mouth near Antrim	1.22	Anna S	Wilson Creek at Morris	x		
01548422	Rattler Run near Morris	0.32	Anna S	do		x	x
01548423	Wilson Creek at Morris	22.8		Babb Creek at Blackwell	x		
01548425	Tributary to Paint Run		Anna S	Stoney Fork	x		
01548427	Stoney Fork near Blackwell	37.1		Babb Creek at Blackwell	x		
01548430	Babb Creek at Blackwell	129		Pine Creek at Blackwell	x		

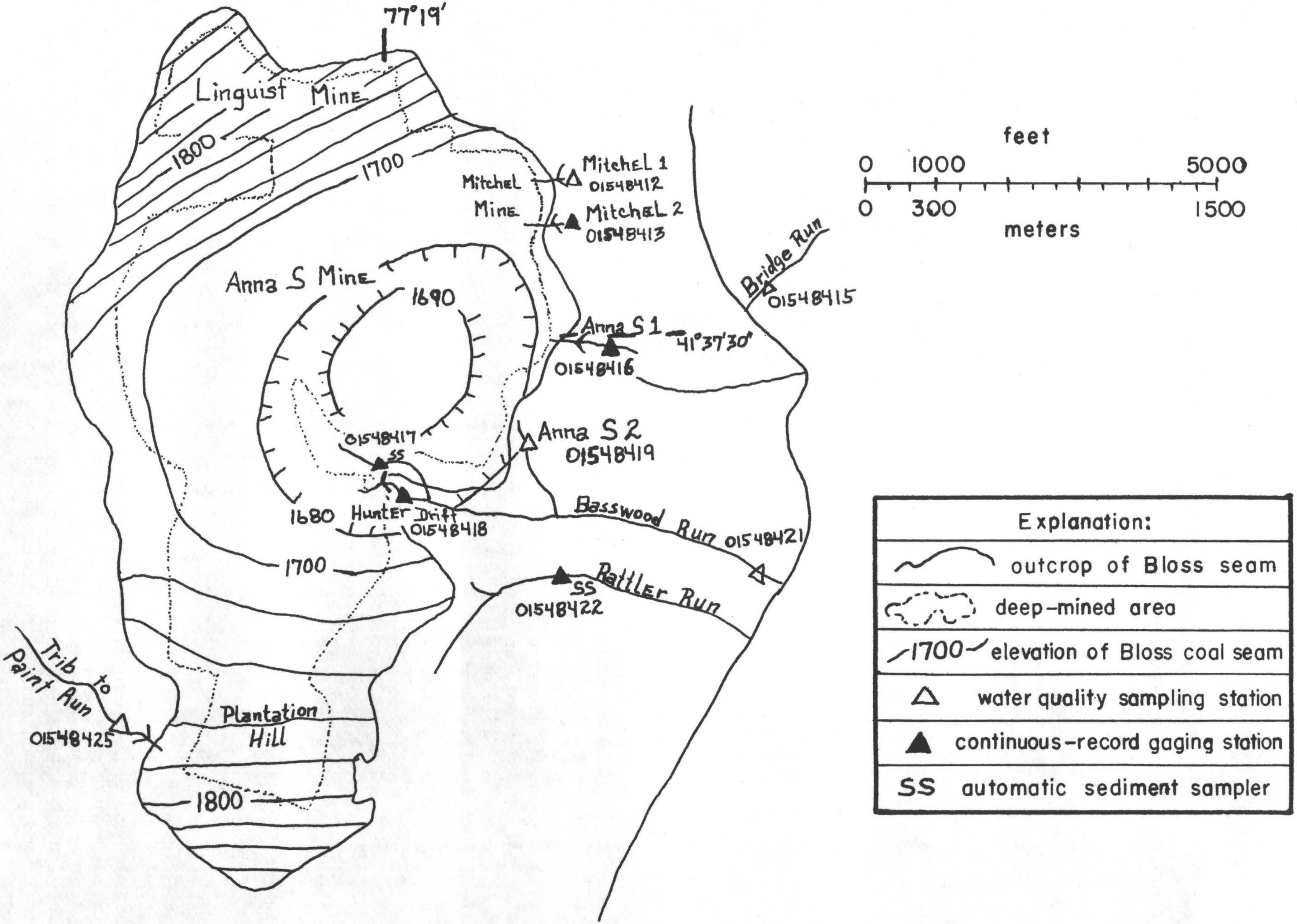

Figure 6.--Anna S mine showing the data-collection points.

BRIDGE RUN

Table 3 lists water discharge, pH, and concentrations and loads of sulfate, dissolved manganese and iron, and acidity as $CaCO_3$ for Bridge Run. Water discharge ranged from 1.3 to 8.1 ft^3/s, pH from 2.9 to 3.6, sulfate from 200 to 360 mg/L, dissolved manganese from 2.4 to 5.4 mg/L, dissolved iron from 3.3 to 7.6 mg/L, and acidity as $CaCO_3$ from 76 to 150 mg/L.

Relations between water discharge and concentrations of sulfate, dissolved manganese and iron, and acidity are shown in figure 7. The figure shows that concentrations of sulfate, dissolved manganese and iron, and acidity decrease as water discharge increases. The figure indicates that when water discharge from the Antrim mine increases 100 percent, concentrations of the four water-quality variables decrease about 20 percent and the transported loads increase about 60 percent. From figure 7, the ratio of sulfate to acidity as $CaCO_3$ is about 3 to 1; that of dissolved iron to dissolved manganese, 1.3 to 1; and that of sulfate to iron, 50 to 1.

MITCHEL 2

Table 4 lists the water discharge, pH, and concentrations and loads of sulfate, dissolved manganese and iron, and acidity as $CaCO_3$ for Mitchel 2. Water discharge ranged from 0.08 to 0.94 ft^3/s, pH from 2.4 to 2.8, sulfate from 390 to 2,300 mg/L, dissolved manganese from 9.6 to 71 mg/L, dissolved iron from 19 to 250 mg/L, and acidity as $CaCO_3$ from 260 to 1,690 mg/L.

Relations between water discharge and concentrations of sulfate, dissolved manganese and iron, and acidity are shown in figure 8. The figure shows that concentrations of sulfate, dissolved manganese and iron, and acidity decrease as water discharge increases. The figure indicates that when water discharge from Mitchel 2 increases 100 percent, concentrations of the four water-quality variables decrease about 30 percent, and the transported loads increase about 40 percent. From figure 8, the ratio of sulfate to acidity as $CaCO_3$ is about 1.7 to 1; that of dissolved iron to dissolved manganese, 2.8 to 1; and that of sulfate to iron, 12 to 1.

ANNA S 1

Table 5 lists water discharge, pH, and concentrations and loads of sulfate, dissolved manganese and iron, and acidity as $CaCO_3$ for Anna S 1. Water discharge ranged from 0.29 to 2.1 ft^3/s, pH from 2.6 to 3.0, sulfate from 300 to 600 mg/L, dissolved manganese from 3.2 to 12.0 mg/L, dissolved iron from 9.2 to 39 mg/L, and acidity as $CaCO_3$ from 200 to 390 mg/L.

Relations between water discharge and concentrations of sulfate, dissolved manganese and iron, and acidity are shown in figure 9. The figure shows that concentrations of sulfate, dissolved manganese and iron, and acidity are not closely related to water discharge. When water discharge from Anna S 1 increases, concentrations of the four water-quality variables remain about the same. This may indicate that a large quantity of acid water is stored within the mine, either as a pool or as unsaturated ground water. From figure 9, the ratio of sulfate to acidity as $CaCO_3$ is about 1.7 to 1; that of dissolved iron to dissolved manganese, 3.5 to 1; and that of sulfate to iron, 24 to 1.

Table 3.--Summary of water discharge, pH, and concentrations and loads of sulfate, dissolved manganese and iron, and acidity as $CaCO_3$ from Bridge Run near Antrim, November 2, 1977, to July 27, 1979

Date	Water discharge (ft^3/s)	pH (units)	Sulfate		Dissolved manganese		Dissolved iron		Acidity as $CaCO_3$	
			Concentration (mg/L)	Load (lb/d)	Concentration (mg/L)	Load (lb/d)	Concentration (mg/L)	Load (lb/d)	Concentration (mg/L)	Load (lb/d)
1977										
November 3	3.2	3.0	290	5,010	4.6	80	6.0	100	100	1,700
November 30	4.0	3.2	280	6,050	3.9	84	4.9	110	85	1,800
December 30	4.8	3.1	230	6,020	3.7	97	3.8	98	76	2,000
1978										
February 9	3.8	3.1	---	---	---	--	---	---	82	1,700
March 2	2.4	3.0	270	3,500	4.2	54	4.4	57	89	1,200
April 13	8.1	3.1	240	10,500	3.0	130	5.8	250	94	4,100
May 5	3.2	3.2	240	4,150	3.5	60	5.0	86	86	1,500
June 16	2.9	3.2	280	4,380	3.7	58	---	---	85	1,300
July 13	1.9	2.9	310	3,180	4.8	49	5.1	52	110	1,100
August 3	1.9	3.0	300	3,110	4.7	4.9	7.1	73	110	1,100
September 7	1.4	3.0	340	2,570	5.0	38	7.4	56	120	910
September 28	1.7	3.0	360	3,300	5.2	48	7.6	70	120	1,100
October 25	1.7	3.0	350	3,200	5.4	50	7.5	69	150	1,380
December 5	1.6	3.0	270	2,330	4.6	40	5.7	49	120	990
December 27	2.0	3.0	270	2,920	4.3	46	6.2	67	120	1,300
1979										
January 29	7.8	2.9	200	8,420	3.2	130	4.4	180	81	3,410
February 22	2.6	3.2	250	3,510	3.9	55	4.3	60	95	1,330
March 20	6.3	3.2	230	7,820	3.0	102	5.2	177	89	3,030
April 26	3.8	3.2	220	4,510	3.3	68	3.3	68	81	1,660
May 31	2.2	3.3	240	2,850	2.4	29	3.8	45	87	1,030
July 3	1.8	3.2	290	2,820	4.3	42	4.7	46	120	1,130
July 27	1.3	3.6	320	2,250	4.9	34	5.3	37	100	730

