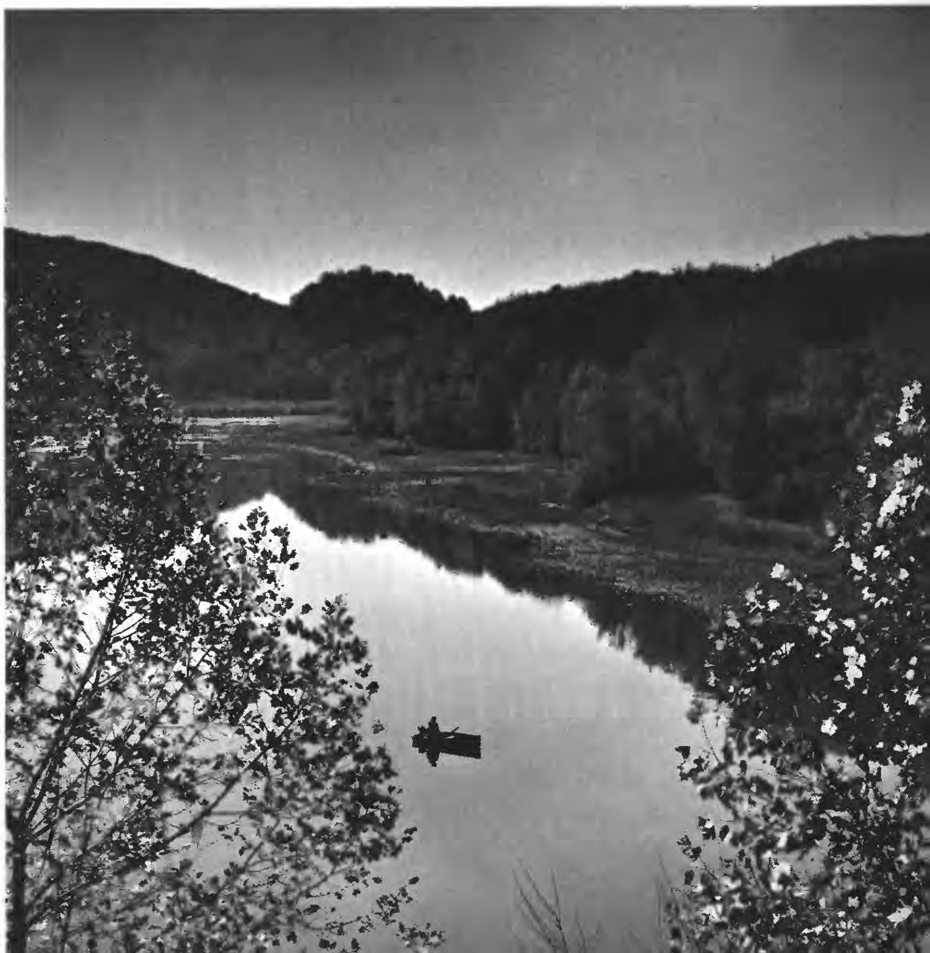
STREAM QUALITY IN APPALACHIA AS RELATED TO COAL-MINE DRAINAGE, 1965

GEOLOGICAL SURVEY CIRCULAR 526



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Cover photographs. Upper left, Strip mine in Appalachia (courtesy of Bureau of Mines, U.S. Department of the Interior). Lower left, Large carp and catfish, part of a scene of dead fish along an Appalachian river (courtesy of Johnny Nicklas, Chief Photographer, Pennsylvania Fish Commission). Lower right, View of Juniata River, Pa. (courtesy of Grant Heilman, Lititz, Pa.).

TABLES

DEFINITION OF TERMS

Acidity.—The capacity of a water for neutralizing a basic solution. Acidity, as used in this report, is caused primarily by the presence of hydrogen ions produced by hydrolysis of the salts of strong acids and weak bases.

Alkalinity.— The capacity of a water for neutralizing an acid solution. Alkalinity in natural water is caused primarily by the presence of carbonates and bicarbonates.

Dissolved solids.—Consist mainly of the dissolved mineral constituents in water and is represented by the residue that remains after evaporation and drying at a temperature of 180°C.

Hardness.— A property of water which causes an increase in the amount of soap that is needed to produce foam or lather. Hardness is produced almost completely by the presence of calcium and magnesium salts in solution. Carbonate hardness is represented by the carbonate and bicarbonate salts of calcium and magnesium. Noncarbonate hardness is represented by all other salts of calcium and magnesium. Hardness is expressed conventionally in terms of an equivalent quantity of calcium carbonate. The following scale may assist the reader in appraising hardness:

Degree of hardness	*Hardness range (ppm)*
Soft	0–60
Moderately hard	61–120
Hard	121–180
Very hard	>180

Parts per million (ppm).— A unit for expressing the concentration of chemical constituents by weight, for example, as grams of constituents per million grams of solution.

pH.— A measure of the hydrogen-ion concentration of a solution. A pH unit is expressed as the negative $\log_{10}$ of the hydrogen-ion concentration. The pH of pure water is 7.0, acid water has a smaller pH and alkaline water a larger pH.

Specific conductance.— A measure of the ability of a water to conduct an electrical current. It is expressed in micromhos at 25°C. Pure water has a very small electrical conductance, but the conductance increases with increasing concentration of dissolved minerals.

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ABSTRACT

A stream-quality reconnaissance at 318 locations in May 1965 offered the first opportunity for a contemporaneous regional collection and appraisal of water-quality data in Appalachia. The results provide a means of regional comparison of the influence of coal-mine drainage on stream quality at approximately median streamflow. The results disclose that the chemical quality of the water at nearly 200 sites did not meet recommended drinking-water standards. At many of these sites, inferior quality was caused by excessive concentrations of solutes commonly associated with coal-mine waters.

Water-quality damage from mine drainage is particularly severe in the more heavily mined northern one-third of the region where high sulfate content, free mineral acidity, and low pH are typical of most affected streams. A deficiency in natural stream alkalinity in this part of the coal region contributes greatly to the massive effect of mine drainage upon stream quality. However, data collected from streams affected by mine drainage along the west edge of this part of the coal field suggest extensive neutralization of mine water. In southern Appalachia coal-mine drainage had less influence on stream quality than in northern Appalachia. Fewer streams in this area were influenced by mine drainage, and the magnitude of stream damage for affected streams was less than in northern Appalachia.

INTRODUCTION

Extensive coal mining in the Appalachian region for several decades has measurably influenced stream quality throughout the area. The deterioration of streams that receive coal-mine drainage has seriously limited the industrial and domestic uses of these waters. This undesirable alteration of natural stream quality has placed economic restrictions on many downstream water users.

Highly detailed individual studies and some broad statewide studies of the mine-drainage problem have varied greatly in technical approach as well as analytical methodology. However, most attempts to understand the problem and to define the extent of stream-quality damage were not designed to measure the relative significance of mine drainage on the water resources of the entire region. Public awareness of the problem balanced by technical concern over water pollution warrants a broad look at water pollution from coal-mine drainage throughout the entire 11-State area known as Appalachia (see subsection on "Coal mining and mine water" for definition of boundaries).

PURPOSE AND SCOPE

To evaluate the significance of this water-pollution problem in Appalachia, to update stream-quality data, and to provide technical continuity in collection of these data, the Geological Survey acquired extensive streamflow and water-quality information in May 1965. This report summarizes the results of the first major regional reconnaissance, describes some basic water-quality characteristics of streams in the area, discusses the observed effects of mine drainage upon stream quality, and delineates areas where stream pollution by coal-mine drainage was most severe during the period of study.

The authors wish to make it clear that this report may present only limited new evidence of stream pollution by mine drainage to those interested in any specific part of Appalachia. The reconnaissance study is intended primarily to offer a means of assessing the magnitude of this water problem throughout the entire region. This report provides a foundation of data to guide future regional studies. It also should assist in the selection of areas that require special, more detailed attention.

ACKNOWLEDGMENTS

The authors are grateful to the many Water Resources Division offices which participated in the collection and appraisal of data presented in this report. We also wish to express thanks to the water resources agencies of the States in the Appalachia region for their cooperative support.

COAL MINING AND MINE WATER

The Appalachia region, as defined in Public Law 89–4 (1965), extends over parts of an 11-State area from Pennsylvania to Alabama (fig. 1). A small area in New York was added to Appalachia after enactment of Public Law 89–4. However, this report covers only that part of Appalachia south of the New York-Pennsylvania boundary. Coal deposits occur in approximately 50,000 square miles of the region and are in 9 of the 11 States. In many areas of Appalachia, coal has been intensively mined for more than 100 years. Records of production in some of these areas are available since post-Civil War years. Table 1 shows the amount of coal mined in Appalachia for the period 1923–63. It is

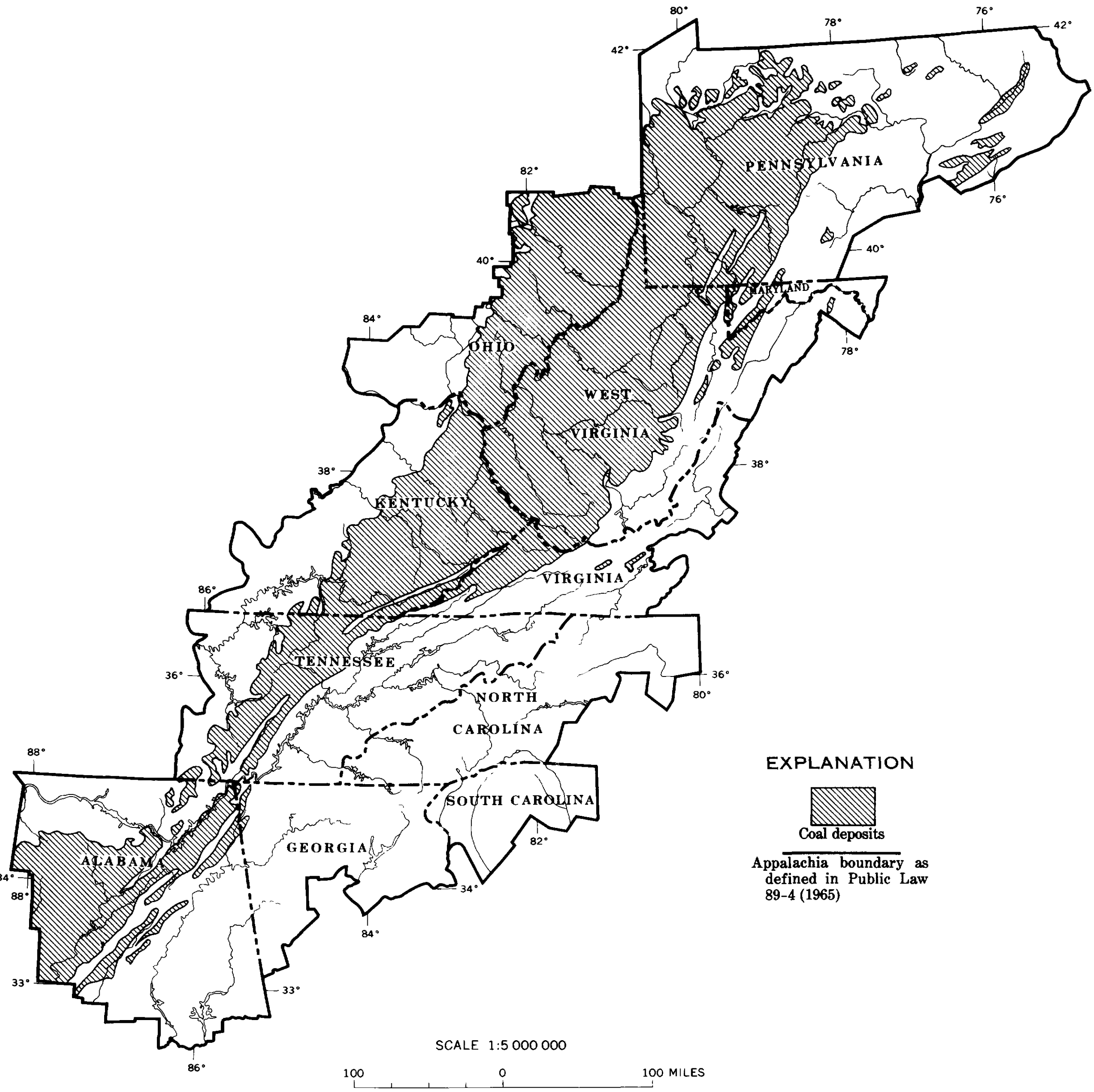

Figure 1.—Location of coal deposits. (From Trumbull, 1960.)

Table 1.—*Total coal production in Appalachia, 1923–63*

State	Total coal produced,[1] in thousands of tons	Percent of total
Alabama	579,000	3.7
Georgia	1,000	.0
Kentucky	1,703,700	10.8
Maryland	61,600	.4
Ohio	1,097,200	6.9
Pennsylvania	6,294,400	39.7
Tennessee	230,700	1.4
Virginia	689,700	4.4
West Virginia	5,180,900	32.7

[1]U.S. Bureau of Mines (1963).

noteworthy that 72 percent of the coal was mined in two northern States—Pennsylvania and West Virginia. Kentucky, Ohio, Virginia, and Alabama also produced significant amounts.

The two principal methods of mining coal, underground mining and strip mining, produce vastly different hydrologic environments. The method used probably affects acid production. Many underground mines are below the zone of saturation,[1] so there is continual contact between sulfuritic material and water—a condition resulting generally in continual production of acid. Many strip mines are above the zone of saturation. This means that the pyritic material is in contact with water only during periods of excessive precipitation and mine drainage is thereby limited.

Underground mining has produced most of the coal in Appalachia. However, recent data reflect a major trend to produce coal by strip mining. Since 1940 the amount of coal produced in the United States by strip mining has increased from 9 to 34 percent U.S. Bureau Mines, 1963). In 1963 strip mining outproduced other methods of mining in Ohio and Maryland (table 2).

While the quantitative significance of various types of coal mining upon water pollution is not known, the problem, process, and products of mine drainage are similar for all types of mining. The problem begins with the physical process of unearthing coal which exposes pyritic materials (FeS_2), commonly associated with coals, to water and air. Braley (1954), Krickovic (1965), and Stumm (1965) state that pyrite reacts with oxygen and water to form ferrous sulfate ($FeSO_4$) and sulfuric acid (H_2SO_4). These chemical processes, whether within mines or waste piles, usually increase the concentrations of certain dissolved solids in the mine water. These index parameters include iron, sulfate, noncarbonate hardness, and total dissolved solids. Free mineral acidity, low pH values, and excessive concentrations of manganese and aluminum also are common characteristics of coal-mine waters. The sulfate in the reaction products makes an excellent indicator of mine-drainage pollution. Available data suggest that the chemical composition of mine waters throughout Appalachia is remarkably similar (table 3).

[1]The zone in which the rocks are saturated with water under hydrostatic pressure.