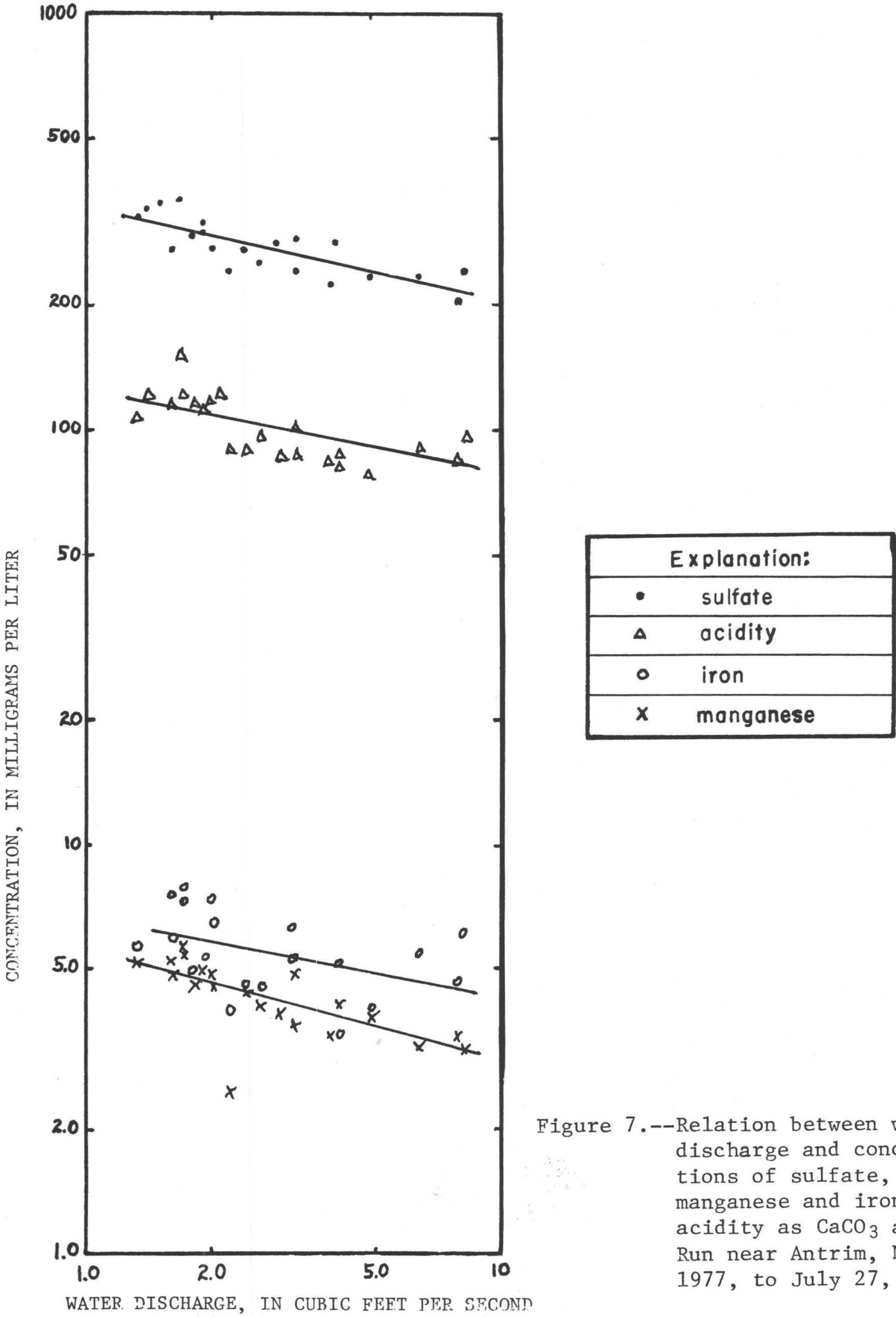

Figure 7.--Relation between water discharge and concentrations of sulfate, dissolved manganese and iron, and acidity as $CaCO_3$ at Bridge Run near Antrim, November 3, 1977, to July 27, 1979.

Table 4.--Summary of water discharge, pH, and concentrations and loads of sulfate dissolved manganese and iron, and acidity as $CaCO_3$ from the Mitchel 2 near Antrim, November 2, 1977, to July 27, 1979

Date	Water discharge (ft^3/s)	pH (units)	Sulfate Concentration (mg/L)	Sulfate Load (lb/d)	Dissolved manganese Concentration (mg/L)	Dissolved manganese Load (lb/d)	Dissolved iron Concentration (mg/L)	Dissolved iron Load (lb/d)	Acidity as $CaCO_3$ Concentration (mg/L)	Acidity as $CaCO_3$ Load (lb/d)
1977										
November 2	0.25	2.7	960	1,300	21.0	28	62	84	640	860
November 30	.26	2.7	670	940	17	24	29	41	410	580
December 29	.47	2.8	620	1,570	16	41	37	94	390	990
1978										
February 9	.25	2.7	720	970	18	24	44	59	450	610
March 1	.12	2.6	990	640	25	16	59	38	600	390
April 12	.75	2.9	390	1,580	9.6	39	19	77	260	1,100
May 4	.20	2.5	800	860	21	23	50	54	500	540
June 15	.31	2.4	1,400	2,340	42	70	130	220	960	1,600
July 13	.10	2.5	1,600	860	42	23	95	51	1,090	590
August 2	.12	2.4	1,900	1,230	55	36	77	50	1,260	820
September 7	.08	2.4	1,800	780	65	28	94	41	1,570	680
September 28	.10	2.4	2,300	1,240	71	38	250	140	1,690	910
October 25	.08	2.4	2,300	990	66	29	240	104	1,630	700
December 5	.13	2.6	1,800	1,260	55	38	180	126	1,200	840
December 27	.18	2.5	1,600	1,550	43	42	140	140	1,060	1,030
1979										
January 29	.94	2.7	1,300	6,600	50	250	120	610	840	4,260
February 23	.16	2.7	1,400	1,210	43	37	150	130	1,040	890
March 19	.87	2.6	1,100	5,170	31	150	90	420	700	3,280
April 25	.30	2.8	1,000	1,620	29	47	72	120	670	1,090
May 31	.26	2.6	1,500	2,110	--	--	--	---	1,050	1,470
July 2	.12	2.6	1,800	1,170	45	29	140	90	1,220	780
July 27	.10	2.6	2,000	1,080	66	36	170	92	1,550	840

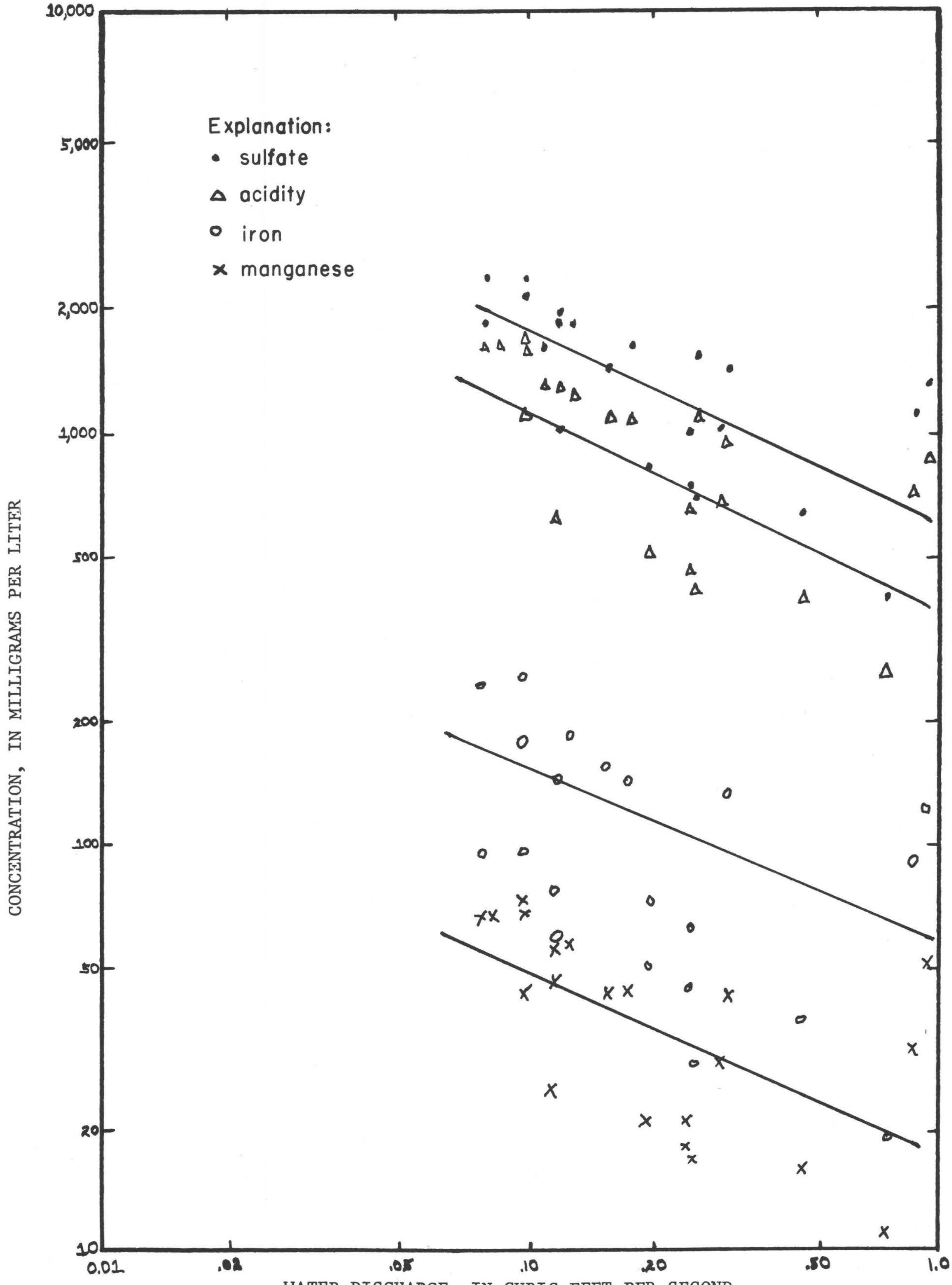

Figure 8.--Relation between water discharge and concentrations of sulfate, dissolved manganese and iron, and acidity as $CaCO_3$, at Mitchel 2 near Antrim, November 3, 1977, to July 27, 1979.