The concentration and composition of mine water, however, may be affected measurably by the presence of soluble rock minerals including calcium carbonate ($CaCO_3$), which in sufficient quantities neutralizes mine acid. This process increases the total hardness through the addition of calcium and magnesium, and can increase carbonate hardness when neutralization raises the pH above 4.5. Even when partial neutralization occurs, mine waters lose some free mineral acidity. Iron and aluminum precipitate at the higher pH produced by neutralization.

The significance of microorganisms in acid formation is discussed by Braley (1954). Braley states that the high acidity of many mine effluents in the bituminous coal region

Table 2.—*Type of mining in Appalachia, 1963*[1]

State	Percent of total production		
	Underground	Strip mining	River dredging
Alabama	77.4	22.6	----------
Georgia	100.0	----------	----------
Kentucky	66.7	33.3	----------
Maryland	36.6	63.4	----------
Ohio	33.7	66.3	----------
Pennsylvania	59.9	35.6	4.5
Tennessee	59.3	40.7	----------
Virginia	92.5	7.5	----------
West Virginia	94.4	5.6	----------

[1] U.S. Bureau of Mines (1963).

Table 3.—*Chemical composition of typical mine waters in Appalachia*

[Results given in parts per million except as indicate]

Mine name	Location	Date	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Total acidity as H_2SO_4	Specific conductance (micromhos at 25°C)	pH	Color
PENNSYLVANIA																						
Delaware River basin																						
Newkirk mine	Near Tamaqua	7–28–65	25	40	5.5	10	60	49	1.5	1.4	0	672	1.2	0.2	0.8	1,060	351	351	382	1,590	2.80	3
Eagle Hill 2	Near Port Carbon	7–28–65	9.5	----	2.8	2.2	84	51	4.3	1.0	84	344	.8	.2	.2	571	420	351	-----	765	7.8	3
Susquehanna River basin																						
Middle Creek mine.	Near Tremont	6–25–65	16	5.6	9.2	4.9	61	48	2.0	1.5	0	427	3.2	0.3	0.4	671	350	350	108	1,080	2.95	1
Glenwhite Run mine 6.	Near Altoona	6–16–65	----	----	10	----	62	---	----	---	0	900	---	---	---	-----	680	680	717	1,740	3.1	--
Allegheny River basin																						
Toby Creek mine 2.	Near Brandy Camp.	6–17–65	----	----	164	----	214	---	----	---	0	1,730	---	---	---	-----	1,560	1,560	1,170	3,080	2.7	--
KENTUCKY																						
Big Sandy River basin																						
Cane Branch mine 1.	Near Wayland	10– 9–58	34	14	18	----	152	28	38	5.6	0	832	2.5	1.9	5.0	1,200	494	494	236	1,870	2.80	--
Ohio River basin																						
Yellow Creek mines.	At Sassafras	1–29–58	----	89	119	9.3	---	---	----	---	0	1,240	---	---	---	1,700	374	374	868	2,180	2.50	--
WEST VIRGINIA																						
Monogahela River basin																						
Norton mine 1	Near Norton	7–15–65	38	48	114	5.1	---	---	----	---	0	1,150	---	1.4	5.4	1,820	630	630	587	2,330	2.70	--
Browns Creek mine A–2.	Near Mount Clare.	9–12–63	3.3	16	217	4.3	---	---	79	8.7	0	1,960	---	---	---	-----	1,130	1,130	490	3,210	2.75	--

may be attributed, in part, to the action of certain bacteria on the pyritic constituents associated with coal.

Some authorities believe that acid cannot be produced in mines without air. Whether the acid-forming reaction involves atmospheric or dissolved oxygen is discussed by Barnes and Clarke (1964). They suggest that acid can be formed merely by dissolving pyritic materials in water.

MINE DRAINAGE AND STREAM QUALITY

The delivery of mine water to the surface drainage system is a critical factor in controlling the extent of stream pollution by coal-mine drainage. Relatively continuous delivery of water to a stream from active and abandoned coal mines creates continuous pollution of the stream. This type of stream-quality damage is of great concern to industrial and domestic users who must maintain extensive treatment facilities to obtain a usable supply of water.

Occasional flushing of mines by excessive precipitation produces temporary, but often more dramatic, stream damage. Mine flushing delivers a large volume of water to a stream for a short time. When this mine effluent is carried downstream to points that normally are not affected by critical levels of pollutants, a fish kill may occur. The West Branch Susquehanna River in Pennsylvania, for example, experienced 20 major fish kills between 1948–62 (Corps of Engineers, 1962) because of the downstream transport of mine effluents by highly localized rains in the mining region.

The cumulative influence of both continuous and occasional stream pollution on fish habitat has been considered by the U.S. Bureau of Sport Fisheries and Wildlife (Kinney, 1964). Kinney reports that Pennsylvania and West Virginia contain over two-thirds of the stream mileage that is adversely affected by coal-mine drainage in Appalachia. There is a striking relationship between Kinney's data and coal production by each State in Appalachia (fig. 2).

Although both continuous mine drainage and mine flushouts are of great public concern, this broad reconnaissance study defines only a part of the continuous effects. In particular, the May field studies measured the influence of mine drainage on stream quality during near-median flow conditions when streams contained fairly dilute waters. Most continuous mine-drainage pollution problems observed in May should be more serious during the June to November low-flow period when stream waters normally are more concentrated.

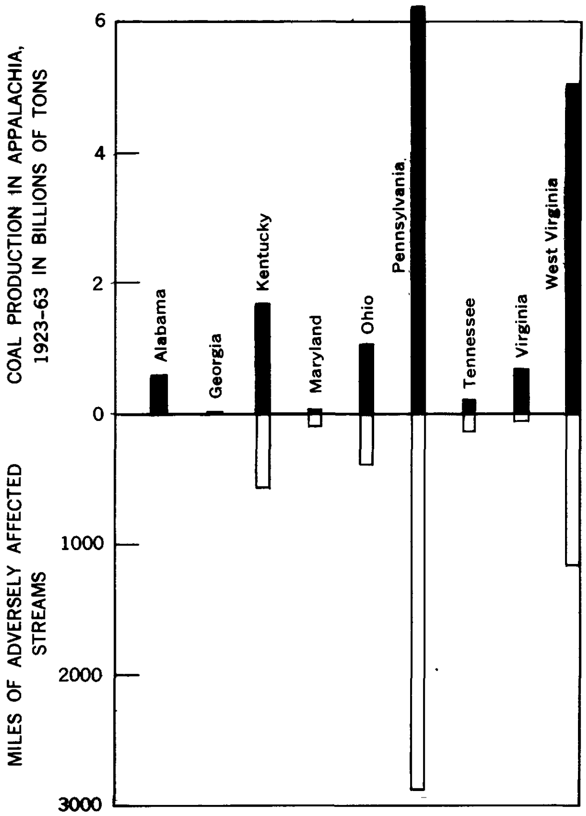

Figure 2.—Comparison of coal production (data from U.S. Bureau of Mines, 1964) to miles of affected streams (data from U.S. Dept. Int., Div. of Fishery Management Services, E.C. Kinney, 1964).

Wherever stream-water quality is affected seriously by coal-mine drainage, many economic limitations are placed on the value of that water for recreational, industrial, and municipal uses. An abundance of mine-drainage constituents increases water-treatment costs and necessitates more frequent replacement of water-treatment facilities. River structures and navigation equipment often need special protection from corrosion by mine drainage. Deposits of sediment create an unattractive environment and render streams and lakes that receive mine discharge unfit for fishing, swimming, and other recreational uses.

Table 4 summarizes common water-use limitations of mine water. These include

Table 4.—*Use limitations of water-quality parameters typical of coal-mine drainage*

Constituent	Objectionable features of excessive concentration	Recommended limiting concentration for indicated use (ppm)[1]						
		Public water supply[2]	Cooling water	Food processing	Pulp and paper making	Plastics manufacturing	Boilers	Textile manufacturing
Sulfate	Diuretic effect, bitter taste.	250	--------	20–250	--------	--------	--------	100
Hardness as $CaCO_3$.	Boiler scale, produces insoluble "curd" when it reacts with soap.	--------	50	10–400	100–200	--------	2–80	0–50
Dissolved solids.	Diuretic effect, unpleasant taste.	500	--------	850	200–500	200	50–3,000	--------
Iron	Unpleasant taste, stains porcelain and linen.	.3	.5	.2	.1–1.0	--------	--------	.1–1.0
Manganese	Unpleasant taste, stains porcelain and linen.	.05	.2–0.5	.2	.05– .5	.02	--------	.1–1.0
Aluminum	Boiler scale.	--------	--------	--------	--------	--------	0–3	--------
Suspended solids.[3]	Clogs treatment facilities and water courses.	5	50	1–10	10–100	--------	0–10	.3–25
pH[4]	Increases corrosiveness.	--------	--------	7.5	--------	--------	8.0–9.6	--------

[1]California Water Quality Control Board (1963).
[2]U.S. Public Health Service (1962).
[3]Turbidity, as silica, in parts per million.
[4]Value not to be less than limits shown.

unpleasant taste, staining, increased corrosiveness, formation of insoluble precipitates, and unpleasant diuretic effects and are caused by excessive concentrations of the mine-drainage index parameters.

STREAM-QUALITY OBSERVATIONS

THE FIELD RECONNAISSANCE

Available geologic, hydrologic, and coal-mining data were used to select sampling sites (pl. 1) for the field reconnaissance. Because broad definition was a primary goal, many water-quality measurements in the 11-State region were made for streams draining an area greater than 100 square miles. In areas of coal mining, sampling sites were selected for streams known or suspected to be influenced by mine drainage, so that the relative stream quality could be assessed. Several additional sites were selected to represent the water quality of streams not affected by mine drainage.

The field reconnaissance in the late spring of 1965 was intended to define general water quality for near-median streamflow conditions. Unregulated streamflow during the study was in the 45–65 percentile range and provided comparative data on the influence of mine drainage on streams in the entire region. Streamflow was generally steady and, therefore, water-quality results were not complicated by the effects of direct runoff from rains. Consequently, most of the analyses provide areawide data on near-average water quality.

During the intensive 9-day study period in May 1965, 11 two-man teams of hydrologists and chemists visted 318 stream sites from northeastern Pennsylvania to central Alabama, an area of more than 160,000 square miles. Field measurements included water discharge, pH, specific conductance, water temperature, dissolved-oxygen concentration, and acidity. Water samples for more detailed analyses were also collected for delivery to U.S. Geological Survey laboratories in the region.

BASIC QUALITY OF STREAMS IN APPALACHIA

Streams in the coal region that are unaffected by mine drainage are of excellent quality. These streams contain very dilute alkaline water, with calcium and bicarbonate the dominant dissolved constituents. During the study period, the bicarbonate content of unpolluted streams in the coal-mining region generally was less than 50 ppm. Unaffected streams adjacent to the coal region contained bicarbonate concentrations from 50 ppm to more than 200 ppm. Plate 1 delineates zones of relatively low and high concentrations of bicarbonate for streams within Appalachia. It is noteworthy that the central zone of low bicarbonate water generally coincides with the coal-field area.

The alkalinity of streams in the southeast edge of Appalachia was generally lower than that observed for other streams within the region. Here streams draining the crystalline-rock terrain of the Piedmont Province contain among the lowest solute content of streams in the Eastern United States (Rainwater, 1962).

Unusually low concentrations of bicarbonate for unaffected streams in the coal-mining region demonstrate the relative inability of most of these streams to neutralize acid-mine water which enters the drainage system. When acid drainage from coal mines reacts with the low natural alkalinity of most streams in the coal region, the result is a large number of seriously affected streams carrying free mineral acidity.

While the May 1965 reconnaissance suggests that unaffected streams in the coal region contain relatively little neutralizing capacity, the bicarbonate alkalinity in some streams affected by mine drainage in parts of Pennsylvania, Ohio, West Virginia, Kentucky, and Virginia, indicates that extensive neutralization takes place within the coal region. Figure 3 illustrates a general area in the coal region where affected streams contain high concentrations (50–200 ppm) of bicarbonate. These high alkalinities may be produced by neutralization from small, highly alkaline tributaries that were not sampled during this reconnaissance. Neutralization also may occur in the mines by contact of water with adjacent calcareous rocks (or by mixture of alkaline water associated with these strata). Scattered evidence of the existence of alkaline mine waters add credibility to the second choice, but it may be a combination of these conditions that produces generally high stream alkalinity in the area noted in figure 3.

Hardness is another water-quality index parameter in which major changes usually occur when mine waters are added to natural streamflow. The ranges in concentrations, zonal boundaries, and related criteria used to describe alkalinity of both unaffected and affected streams are similar for total-hardness data collected during the reconnaissance. Where mine drainage has not influenced stream quality in the coal region, total hardness was nearly always less than 50 ppm. In the areas immediately adjacent to the coal region, total hardness ranged from 50 ppm to 300 ppm or more. Again, streams draining the Piedmont province of southeastern Appalachia were most dilute, the hardness values ranging generally from 10 to 20 ppm.

Salty water brought to the earth's surface while developing oil and gas wells often affects stream quality. The May 1965 data indicate that only a few major streams in Ohio, Kentucky, and Pennsylvania contained concentrations of chlorides in excess of 100 ppm, and the concentrations exceeded U.S. Public Health Service (1962) "Drinking Water Standards" of 250 ppm at only two sites. The chloride data indicate that although some brine pollution does exist in Appalachia, it is not a major problem on large streams during median flow.

The nitrate and phosphate content of stream water is considered a secondary indicator of pollution from untreated or treated domestic wastes as well as from some industrial wastes. In Appalachia, observed concentrations of nitrates and phosphates were low during the May 1965 reconnaissance. Concentrations of both constituents were well below recommended limits for public water supplies and also were acceptable for most industrial uses of water. The lack of these constituents in water, in fact, suggests a deficiency of some key nutrients that fertilize aquatic plants. This deficiency may provide a poorer environment for many types of aquatic insects and fish which, in turn, can exert some limitation on recreational development of the water.

Dissolved-oxygen concentration may also serve as an indicator of pollution by domestic and industrial waste. Although observed dissolved-oxygen values represent only an instantaneous evaluation of a complex and dynamic system of stream deoxygenation and reaeration, data collected during the reconnaissance offer means for a limited appraisal of stream conditions. In Appalachia, most observed dissolved-oxygen concentrations were above the suggested value of 5.0 ppm (California Water Quality Control Board, 1963, p. 181), necessary for a favorable environment for fish and other aquatic life. The dissolved-oxygen concentration was less than 5.0 ppm at only 10 of 318 locations.