Table 5.--Summary of water discharge, pH, and concentrations and loads of sulfate, dissolved manganese and iron, and acidity as $CaCO_3$ from Anna S 1 near Antrim, November 3, 1977, to July 27, 1979

Date	Water discharge (ft^3/s)	pH (units)	Sulfate Concentration (mg/L)	Sulfate Load (lb/d)	Dissolved manganese Concentration (mg/L)	Dissolved manganese Load (lb/d)	Dissolved iron Concentration (mg/L)	Dissolved iron Load (lb/d)	Acidity as $CaCO_3$ Concentration (mg/L)	Acidity as $CaCO_3$ Load (lb/d)
1977										
November 3	1.1	2.8	350	2,080	3.4	20	16	95	270	1,500
December 1	1.3	2.9	320	2,250	3.2	22	12	84	230	1,600
December 29	1.4	3.0	360	2,720	5.2	39	17	130	230	1,700
1978										
February 9	1.1	2.8	360	2,140	5.3	31	18	110	230	1,400
March 1	.65	2.8	340	1,190	4.4	15	13	46	220	770
April 13	2.0	2.8	300	3,240	4.1	44	15	160	230	2,500
May 4	.90	2.8	300	1,460	4.0	19	14	68	200	970
June 15	.97	2.7	300	1,570	4.1	21	--	--	210	1,100
July 13	.42	2.9	340	770	3.6	8.2	9.2	21	200	450
August 2	.35	2.9	340	640	3.5	6.6	19	36	230	430
September 7	.35	2.8	450	850	7.0	13	22	42	310	590
September 29	.30	2.8	540	870	8.5	14	25	40	350	570
October 25	.29	2.8	480	750	8.1	13	25	39	340	540
December 4	.31	2.8	590	990	11.0	18	29	48	380	630
December 27	.64	2.7	560	1,940	9.4	32	32	110	390	1,350
1979										
January 29	2.0	2.9	600	6,480	12.0	130	39	420	390	4,210
February 23	.62	2.8	380	1,270	5.1	17	16	53	270	900
March 19	2.1	2.6	470	5,330	6.4	73	26	290	300	3,400
April 25	1.2	2.8	330	2,140	4.2	27	12	78	230	1,460
May 31	.64	3.0	350	1,210	9.5	33	11	38	240	810
July 2	.41	2.9	420	930	5.0	11	12	27	240	530
July 27	.39	2.9	380	800	5.3	11	13	27	260	540

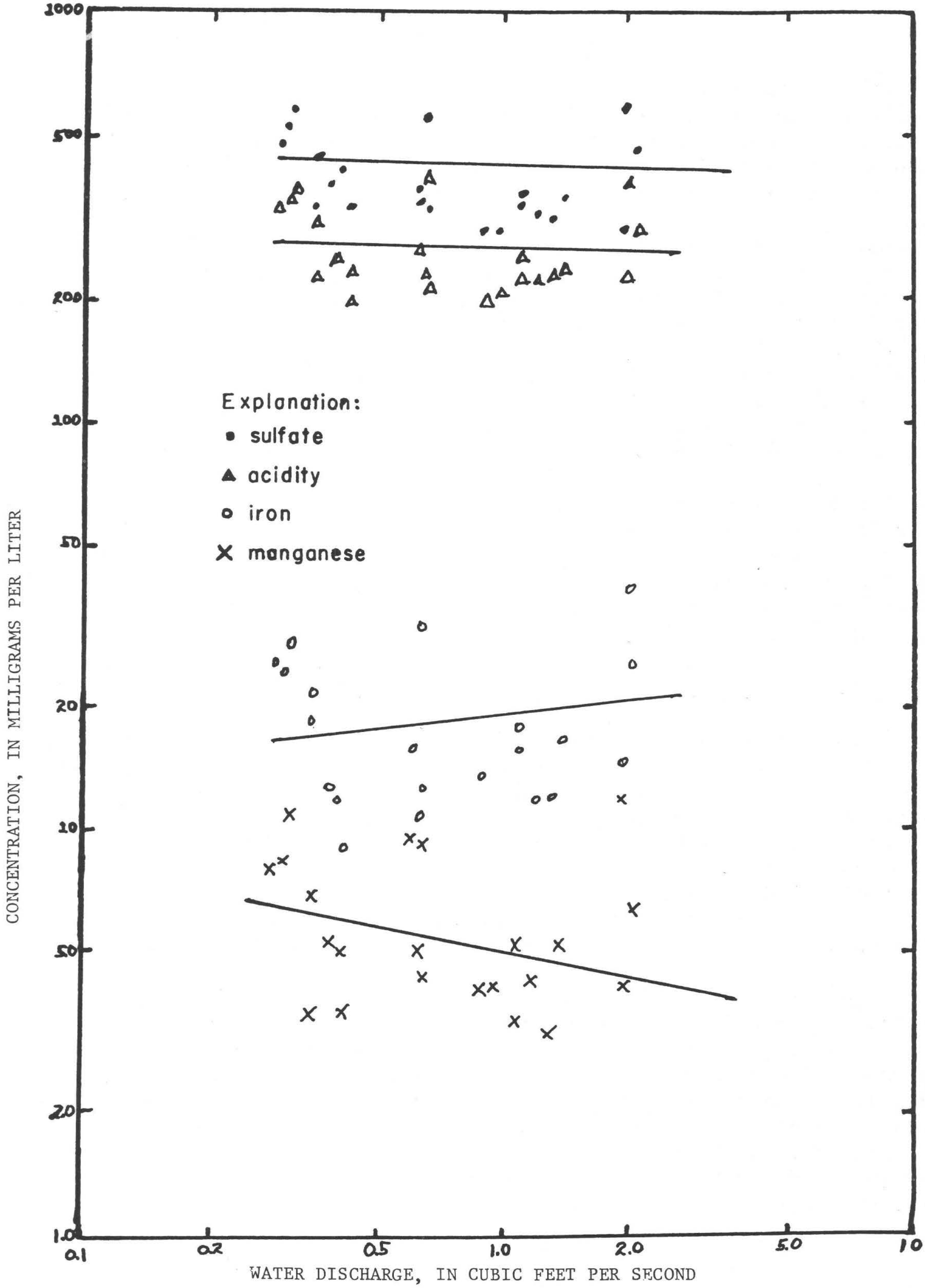

Figure 9.--Relation between water discharge and concentrations of sulfate, dissolved manganese and iron, and acidity as $CaCO_3$, at Anna S 1 near Antrim, November 3, 1977, to July 27, 1979.

HUNTER DRIFT

Table 6 lists water discharge, pH, and concentrations and loads of sulfate, dissolved manganese and iron, and acidity as $CaCO_3$ for Hunter Drift. Water discharge ranged from 0.31 to 2.2 ft^3/s, pH from 2.3 to 2.8, sulfate from 300 to 1,600 mg/L, dissolved manganese from 2.5 to 22 mg/L, dissolved iron from 22 to 210 mg/L, and acidity as $CaCO_3$ from 240 to 1,180 mg/L.

Relations between water discharge and concentrations of sulfate, dissolved manganese and iron, and acidity are shown in figure 10. The figure shows that concentrations of sulfate, dissolved manganese and iron, and acidity decrease as water discharge increases. The figure indicates that when water discharge from the Hunter Drift increases 100 percent, concentrations of the four water-quality variables decrease about 20 percent, and the transported loads increase about 60 percent. From figure 10, the ratio of sulfate to acidity as $CaCO_3$ is about 1.3 to 1; that of dissolved iron to dissolved manganese, 8 to 1; and that of sulfate to iron, 10 to 1.

Ratios of sulfate to acidity as $CaCO_3$, dissolved iron to dissolved manganese, and sulfate to iron for the four discharges are summarized on table 7. The largest variations in ratios involve iron. High sulfate to iron ratios may indicate that some iron is deposited before the flow reaches the surface or, in the case of Bridge Run, some iron may be deposited in the channel before the flow reaches the sampling point.

CHANGES IN WATER QUALITY

Figure 11 shows the acidity values in mg/L as $CaCO_3$ for Mitchel 2, Bridge Run, Anna S 1, and Hunter Drift plotted with respect to time. Data for the 1975 and 1976 period were collected by Kantz, and data since November 1977 were collected as part of this study. From figure 11, it can be seen that the acidity of Mitchel 2 and Hunter Drift are significantly greater than during the 1975-76 period and that the acidity of the Hunter Drift is still increasing. Acidity of the Mitchel 2 discharge was 1,550 mg/L on July 27, 1979, which is about 250 mg/L below the peak concentration measured during September 1978; however, the peak value for the year may not have been reached as of the July sampling.

Figure 11 also shows the effects that season has on acidity. For example, the acidity of Bridge Run ranged from 150 mg/L in October 1978 to 81 mg/L in April 1979. The acidity of the Mitchel 2 discharge ranged from 1,800 mg/L in September 1978 to 670 in April 1979. When acidity from the most recent 12 months (fig. 11) of data ending July 27, 1979, is compared to the data collected by Kantz (July 1975-June 1976), significant differences can be seen. Table 8 lists the mean acidities of Mitchel 2, Bridge Run, Anna S 1, and Hunter Drift for the periods July 1975-June 1976 and September 1978-July 1979, as well as the percentage of the basin that has been daylighted.

Table 6.--Summary of water discharge, pH, and concentrations and loads of sulfate, dissolved manganese and iron, and acidity as $CaCO_3$ from Hunter Drift near Antrim, November 3, 1977, to July 27, 1979

Date	Water discharge (ft^3/s)	pH (units)	Sulfate Concentration (mg/L)	Sulfate Load (lb/d)	Dissolved manganese Concentration (mg/L)	Dissolved manganese Load (lb/d)	Dissolved iron Concentration (mg/L)	Dissolved iron Load (lb/d)	Acidity as $CaCO_3$ Concentration (mg/L)	Acidity as $CaCO_3$ Load (lb/d)
1977										
November 3	1.2	2.8	500	3,240	3.6	23	46	300	410	2,700
December 1	1.4	2.7	400	3,020	3.2	24	28	210	310	2,300
December 30	1.7	2.7	410	3,760	3.4	31	32	290	330	3,000
1978										
February 9	1.2	2.6	420	2,720	3.6	23	35	230	310	2,000
March 1	.60	2.5	550	1,780	4.5	15	49	160	430	1,400
April 13	2.2	2.8	300	3,560	2.5	30	22	260	240	2,900
May 4	.78	2.7	430	1,810	3.8	16	38	160	320	1,300
June 15	1.2	2.5	420	2,720	3.9	25	30	190	320	2,100
July 13	.39	2.6	610	1,280	5.4	11	54	110	480	1,000
August 2	.40	2.6	700	1,510	6.7	14	56	120	550	1,200
September 7	.46	2.6	810	2,010	8.8	22	59	150	530	1,300
September 29	.47	2.7	820	2,080	8.7	22	78	200	610	1,500
October 25	.31	2.6	880	1,470	9.1	15	92	150	690	1,150
December 4	.32	2.6	900	1,560	8.8	15	100	170	850	1,460
December 27	.63	2.6	760	2,590	7.3	25	82	280	570	1,940
1979										
January 29	2.2	2.7	590	7,010	6.1	72	63	750	460	5,460
February 23	.55	2.6	970	2,880	15	45	100	300	660	1,960
March 20	2.0	2.7	740	7,990	14	150	72	780	530	5,720
April 25	1.2	2.8	720	4,670	13	84	74	480	560	3,630
May 31	.90	2.7	980	4,760	--	--	100	490	780	3,790
July 2	.57	2.8	1,400	4,310	22	68	190	580	1,100	3,380
July 27	.50	2.3	1,600	4,320	--	--	210	570	1,180	3,190

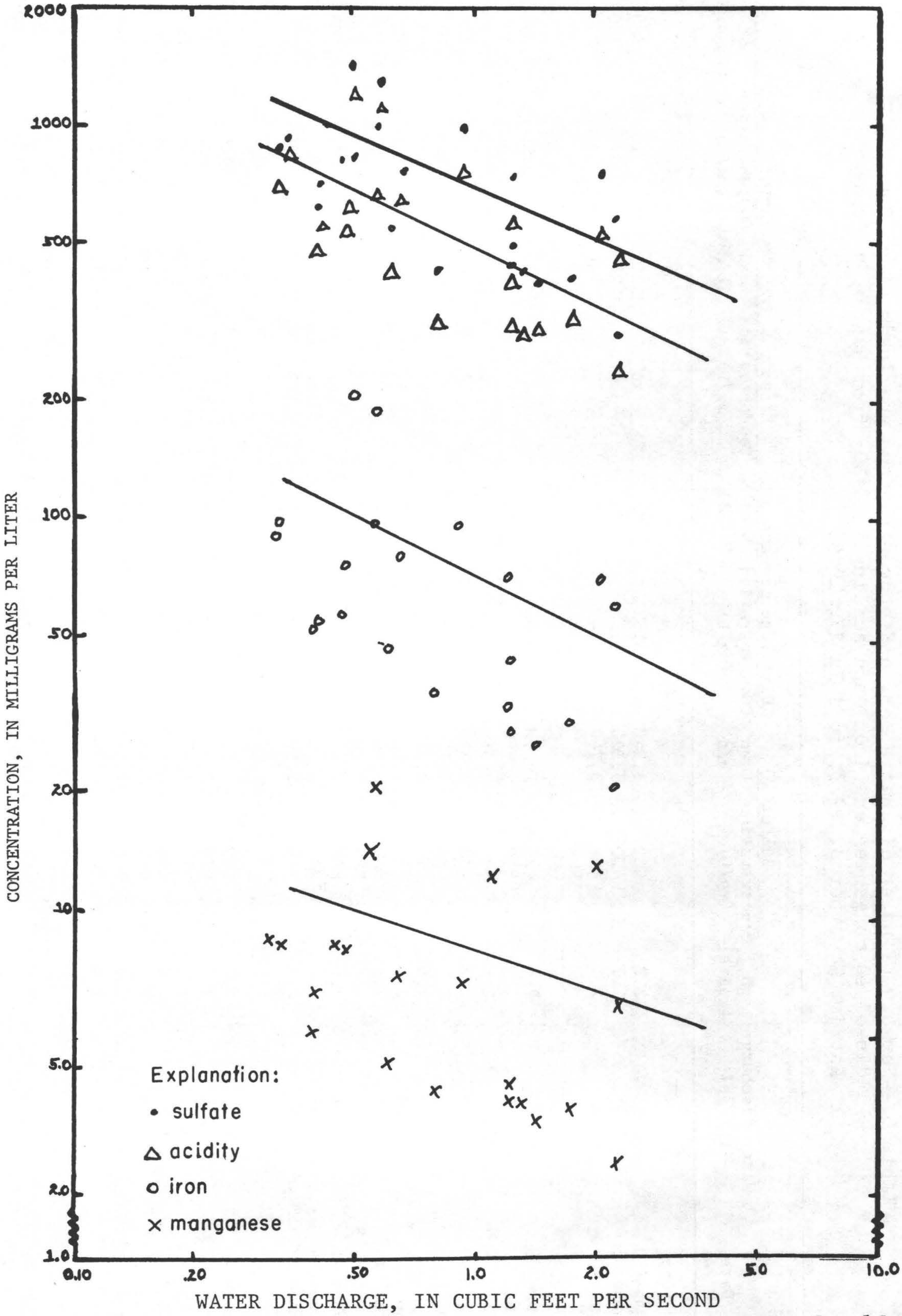

Figure 10.--Relation between water discharge and concentrations of sulfate, dissolved manganese and iron, and acidity as $CaCO_3$, at Hunter Drift near Antrim, November 3, 1977, to July 27, 1979.

Table 7.--Ratios of sulfate to acidity as $CaCO_3$, dissolved iron to dissolved manganese, and sulfate to iron for Bridge Run, Mitchel 2, Anna S 1, and Hunter Drift near Antrim, November 2, 1977, to July 27, 1979.

Site	Ratios		
	Sulfate to acidity	Dissolved iron to dissolved manganese	Sulfate to iron
Bridge Run	3:1	1.3:1	50:1
Mitchel 2	1.7:1	2.8:1	12:1
Anna S 1	1.7:1	3.5:1	24:1
Hunter Drift	1.3:1	8:1	10:1

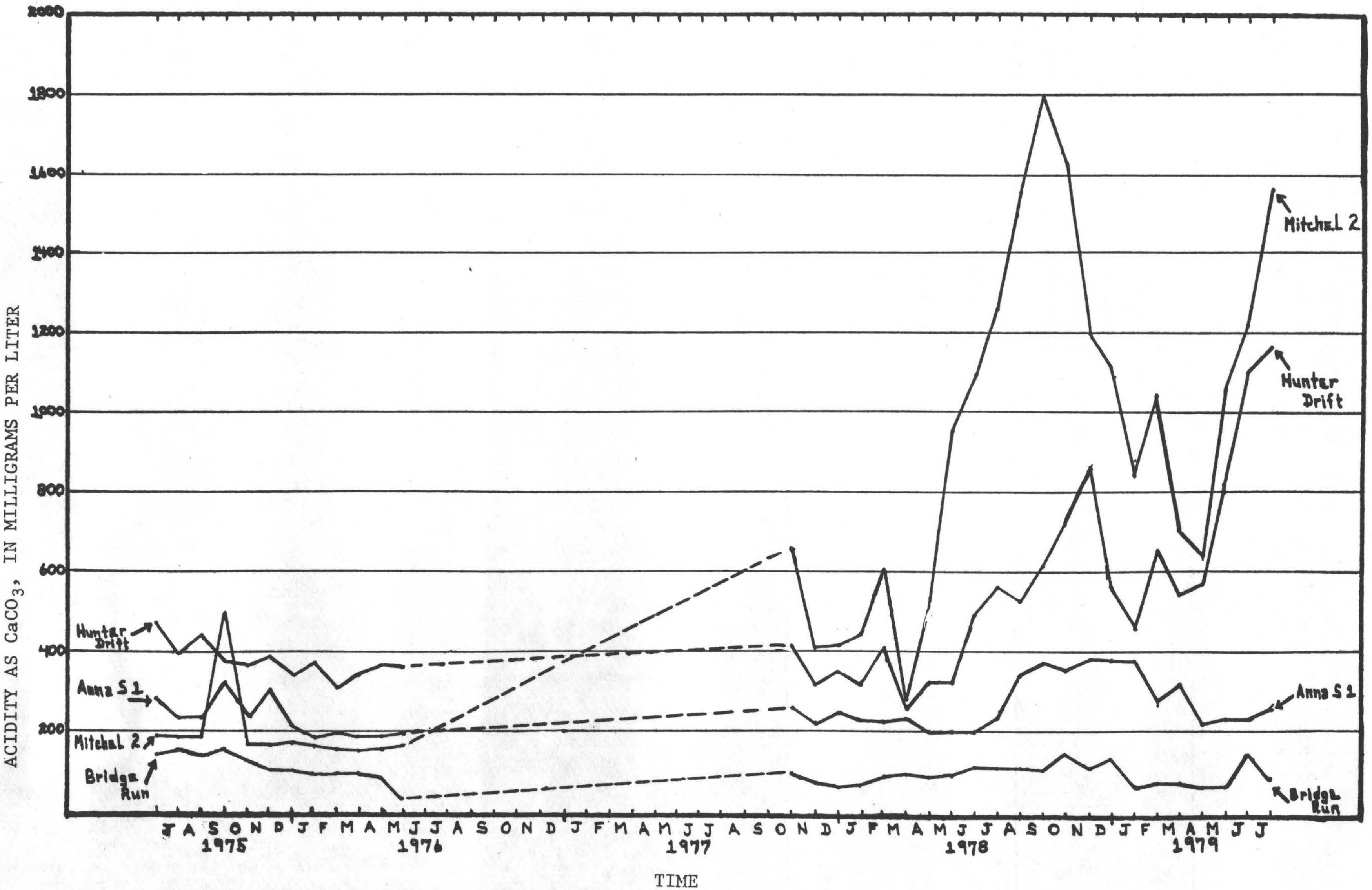

Figure 11.--Acidity values in milligrams per liter as $CaCO_3$ for Mitchel 2, Bridge Run, Anna S 1, and Hunter Drift mine discharges near Antrim, July 1975 to July 1979. (Data from 1975-76 was collected by Boyer, Kantz, for Operation Scarlift study.)

Table 8.--Mean acidity at Mitchel 2, Bridge Run, Anna S 1, and Hunter Drift near Antrim, for July 1, 1975, to June 15, 1976, and September 7, 1978, to July 27, 1979

	Mean acidities, in milligrams per liter as $CaCO_3$			
	Mitchel 2	Bridge Run	Anna S 1	Hunter Drift
1975-76	176	118	212	348
1978-79	1190	106	307	710
Percentage change	+580	-10	+45	+100
Percentage of basin daylighted	25	0	5	15

The acidity of the Mitchel 2 discharge changed the most, from an average of 176 mg/L in 1975-76 to an average of 1,190 in 1978-79, an increase of 580 percent. The acidity of the Hunter Drift discharge increased from an average of 348 mg/L during 1975-76 to an average of 710 mg/L during 1978-79, an increase of 100 percent. The acidity of Anna S 1 increased from an average of 212 mg/L during 1975-76 to an average of 307 during 1978-79, an increase of 45 percent. Acidity of Bridge Run decreased about 10 percent, from an average of 118 mg/L during 1975-76 to an average of 106 mg/L during 1978-79.