EFFECTS OF MINE DRAINAGE ON STREAM QUALITY

The presence of free mineral acidity in a stream is the most serious evidence of water-quality damage by mine drainage. The May 1965 data clearly demonstrate that mine

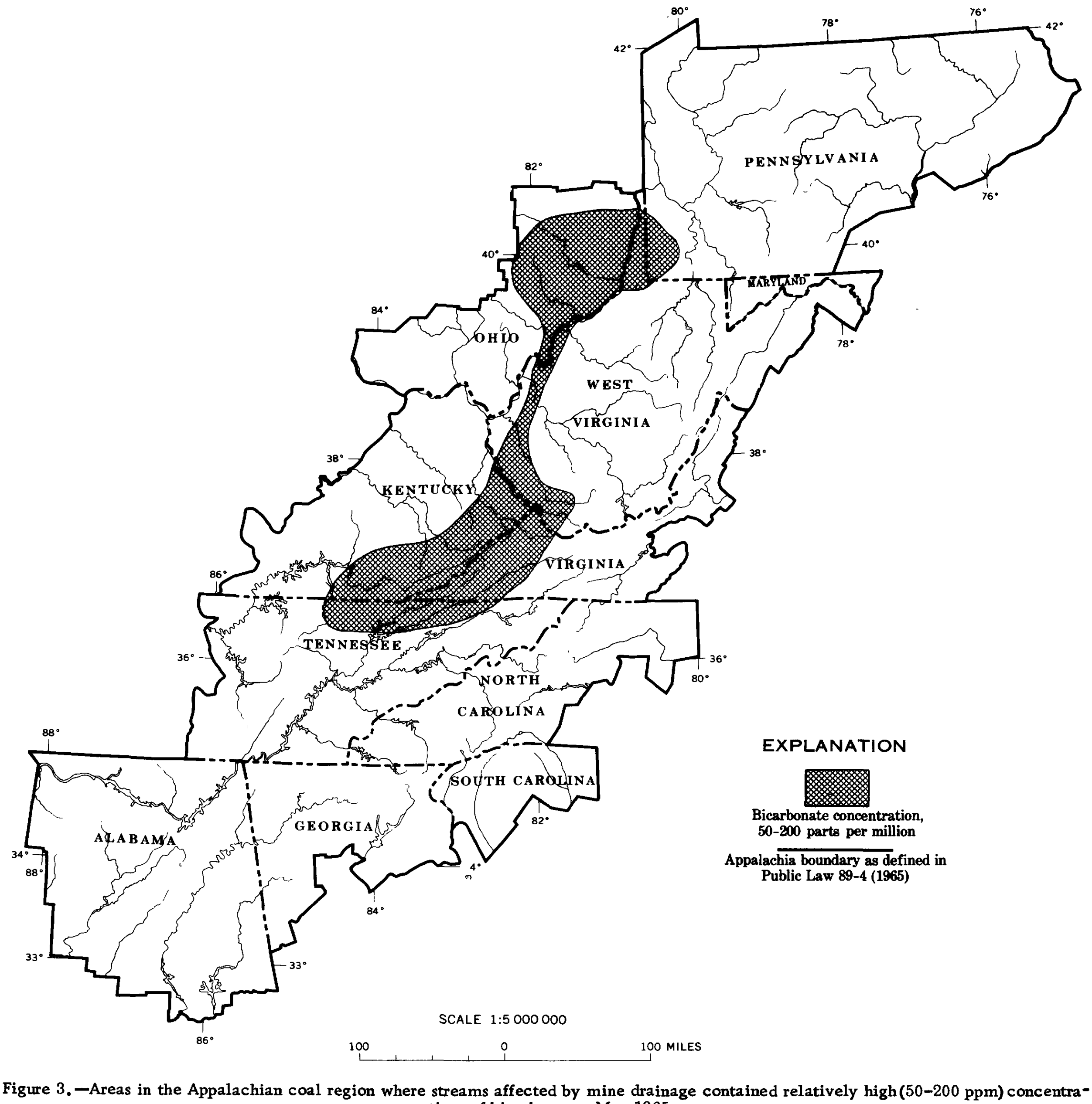

Figure 3.—Areas in the Appalachian coal region where streams affected by mine drainage contained relatively high (50–200 ppm) concentrations of bicarbonate, May 1965.

drainage damages the chemical quality of streams more severely in the northern one-third of Appalachia than in the rest of Appalachia. (See pl. 1.) Free mineral acidity occurs in rivers as large as West Branch Susquehanna River, Kiskiminetas River, Casselman River, North Branch Potomac River, Monongahela River, and Raccoon Creek.

The abundance of acid mine waters in northern Appalachia may be due to several factors or to a combination of these factors. There is more coal mined in the north than in the south. This implies more extensive exposure of sulfuritic material to an acid-producing environment. Also, the amount of sulfuritic material exposed for each ton of coal mined in the north may be greater than in the south.

Further evidence of the abundance of acid water in northern Appalachia is shown on plate 1 as daily loads of sulfuric acid that were measured during the study period. Yearly acid loads at several locations are reported in U.S. Geological Survey Hydrologic Investigations Atlas HA–198 (Schneider and others, 1965). The May 1965 data illustrate the immense magnitude of the mine-drainage problem in the West Branch Susquehanna River, Monongahela River, and Kiskiminetas River basins where the loads of acid per square mile are greater than those of other major basins in Appalachia.

The key index solute, sulfate, is used in this report to describe the influence of mine drainage on stream quality during median flow. Since observed concentrations of sulfate for unaffected streams draining the coal region were low (less than 20 ppm) during the study period, concentrations of sulfate greater than 20 ppm are used to describe the measured effect of mine drainage on stream quality (pl. 1). The chemical quality of most major tributaries of the Susquehanna and Ohio Rivers that drain the Appalachian coal fields is affected to some extent by mine drainage. In the northern one-half of the coal region, only a few streams draining an unmined part of the Kanawha River basin are not influenced by mine drainage using sulfate concentration as an indicator of mine drainage. Farther south in parts of Tennessee, Georgia, and Alabama, scattered mining has little effect on the chemical quality of major streams in the area during median flow.

Figure 4 shows the north to south trend of sulfate content for streams affected by mine drainage. The median concentration of sulfate for affected streams in Pennsylvania and Ohio is 160 ppm, but only 45 ppm for streams in Tennessee and Alabama. This decrease in sulfate concentration provides further evidence of less intense mine-drainage problems in southern Appalachia.

The effect of mine drainage on the hardness of water is shown in figure 5. Note the greater percentage of samples in the hard and very hard class for mine-polluted waters. Median hardness was 130 ppm for affected sites, and only 30 ppm for unaffected sites.

With U.S. Public Health Service (1962) "Drinking Water Standards" as a guide for defining the limitations placed on stream use by mine drainage (table 4), it is apparent that mine drainage has seriously affected the utility of many streams in the region for domestic or municipal supply. Sampling sites where water-quality parameters exceeded recommended drinking water standards are shown in plate 1. Water quality at nearly 200 sites in the region did not meet recommended water standards. Table 5 describes the effects of mine-drainage index solutes on the potential use of these waters for municipal supplies. A comparison of data in table 4 with chemical-quality data in table 6 also suggests that several streams will not meet the water-quality criteria for many industrial uses of water.