When the percentage increases in acidity are compared to the area that has been daylighted, a general trend can be noticed. At Bridge Run, daylighting was not done, and acidities decreased 10 percent, while at Mitchel 2, 25 percent was daylighted, and acidities increased 580 percent. The percentage of the basin that has been daylighted is plotted in figure 12 versus the mean acidity for the latest 12-month period. The figure indicates that as more of the area is daylighted, acidities increase. The percentages daylighted represent the percentage of the underground mines removed. Only small areas have been completely restored and revegetated, and significant areas of toxic spoils are still exposed. As the areas are restored, the acidity levels should decrease.

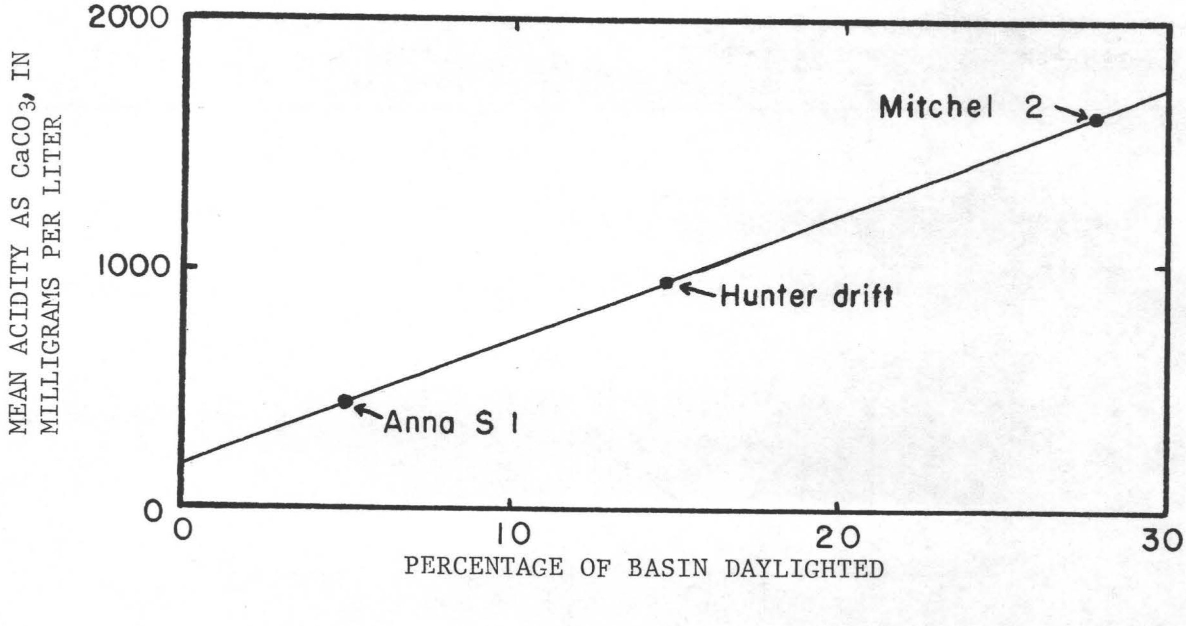

Figure 12.--Relation between percentage of the basin daylighted and mean acidity of the discharges, Mitchel 2, Anna S 1, and Hunter Drift near Antrim, September 7, 1978, to July 27, 1979.

In addition to the large seasonal variations in acidity, variations may also occur on a storm basis. During March 1-May 30, 1978, a portable water-quality monitor was operated at the Hunter Drift site. The water-quality monitor collected data every 30 minutes on pH, conductivity, water temperature, and dissolved oxygen. Stream discharge was also recorded from the Hunter Drift. During that period, discharge totaled 388 acre-feet. As the Hunter Drift may drain an area of about 400 acres, discharge from the Hunter Drift during March, April, and May 1978, amounted to about 11.6 in. of precipitation.

Precipitation was 11.3 in. during the 3-month period: 6.5 in. as snowmelt or rainfall from March 1 to April 4 and 4.85 in. from April 4 to May 30. Figure 13 shows the hydrograph and the daily mean specific conductance values.

From figure 13 it can be seen that water discharge from the Hunter Drift ranged from 0.5 ft^3/s on March 8 to 7.0 ft^3/s on March 24, 1978. Specific conductance ranged from 1,580 micromhos per centimeter on March 18 to 980 on April 9.

In most streams, conductance varies inversely with streamflow. Minimum levels of conductance generally correspond with peak streamflows. The lag time shown in figure 13 indicates that underground storage of mine water is sufficient to counteract the effects of dilution from precipitation. Most of the underground storage is probably unsaturated ground water above the mine floor, water in the process of perculating from the surface to the water table.

From figure 13, it can be seen that a second period of high discharge occurred during May. On May 13 and 14, 1978, precipitation totaled 1.93 in. Streams unaffected by mine drainage peaked about noon on May 14. The Hunter Drift discharge did not peak until late on May 15. Specific conductance of the Hunter Drift discharge did not vary significantly during the May storm. Because discharge from the Hunter Drift peaked as area streams receded it is apparent that the percentage of the streamflow made up of mine drainage may vary considerably.

NEUTRALIZATION AND DILUTION OF MINE DISCHARGE

Acid discharges from the Antrim and Anna S mines are partly neutralized and diluted by alkalinity and water discharge from Wilson Creek. The amounts of water discharge and alkalinity in Wilson Creek vary with the season and weather conditions. Because it is generally desirable to maintain the pH of a stream at 6.0 units or higher, the alkalinity in the streamflow available for neutralizing acid water can be determined by titrating samples of the streamflow to pH 6.0.

Figure 14 shows the relation between water discharge and the alkalinity concentration in mg/L as $CaCO_3$ and load in pounds per day. Alkalinity concentration is shown as milligrams per liter (mg/L) from the pH of the stream at the time of sampling to an endpoint of pH 6.0. The alkalinity load is also calculated to pH 6.0. As flow in Wilson Creek increases, the alkalinity in mg/L as $CaCO_3$ tends to decrease, but the alkalinity load (water discharge times alkalinity concentration) tends to increase. At a water discharge of 1 ft^3/s, the alkalinity available to pH 6.0 is 55 mg/L and the alkalinity load, 300 lb/d. At a water discharge of 10 ft^3/s, the alkalinity is 19 mg/L and the alkalinity load 1,070 lb/d. The neutralization potential of Wilson Creek is generally determined by the amount of streamflow. During periods of high flow, figure 14 shows that Wilson Creek can neutralize more acid discharge. However, except for peak flows during storms, increased flows in Wilson Creek were usually accompanied by increased mine discharges.

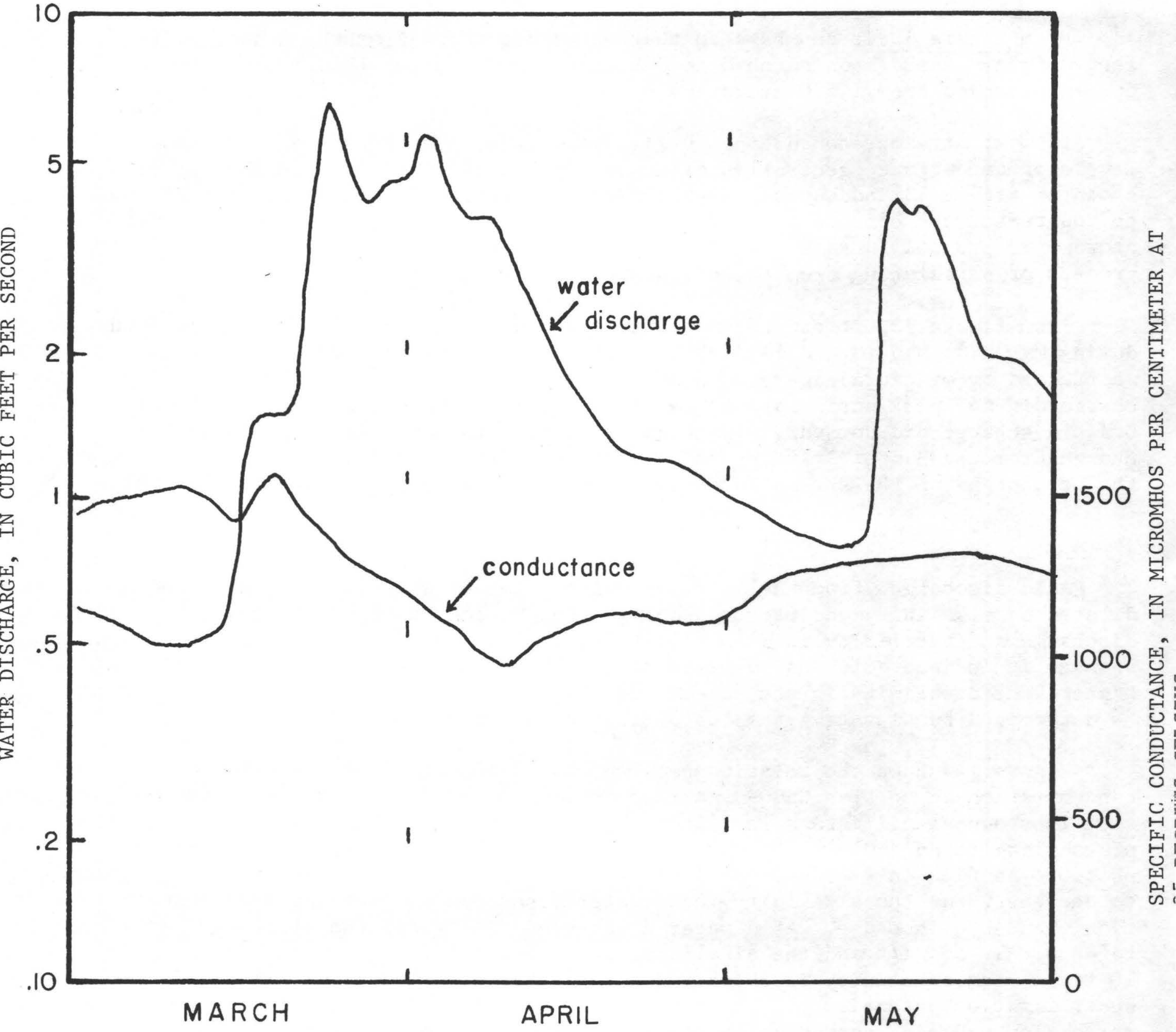

Figure 13.--Water discharge and specific conductance in micromhos per centimeter, Hunter Drift near Antrim, March 1 to May 31, 1978.