Table 5.—*Effect of mine drainage on the potential use of streams draining the coal region of Appalachia, May 1965*

Water-quality parameter	Percentage of sample sites where concentrations exceeded drinking water standards	
	Sites unaffected by coal-mine drainage	Sites affected by coal-mine drainage
Iron	6	35
Manganese	34	83
Sulfate	0	22

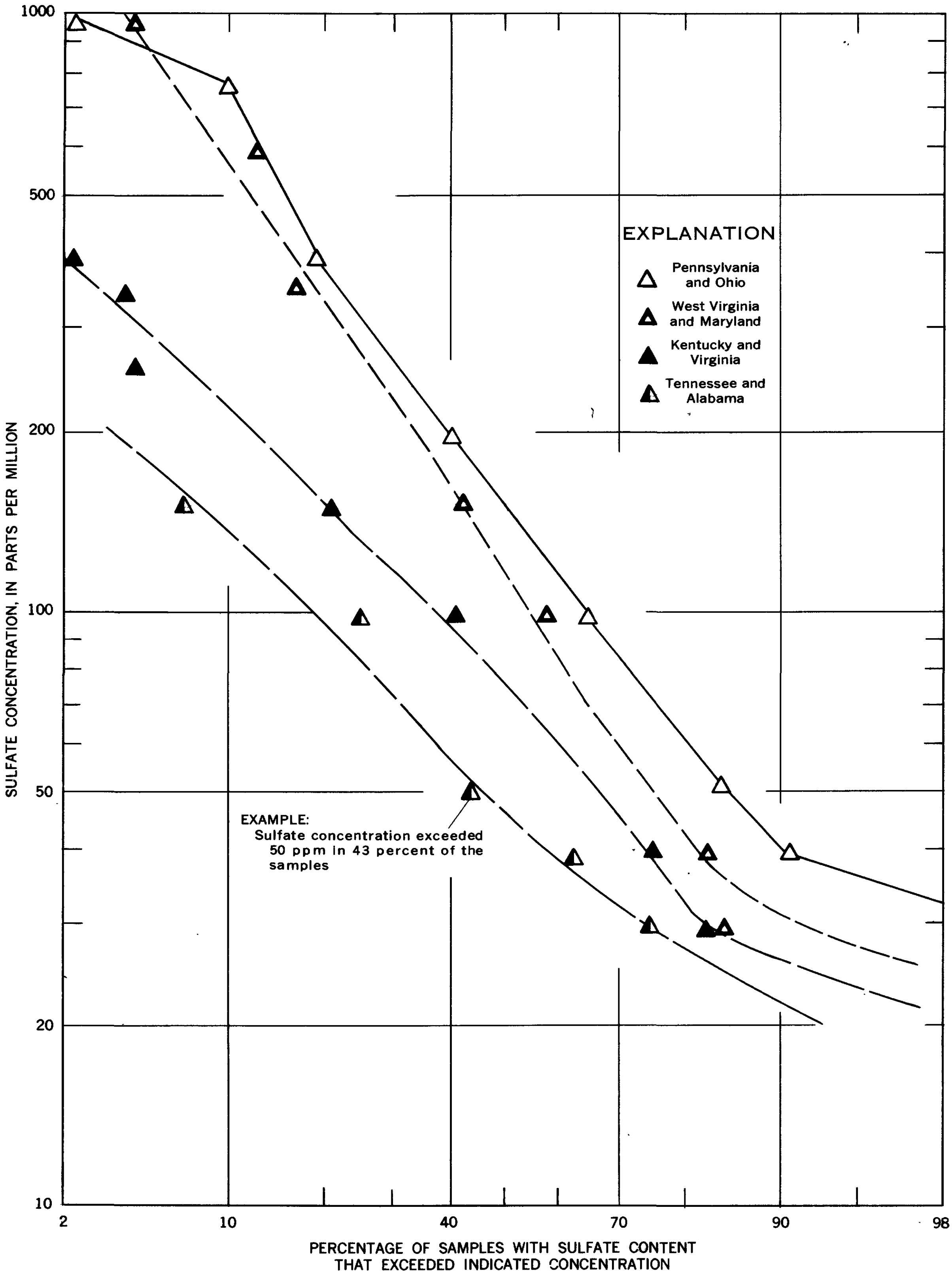

Figure 4.—Effect of coal-mine drainage on sulfate content from northern to southern Appalachia, May 1965.

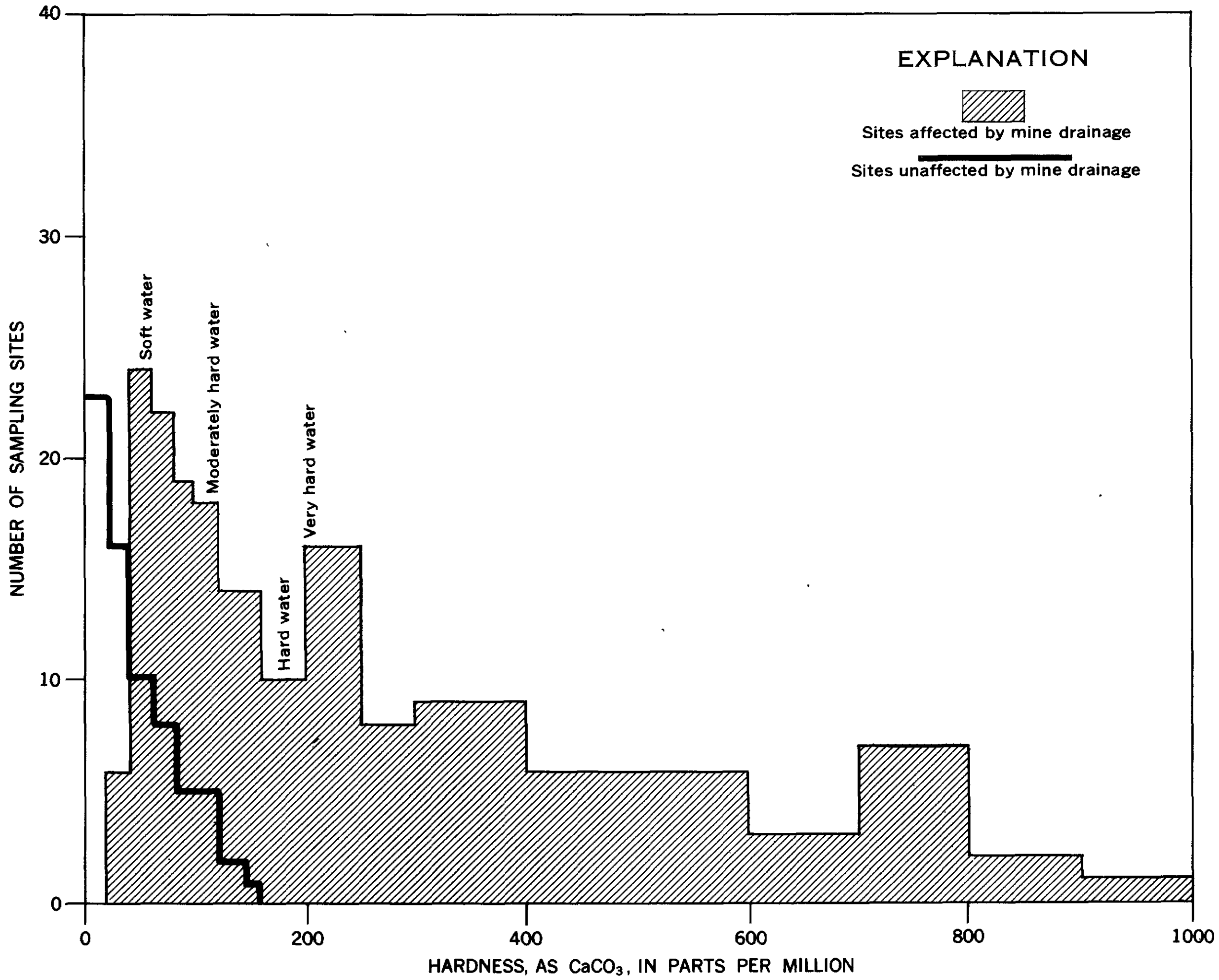

Figure 5.—Effect of mine drainage on the hardness of water, May 1965.

NEUTRALIZATION OF ACID STREAMS

The mixture of alkaline streams with mine-drainage waters eventually neutralizes all acid streams in Appalachia. Even in the badly polluted upper Ohio River basin, the added flow from the Allegheny River and other more alkaline downstream tributaries ultimately produces water of fair quality (fig. 6). Observed pH increases from less than 4.7 in the Monongahela River to approximately 7.0 in the Ohio River at Stratton, Ohio. There is also a gradual increase in the ratio of bicarbonate to sulfate between these two sites. Stream hardness continues to increase downstream, but a greater part of the hardness is carbonate hardness.

Thus, while the problem of stream pollution by mine drainage is particularly serious in headwater areas of Appalachia near active and abandoned mines, the alkaline contribution of streams both in and out of the coal region measurably improves the quality of affected waters.

CONCLUSIONS AND RECOMMENDATIONS

The May 1965 field reconnaissance discloses that the water quality at 194 of 318 sampling sites was measurably influenced by mine drainage. Thirty sites contained water with free mineral acidity. Nearly all major acid streams in Appalachia were in the northern one-third of the region.

The natural alkalinity of streams within the coal region was generally low, usually less than 50 ppm. The reconnaissance discloses that most of these streams are relatively incapable of neutralizing large quantities of acid mine water. However, high bicarbonate content was fairly typical of many streams affected by mine drainage within a

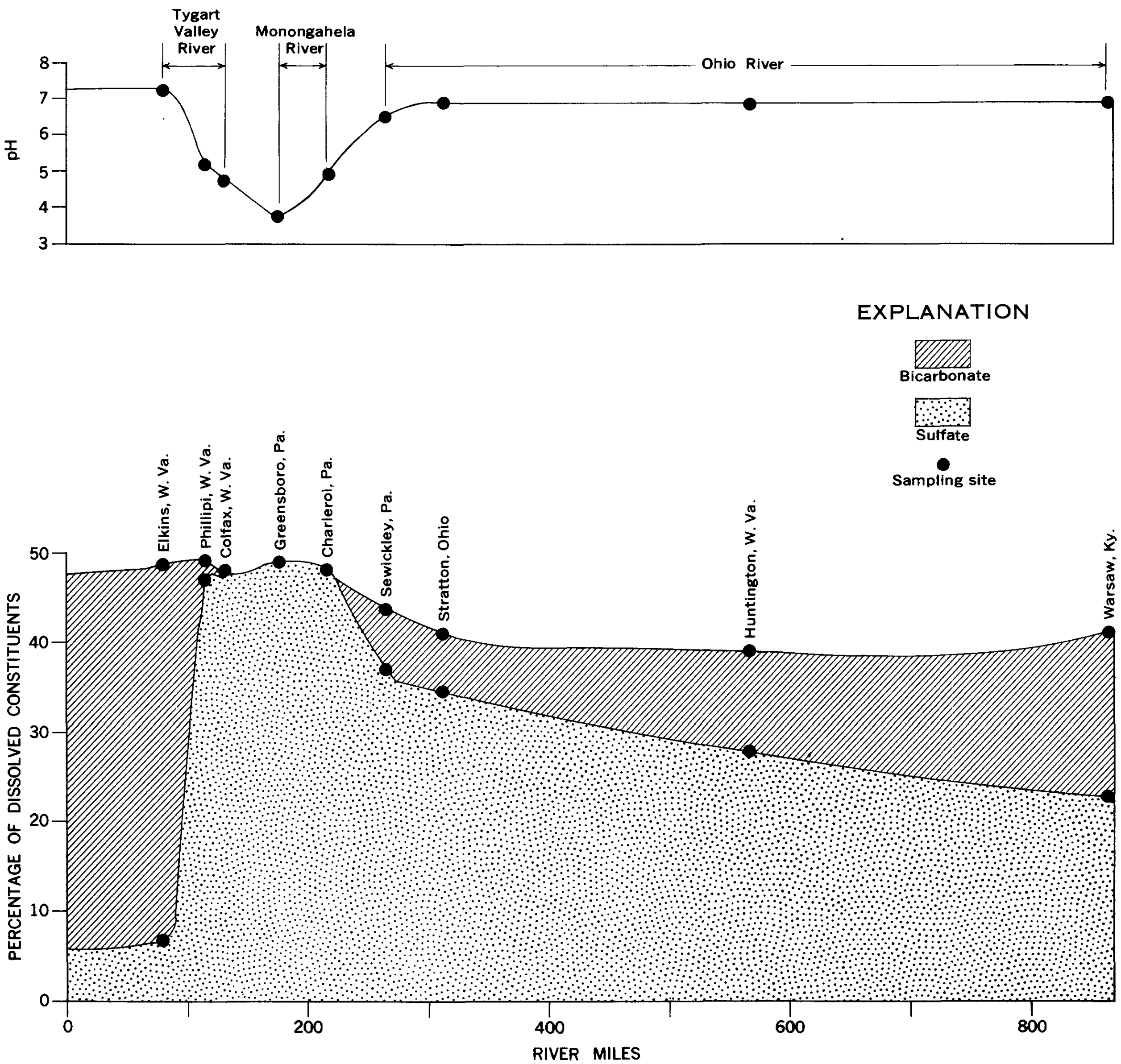

Figure 6.—Changes in the composition of a mine-polluted stream during neutralization, Ohio River basin, May 1965.

comparatively narrow area of the coal region from eastern Ohio to western Virginia. Apparently, there is significant neutralization of mine water in this area either by alkaline water in the mines, or by small unaffected headwater tributaries.

Analysis of sulfate content of streams affected by mine drainage indicates that less sulfate occurs in streams in the south half of the region. These data also provide further evidence that less acid water is produced per square mile in the south than in the north, probably because of less intense mining.

More serious water-quality damage from coal-mine drainage occurs in: the West Branch Susquehanna River, Kiskiminetas River, and Casselman River basins in Pennsylvania; North Branch Potomac River basin in Maryland; Monongahela River basin in Pennsylvania and West Virginia; and Raccoon Creek basin in Ohio.

Regardless of size or degree of acidity, all streams affected by mine drainage are ultimately neutralized by the inflow of alkaline water.

Future regional studies should be designed to provide data for better definition of: (1) the significance of mine drainage upon stream quality during low-flow conditions, (2) types of hydrologic environment that produce sudden flushes of mine water to streams which normally contain relatively little mine water, and (3) the geologic and hydrologic factors contributing to high alkalinity of affected streams within isolated parts of the region.

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BASIC DATA

Table 6.—*Field determinations and laboratory analyses (in parts per million except as indicated) for stream samples, May 1965*

This table includes all field and laboratory determinations, data and time of sample collection, and location and drainage area of sampling sites. The data are listed according to State. This will offer a convenient reference to any water managers or resource agencies interested in specific results. Field and laboratory pH values are both shown in the table. Examination of the data shows some differences between these two values. This difference is observed frequently and may be explained by several factors. Hydrolysis during sample storage and changes in carbon dioxide equilibrium between the sample and the atmosphere are predominant factors in this change. Again, having both of these values realizes maximum utility of the data and reveals any change in pH during storage and the direction and magnitude of the change.

Water-resources agencies agree the first end point in the acidity determination should be pH 4.5. The titration to 4.5 essentially represents free mineral acidity. However, there are various methods suggested for determining the acidity remaining above pH 4.5. The U.S. Geological Survey (Rainwater and Thatcher, 1960, p. 87–92) suggests an end point of pH 7.0. The American Public Health Association (1960, p. 42, 43) suggests an end point of pH 8.3. Because of these differences, it was decided to use both suggested final end points for the acidity determination. Having both of these values allows comparison of previous information and assists in realizing maximum utility of the data.