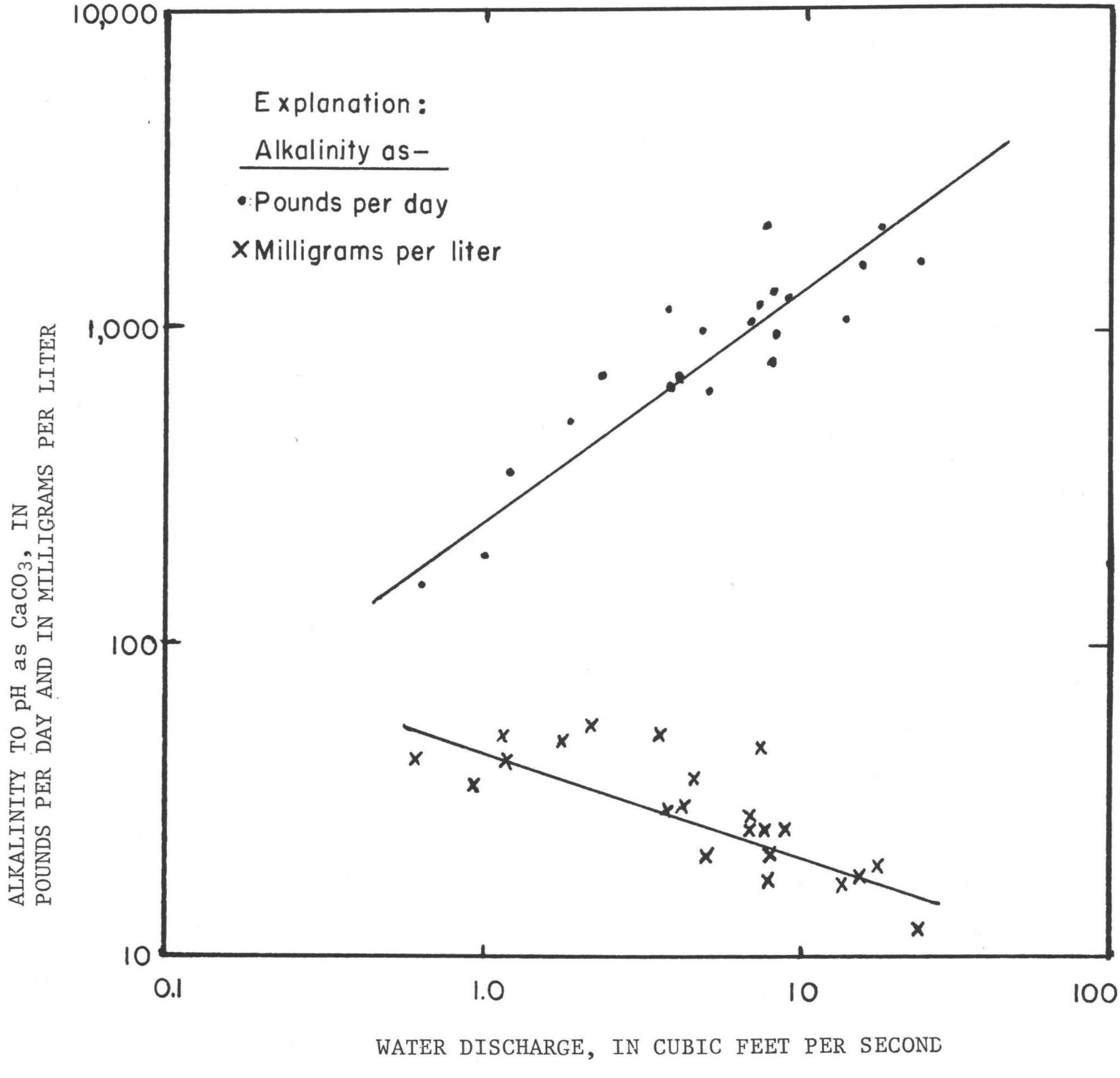

Figure 14.--Relation between water discharge and alkalinity, Wilson Creek above Sand Spring Run, near Antrim, November 3, 1977, to July 27, 1979.

During the summer, the ability of Wilson Creek to neutralize the inflowing acid load decreased to its lowest level because of reduced streamflow and alkalinity load. Table 9 lists the water discharge and available alkalinity of Wilson Creek above Sand Spring Run for the periods when samples were collected from November 2, 1977, to July 27, 1979. The alkalinity listed in the table is the alkalinity available when the samples were titrated from their initial pH to a pH of 6.0. The largest alkalinity load as $CaCO_3$ was calculated on January 29, 1979, and was 2,050 lb/d. The lowest alkalinity load calculated was 150 lb/d on July 13, 1978.

Table 9 also lists the acidity as $CaCO_3$ to pH 6.0 of the Bridge Run discharge from the Antrim mines and cumulative total acidities from the three major Anna S discharges. Generally, Wilson Creek did not have enough available alkalinity to neutralize the acid discharge from either the Antrim or the Anna S mine and maintain a pH of 6.0 during the periods when samples were collected.

Wilson Creek had the highest neutralization potential when samples were collected on December 27, 1978. Available alkalinity as $CaCO_3$ was 2,020 pounds per day (lb/d), acid discharge from Bridge Run was 1,180 lb/d, and acid discharge from the Anna S mine was 3,820 lb/d. On December 27, 1978, Wilson Creek was transporting enough alkalinity to neutralize 171 percent of the Bridge Run discharge, 53 percent of the discharge from the Anna S mine, or 40 percent of the combined discharge from Bridge Run and Anna S. Wilson Creek had the lowest neutralization potential on July 27, 1979. Available alkalinity was 190 lb/d, acid discharge from Bridge Run was 600 lb/d, and acid discharge from the Anna S mine was 3,990 lb/d. On July 27, 1979, Wilson Creek was transporting enough alkalinity to neutralize 32 percent of the acid discharge from Bridge Run, 5 percent of the acid discharge from the Anna S mine, or 4 percent of the combined discharge from Bridge Run and Anna S.

The neutralization potential of Wilson Creek is shown on figure 15. Water discharge from Wilson Creek above Sand Spring Run is plotted against the percent of the acid discharge that it can neutralize to pH 6.0. From the graph, it can readily be seen that as discharge in Wilson Creek increased the neutralization potential also increased. An extrapolation of the relation between discharge and available alkalinity to pH 6.0 in Wilson Creek (fig. 15) also shows that neutralization of the acid discharges would require a streamflow of at least 100 ft^3/s. As the drainage area of Wilson Creek is only 12.6 mi^2, a discharge of 8 $(ft^3/s)/mi^2$ would be required, and flows of this magnitude are not normally maintained for long periods.

WATER QUALITY OF BABB CREEK AT BLACKWELL

The pH of Babb Creek at Blackwell is normally less than 6.0. Table 10 lists the results of monthly samples collected between November 4, 1977, and July 2, 1979. Of the 21 times when samples were collected, the pH was less than 6.0 on 13 occasions. Acidities to pH 6.0 were greater than 1.0 mg/L on eight occasions, four during 1978 and four during 1979. The increased acid discharges, noted earlier, from the Anna S mine have not had a readily detectable impact on Babb Creek at Blackwell.

Table 9.--Neutralization potential of Wilson Creek above Sand Spring Run, and the acidities of the major mine discharges, November 2, 1977, to July 27, 1979

	WILSON CREEK		BRIDGE RUN			COMBINED DISCHARGES FROM THE ANNA S MINE		
Date	Water discharge (ft^3/s)	Available alkalinity as $CaCO_3$ to pH 6.0 (lb/d)	Water discharge (ft^3/s)	Acidity as $CaCO_3$ to pH 6.0 (lb/d)	Percentage of Bridge Run discharge that can be neutralized to pH 6.0	Water discharge (ft^3/s)	Acidity as $CaCO_3$ to pH 6.0 (lb/d)	Percentage of discharge from Anna S mine that can be neutralized to pH 6.0
1977								
November 2, 3	7.1	1,070	3.2	1,490	72	2.5	4,170	26
November 30	9.1	1,280	4.0	1,620	79	2.0	3,890	33
December 29, 30	14.2	1,330	4.8	1,670	80	3.6	4,790	28
1978								
February 9	8.2	800	3.8	1,440	55	2.5	3,410	23
March 1, 2	4.0	650	2.4	970	67	1.4	2,180	30
April 12, 13	24.2	1,570	8.1	3,500	45	5.0	5,390	29
May 3, 4, 5	5.3	630	3.2	1,300	48	1.9	2,540	25
June 15, 16	4.0	670	2.9	1,130	60	2.5	4,190	16
July 13	.65	150	1.9	1,010	15	.91	1,760	9
August 2, 3	1.2	280	1.9	1,020	27	.87	2,090	13
September 7	1.2	360	1.4	790	45	.89	2,120	17
September 28, 29	1.9	500	1.7	950	53	.87	2,620	19
October 25	2.4	710	1.7	1,190	60	.68	2,070	34
December 4, 5	8.4	1,270	1.6	920	138	.76	2,460	52
December 27	7.8	2,020	2.0	1,180	171	1.4	3,820	53
1979								
January 29, 30	19.0	2,050	7.8	3,120	66	5.1	11,600	18
February 22, 23	4.8	980	2.6	1,130	87	1.3	3,120	31
March 19, 20	16.0	1,560	6.3	2,650	59	5.0	10,500	15
April 24, 25, 26	7.5	1,130	3.8	1,440	78	2.7	5,310	21
May 31	8.2	930	2.2	910	102	1.8	4,980	19
July 2, 3	3.8	1,070	1.8	930	115	1.1	3,960	27
July 27	1.0	190	1.3	600	32	.99	3,990	5

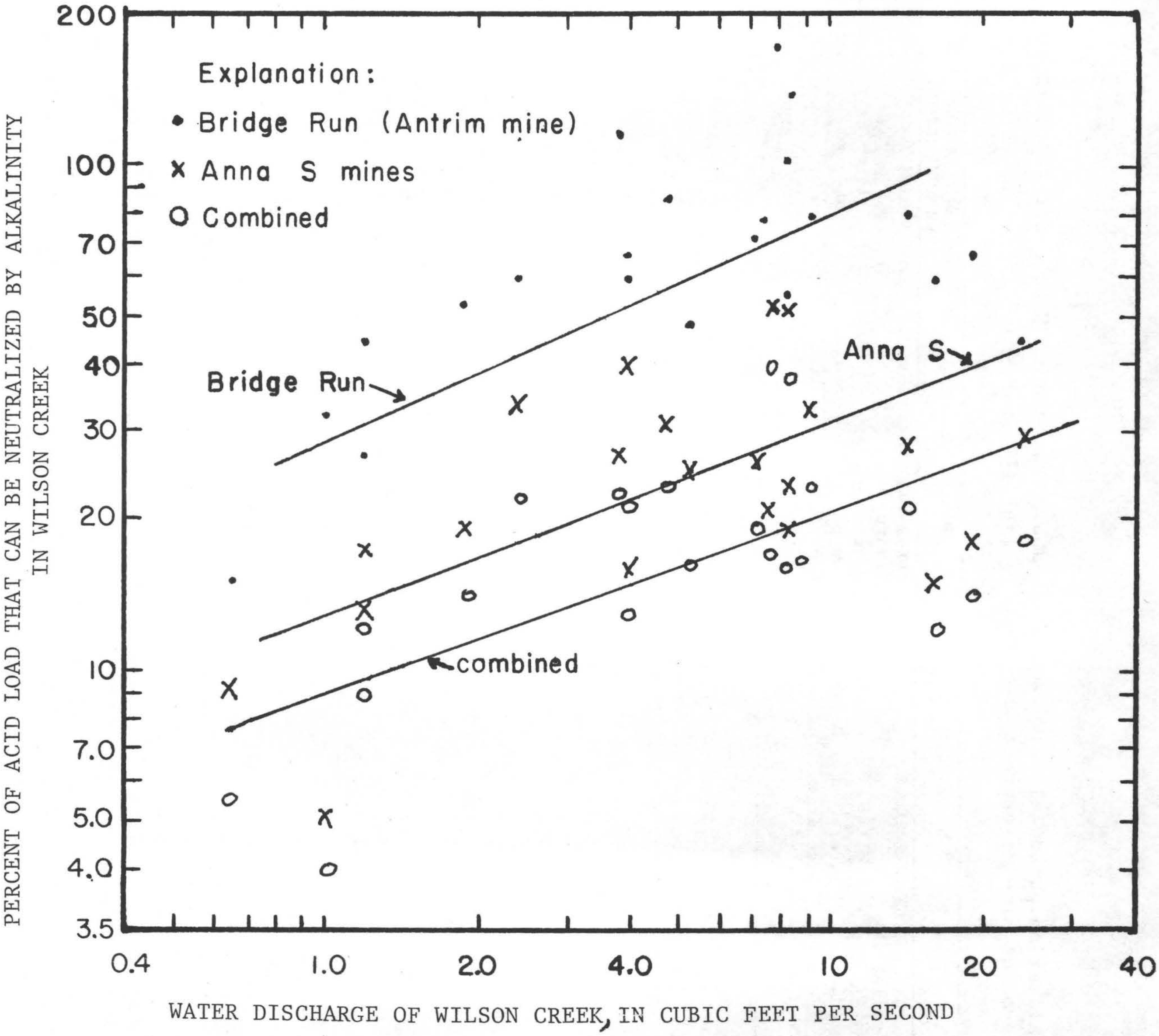

Figure 15.--Relation between water discharge of Wilson Creek above Sand Spring Run and the capacity of Wilson Creek to neutralize the acid inflow, November 2, 1977, to July 27, 1979.

Table 10.--Summary of water discharge, pH, surplus (+) or deficiency (-) of alkalinity as milligrams per liter of $CaCO_3$ to pH 6.0, and concentrations of sulfate, and dissolved iron and manganese, Babb Creek at Blackwell, November 4, 1977, to July 2, 1979

Date	Discharge (ft^3/s)	pH (units)	Surplus (+) or deficiency (-) of alkalinity as $CaCO_3$ to pH 6.0 (mg/L)	Sulfate (mg/L)	Iron (mg/L)	Manganese (mg/L)
1977						
November 4	541	6.4	+2.2	36	0.00	0.43
December 1	620	7.0	+7.0	21	.05	.20
December 30	160	5.8	- .4	33	.15	.40
1978						
February 10	120	5.6	- .4	38	.16	.41
March 1	83	5.9	- .4	41	.32	.44
April 14	319	5.3	-1.6	30	.27	.32
May 4	89	5.4	-1.0	37	.11	.44
June 16	97	5.6	- .8	38	---	.44
July 13	20	4.9	-3.4	59	.04	.60
August 3	28	6.5	+1.0	60	.31	.53
September 7	18	6.2	+ .4	67	.08	.68
September 29	21	5.5	-1.4	71	.04	.81
October 25	30	7.1	+2.4	69	.26	.64
December 5	132	6.8	+6.0	32	.02	.38
December 27	80	6.2	+ .8	42	.09	.56
1979						
January 30	303	5.1	-4.4	38	.44	.52
February 22	56	5.2	-6.6	50	.05	.62
March 20	292	5.2	-3.8	35	.11	.48
April 24	230	5.5	-1.4	40	.21	.48
May 31	158	6.1	+ .2	36	.10	.55
July 3	63	6.7	+1.6	47	.02	.84

Sulfate and dissolved manganese do not precipitate readily and remain in solution at the pH levels measured at Blackwell. Figure 16 shows the relation between water discharge of Babb Creek at Blackwell and concentrations of sulfate and dissolved manganese. Data from the first year of sampling are plotted separately from that for the second year of sampling. Differences can be seen in the relation between water discharge and the concentration of manganese, indicating higher concentrations of manganese during the last year of sampling. Similar differences are not apparent in the relation between water discharge and the concentration of sulfate. At the times when samples were collected, the amount of alkalinity as $CaCO_3$ required to provide a minimum pH of 6.0 ranged (table 11) from a deficiency of 7,200 lb/d to a surplus of 4,300 lb/d. The median deficiency was 370 lb/d.

Sulfate concentrations of samples collected from Babb Creek at Blackwell (table 12) ranged from 30 to 71 mg/L, and the discharge of sulfate load ranged from 6,400 to 62,000 lb/d. Most of the sulfate load was discharged by Wilson Creek at Morris.

Concentrations and loads of dissolved manganese are shown on table 13. Concentrations of manganese in samples collected from Babb Creek at Blackwell ranged from 0.32 to 0.81 mg/L and loads of manganese from 65 to 850 lb/d. Most of the manganese load was discharged by Wilson Creek at Morris.

SUSPENDED SEDIMENT

Suspended-sediment discharge was measured at three sites equipped with automatic samplers (figs. 5 and 6). Wilson Creek above Sand Spring Run (01-5484.08) was sampled to determine sediment loads transported from the area unaffected by mining. A station was located on Basswood Run just upstream from the Hunter Drift to collect streamflow and suspended-sediment discharge data from a forested area before, during, and after daylighting.

A third streamflow and suspended-sediment sampling station was located on Rattler Run. Runoff from 0.3 miles of improved haul road drained into Rattler Run above the sampling location. Average traffic on this section of road was about 120 heavy trucks and 25 light trucks per day.

Suspended-sediment yields in Wilson Creek above Sand Spring Run averaged 120 tons per square mile per year $(tons/mi^2)/yr$. Eighty percent of the time the suspended-sediment concentration was less than 5 mg/L. The highest daily mean suspended-sediment concentration was 1,180 mg/L on September 19, 1978. On that date, 357 tons of sediment was transported.

Suspended-sediment yields from Basswood Run averaged less than 5 $(tons/mi^2)/yr$. Even though the stream drained an area of 0.57 mi^2 it was dry about 70 percent of the time. Collapse of the structure above the deep mines has produced high infiltration rates. The increased infiltration is discharged as mine drainage. The lack of runoff and the 100 percent forest cover with no roads, produced the low sediment yields. Maximum suspended-sediment concentrations observed were less than 3 mg/L for 95 percent of the time.

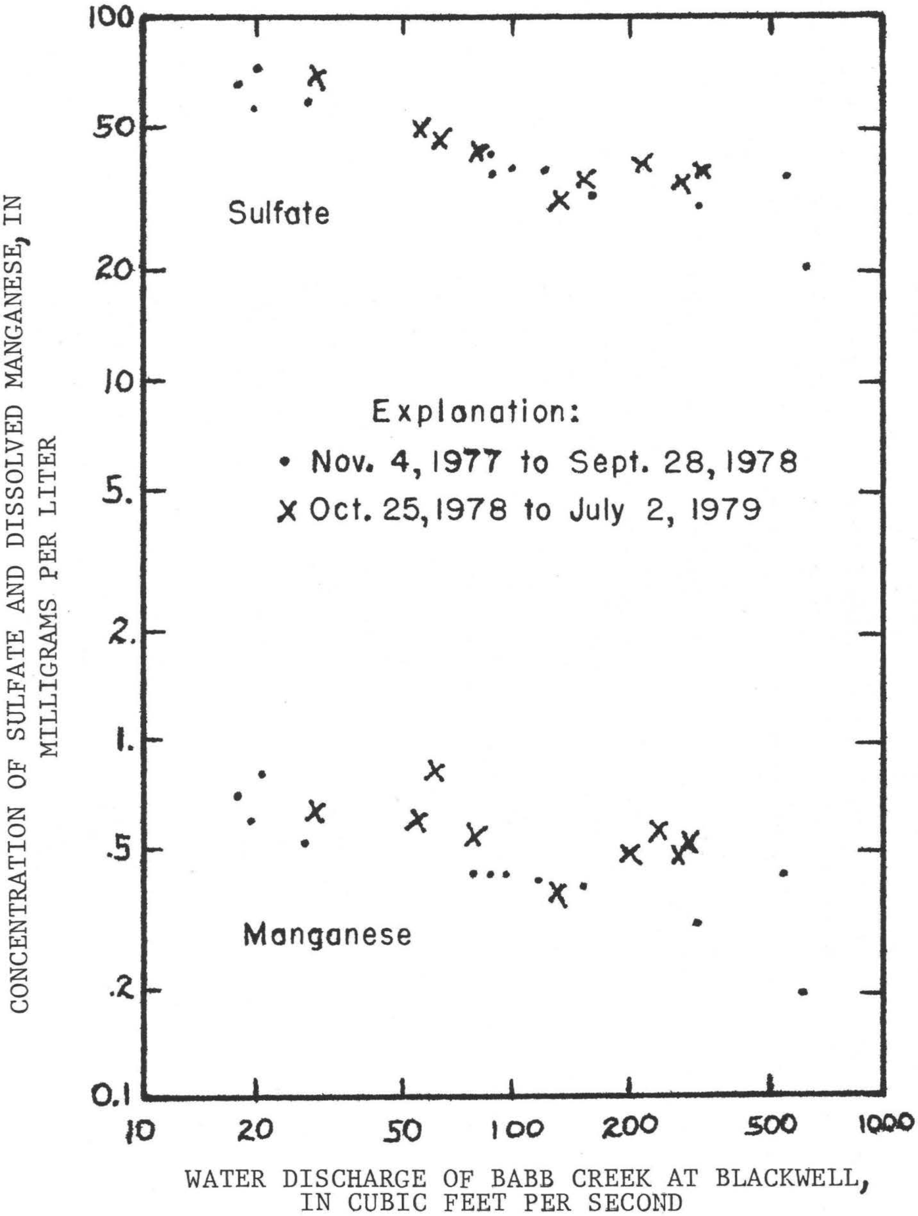

Figure 16.--Relation between water discharge and the concentrations of sulfate and dissolved manganese, Babb Creek at Blackwell, November 4, 1977, to July 27, 1979.

Table 11.--Alkalinity available (+) or required (-) as $CaCO_3$ in pounds per day to produce pH 6.0 discharges at indicated sites, December 29, 1977, to July 3, 1979

Date	Babb Creek at Morris	Wilson Creek above Sand Spring Run	Wilson Creek at Morris	Stony Fork near Blackwell	Babb Creek at Blackwell
1977					
December 29, 30	-1,640	1,330	-4,960	2,020	-340
1978					
February 9, 10	-560	800	-3,480	1,670	-260
March 1, 2	-300	650	-2,000	970	-180
April 12-14	-1,700	1,570	-5,400	3,350	-2,760
May 3, 4	-750	630	-2,720	1,100	-480
June 15, 16	0	670	-2,990	680	-420
July 13	-35	150	-1,550	180	-370
August 2, 3	-240	280	-1,560	470	150
September 7	0	360	-2,200	380	39
September 28, 29	-29	500	-1,850	480	-160
October 25	14	710	-1,520	760	390
December 4, 5	290	1,270	-910	4,630	4,300
December 27, 30	0	2,020	-3,230	2,600	340
1979					
January 29, 30	-2,600	2,050	-9,880	2,330	-7,200
February 22, 23	-550	980	-3,090	1,060	-2,000
March 19, 20	-2,170	1,560	-10,700	2,330	-6,000
April 24, 25, 26	-1,500	1,130	-6,860	2,800	-1,740
May 31	470	930	-3,890	3,400	170
July 2, 3	410	1,070	-2,720	1,780	544

Table 12.--Concentrations and loads of sulfate transported by Babb Creek and its tributaries, December 29, 1977, to July 3, 1979

Date	Babb Creek at Morris		Wilson Creek at Morris		Stony Fork near Blackwell		Babb Creek at Blackwell	
	Concentration (mg/L)	Load (lb/d)	Concentration (mg/L)	Load (lb/d)	Concentration (mg/L)	Load (lb/d)	Concentration (mg/L)	Load (lb/d)
1977								
December 29, 30	23	9,940	85	17,400	25	5,260	33	29,000
1978								
February 9, 10	23	5,840	93	11,500	28	3,810	38	25,000
March 1, 2	28	4,690	120	8,100	28	2,420	41	18,000
April 12, 13, 14	19	14,670	71	19,500	20	7,180	30	52,000
May 3, 4	25	10,410	110	10,100	26	2,670	37	18,000
June 15, 16	23	5,090	30	11,200	36	2,720	38	20,000
July 13	35	1,549	210	4,990	67	1,013	59	6,400
August 2, 3	29	1,720	200	5,670	35	813	60	9,100
September 7	31	1,410	220	6,180	45	850	67	6,500
September 28, 29	32	1,572	230	7,200	43	980	71	8,100
October 25	32	2,300	190	6,300	39	1,400	69	11,000
December 4, 5	23	6,700	84	8,900	26	5,200	32	23,000
December 27	24	4,300	110	8,100	30	3,700	42	18,000
1979								
January 29, 30	25	18,000	100	32,000	28	11,000	38	62,000
February 22, 23	29	5,300	130	9,100	32	2,400	50	15,000
March 19, 20	23	17,000	99	28,000	21	8,200	35	55,000
April 24, 25, 26	23	9,600	110	18,000	26	5,600	40	50,000
May 31	22	6,400	96	12,000	27	7,400	36	31,000
July 2, 3	31	6,400	190	8,900	28	1,400	47	16,000

Table 13.--Concentrations and loads of dissolved manganese transported by Babb Creek and its tributaries, December 29, 1977, to July 3, 1979

Date	Babb Creek at Morris		Wilson Creek at Morris		Stony Fork near Blackwell		Babb Creek at Blackwell	
	Concentration (mg/L)	Load (lb/d)	Concentration (mg/L)	Load (lb/d)	Concentration (mg/L)	Load (lb/d)	Concentration (mg/L)	Load (lb/d)
1977								
December 29, 30	0.40	173	1.2	246	0.21	44	0.40	350
1978								
February 9, 10	.36	91	1.4	174	.20	27	.41	260
March 1, 2	.38	64	1.7	115	.23	20	.44	200
April 12, 13, 14	.25	193	1.0	275	.16	57	.32	550
May 3, 4	.35	146	1.5	138	.25	26	.44	210
June 15, 16	.31	69	2.0	173	.30	23	.44	230
July 13	.46	20	3.3	78	.07	1.1	.60	65
August 2, 3	.57	34	3.1	88	.13	3.0	.53	80
September 7	.49	22	5.0	140	.13	2.5	.68	66
September 28, 29	.49	24	3.7	116	.37	8.4	.81	92
October 25	.42	30	3.1	100	.31	11	.64	100
December 4, 5	.34	99	1.4	150	.23	46	.38	270
December 27	.38	68	1.8	130	.33	41	.56	240
1979								
January 29, 30	.35	260	1.8	570	.24	93	.52	850
February 22, 23	.42	77	2.7	190	.31	23	.62	190
March 19, 20	.29	210	1.8	510	.15	58	.48	760
April 24, 25, 26	.33	140	1.8	300	.21	45	.48	600
July 2, 3	.36	74	2.9	140	.14	70	.55	190

Suspended-sediment discharge in Rattler Run was significantly affected by the improved haul road. Suspended-sediment yields from Rattler Run averaged 50 tons per year, of which about 48 tons came from the haul roads. As 1,500 ft of haul road (occupying an area of 1.0 acres) was in the drainage basin, the haul road contributed about 48 tons of sediment per acre per year. This compares with 0.01 tons per acre per year from an area 100 percent forested and 0.20 tons per acre per year from Wilson Creek above Sand Spring Run. Peak suspended-sediment concentrations in Rattler Run were about 15,000 mg/L; however, most of the time, they were less than 5 mg/L.

SUMMARY

The Anna S mine, that underlies about 850 acres drained by three major discharges is being daylighted. The Hunter Drift drains an underground area of about 400 acres; the Anna S 1, main entry, 330 acres; and the Mitchel 2 discharge about 120 acres. Daylighting began in the section drained by the Mitchel discharge in the fall of 1976 and in the area drained by the Hunter Drift discharge in the winter of 1978. From April to August 1979, no mining was done at either site. As of August 1, 1979, 55 acres (15 percent) had been daylighted in the Hunter Drift basin, 15 acres (5 percent) in the Anna S main entry basin, and about 30 acres (25 percent) in the Mitchel basin. About 30 percent of the area daylighted in the Mitchel basin has been backfilled to date, leaving toxic spoils exposed to the air. The area that has not been daylighted is forested, and some timber has been harvested ahead of the mining operations.

Data collected since November 1977 indicate that the acidity of Mitchel 2 and Hunter Drift has increased significantly and that the acidity of the Hunter Drift is still increasing. The acidity of the Mitchel 2 discharge changed the most, from an average of 176 mg/L in 1975-76 to an average of 1,190 in 1978-79, an increase of 580 percent. The acidity of the Hunter Drift discharge increased from an average of 348 mg/L during 1975-76 to an average of 710 mg/L during 1978-79, an increase of 100 percent. The acidity of Anna S 1 increased from an average of 212 mg/L during 1975-76 to an average of 307 during 1978-79, an increase of 45 percent. Acidity of Bridge Run decreased about 10 percent, from an average of 118 mg/L during 1975-76 to an average of 106 mg/L during 1978-79.

When the percentage increases in acidity are compared to the percentage of the area that has been daylighted, a general trend can be noticed. As the area daylighted increases, the acidity of the discharge increases.

Acid discharges from Antrim and Anna S mines are partly neutralized and diluted by available alkalinity and water discharge from Wilson Creek. The amount of water discharge and alkalinity available in Wilson Creek varies with season and weather. As streamflow increased, the alkalinity tended to decrease, but the alkalinity load (water discharge times alkalinity concentration) tended to increase. At a water discharge of 1.0 ft^3/s, the alkalinity as $CaCO_3$ available to pH 6.0 was 55 mg/L, and the alkalinity load was 300 lb/d. At a water discharge of 10 ft^3/s, the alkalinity as $CaCO_3$ was 19 mg/L, and the alkalinity load was 1,070 lb/d.

The pH of Babb Creek at Blackwell is normally less than 6.0. Of the 21 times when samples were collected, the pH was less than 6.0 on 13 occasions. Acidities, to pH 6.0, were greater than 1.0 mg/L on eight occasions, four during 1978 and four during 1979. The increased acid discharges from the Anna S mine have not had a readily detectable impact on Babb Creek at Blackwell.

The water-quality of Babb Creek and its tributaries was surveyed by the Pennsylvania Fish Commission on October 23 and 24, 1947. A sample collected near the mouth of Babb Creek at Blackwell had a pH of 4.8, an acidity of 12 mg/L as $CaCO_3$, and an alkalinity of 7 mg/L as $CaCO_3$. When sampled by the USGS on July 22, 1970, the pH was 5.2, and the specific conductance was 182 micromhos. Additional samples were collected during 1975 and 1976 as part of a study called Operation Scarlift. On August 5, 1975, the pH was 5.0, the acidity was 20 mg/L as $CaCO_3$, and the alkalinity was 6 mg/L as $CaCO_3$.

Suspended-sediment discharge was measured at three sites equipped with automatic samplers. Wilson Creek above Sand Spring Run was sampled to determine sediment loads transported by the area of Wilson Creek unaffected by mining. Suspended-sediment discharge in Wilson Creek above Sand Spring Run averaged 0.20 tons per acre per year. A station was located on Basswood Run just upstream from Hunter Drift discharge to collect streamflow and suspended-sediment discharge data before, during, and after mining. Sediment discharge from Basswood Run averaged less than 0.01 tons per acre per year.

A third suspended-sediment sampling station was located on Rattler Run. Runoff from 0.3 mile of improved haul road drained into Rattler Run above the sampling location. Average traffic on this section of road was about 120 heavy trucks and 25 light trucks per day. Suspended-sediment discharge in Rattler Run was significantly affected by the improved haul road, which contributed about 48 tons of sediment per acre per year.

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