Applachia map no.	USGS station	Stream sampling site and drainage area, in square miles (in parenthesis)	Date	Time	Field determination: Water discharge (cfs)	pH	Water temperature (°F)	Dissolved oxygen: Concentration, ppm	Dissolved oxygen: Percent saturation	Acid concentration to indicate pH, (as H_2SO_4): 4.5	7.0	8.3	Laboratory analyses: Aluminum (Al)	Total iron (Fe)	Total manganese (Mn)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Phosphate (PO_4)	Nitrate (NO_3)	Hardness as $CaCO_3$: Calcium, magnesium	Noncarbonate	Potential free acidity to pH 8.3 as H_2SO_4	Specific conductance (micromhos at 25°C)	pH	Color
		PENNSYLVANIA [See pl. 1 for map number] Susquehanna River basin																								
1	1–5415	Clearfield Creek at Dimeling, Pa. (371).	5–18–65	0800	295	3.50	57	8.9	86	20	44	49	4.0	1.6	2.7	0	207	4.5	0.00	1.0	169	169	44	507	3.75	5
2	1–5423	Moshannon Creek (near mouth) near Moshannon, Pa. (255).	5–17–65	1030	291	2.85	62	8.2	84	83	110	120	8.8	9.4	3.6	0	301	3.5	.00	.8	190	190	110	810	3.20	5
3	1–5450	Kettle Creek near Westport, Pa. (233).	5–17–65	1400	450	7.6	60	9.2	92	----	----	----	.2	.02	.21	19	18	2.0	.00	.1	30	15	----	77	6.9	2
4	1–5427.9	Bennett Branch Sinnemahoning Creek (near mouth) at Driftwood, Pa. (350).	5-18-65	1030	508	3.65	60	9.3	93	9.8	20	20	1.4	.81	.51	3	59	3.0	.05	.4	51	48		152	5.5	5
5	1–5455	West Branch Susquehanna River at Renovo, Pa. (2975).	5–18–65	1230	4,000	4.25	66	8.0	86	0	9.8	9.8	.8	.38	.57	6	47	2.4	.00	.0	47	42	----	130	6.2	6
6	1–5479.9	Beech Creek (near mouth) at Beech Creek, Pa. (172).	5–17–65	1730	285	4.20	60	9.2	92	4.9	15	20	1.6	.20	1.2	3	59	1.4	.02	.4	49	47	4.9	147	5.2	5
7	1–5484.3	Babb Creek at Blackwell, Pa. (129).	5–18–65	1530	131	7.0	66	8.1	87	----	----	----	.9	.50	.43	5	45	3.0	.00	.1	41	37	----	124	6.8	2
8	1–5480.82	North Bald Eagle Creek below Fishing Creek at Mill Hall, Pa. (106).	5–17–65	1630	771	6.6	61	9.1	91	----	----	----	.2	.02	.16	81	25	3.3	.02	.8	86	20	----	190	7.6	8
9	1–5163	Tioga River at Covington, Pa. (106)	5–18–65	1730	129	4.10	67	7.8	85	4.9	24	39	4.1	2.6	1.5	0	95	5.5	.00	.7	65	65	29	246	4.10	5
10	1–5360	Lackawanna River at Old Forge, Pa. (332).	5–19–65	0900	212	6.2	65	6.3	66	----	----	----	.2	.16	.95	28	102	9.7	.05	.3	109	86	----	308	6.9	12
11	1–5365	Susquehanna River at Wilkes-Barre, Pa. (9,960).	5–19–65	1030	7,600	7.4	68	7.5	82	----	----	----	.1	.06	.35	56	65	8.6	.10	.2	105	59	----	253	7.1	10
12	1–5386	Nescopeck Creek (near mouth) at Nescopeck, Pa. (170).	5–19–65	1330	179	3.60	65	7.6	80	20	69	74	8.8	1.2	3.1	0	203	4.5	.00	.3	142	142	59	425	4.10	4
13	1–5403.5	Catawissa Creek (near mouth) at Catawissa, Pa. (150).	5–19–65	1600	126	4.25	68	7.9	86	4.9	24	29	3.2	.16	.57	0	62	3.5	.00	.1	46	46	15	162	4.6	5
14	1–5545	Shamokin Creek at Weigh Scale, Pa. (54.2).	5–19–65	1645	124	4.7	68	----	----	0	120	150	2.0	37	6.2	0	598	8.0	.00	.3	506	506	110	1,430	4.45	10
15	1–5552.52	Mahanoy Creek (near mouth) near Dornsife, Pa. (150).	5–19–65	1815	135	6.4	71	7.2	80	----	----	----	.2	.00	7.8	26	891	6.5	.00	1.9	892	871	----	1,510	7.5	4
16	1–5555	East Mahantango Creek near Dalamatia, Pa. (162).	5–20–65	0850	71.5	6.8	64	7.8	82	----	----	----	.5	.11	1.0	9	70	3.5	.00	1.2	70	63	----	186	6.5	6
17	1–555.6	Wiconisco Creek at Loyalton, Pa. (60.7).	5–20–65	0915	62.5	6.8	58	8.5	84	----	----	----	.2	.06	.21	30	44	2.0	.00	.3	62	38	----	161	6.8	5
18	1–5718	Swatara Creek at Ravine, Pa. (43.3)	5–20–65	1050	34	4.6	60	9.0	90	0	15	24	1.8	4.7	1.7	0	165	3.5	.00	.1	241	150	20	371	4.15	4
50	1–5407	West Branch Susquehanna River at McGees Mills, Pa. (102).	5–19–65	1330	74	5.2	67	8.6	94	0	4.9	9.8	.7	.18	1.2	3	354	5.5	.00	.9	303	300	9.8	706	4.85	7
51	1–5410	West Branch Susquehanna River at Bower, Pa. (315).	5–19–65	1200	192	6.8	65	8.6	90	----	----	----	.2	.03	.51	9	190	6.5	.00	1.2	173	165	----	440	6.3	7

52	----------	Trough Creek at Trough Creek, Pa.	5-20-65	1230	41	6.3	66	8.8	94	----	----	----	.2	.08	.00	10	17	2.1	.00	.7	22	14	----	61	6.3	7
53	1-5630	Raystown Branch Juniata River near Huntingdon, Pa. (957).	5-20-65	1045	2,900	8.0	66	7.8	83	----	----	----	.2	.09	.00	56	33	4.3	.00	.6	76	30	----	176	7.1	15
54	1-5558.4	Burgoon Run (Hwy. 764) at Eldorado, Pa. (15.1).	5-20-65	0710	8.0	3.10	56	9.0	85	110	160	170	16	16	5.4	0	332	4.5	.00	1.4	158	158	170	988	2.90	5

Allegheny River basin

24	3-420	Blacklick Creek at Josephine, Pa. (192).	5-20-65	1825	129	2.95	71	7.5	85	170	240	250	35	9.0	2.2	0	569	9.5	.00	1.2	224	224	270	1,450	2.85	5
25	3-425	Two Lick Creek at Graceton, Pa. (171).	5-20-65	1910	65	3.25	70	5.8	65	93	150	160	16	17	2.4	0	469	17	.00	.6	258	258	150	1,160	3.00	5
26	3-450	Loyalhanna Creek at Kingston, Pa. (172).	5-20-65	1655	168	8.7	67	9.0	98	----	----	----	.2	.08	.81	28	32	4.3	.00	.6	52	29	----	124	6.9	8
27	3-470	Loyalhanna Creek at Loyalhanna Creek Dam, Pa. (292).	5-21-65	0800	214	3.70	67	8.0	87	9.8	20	20	.9	1.9	2.1	0	244	11	.00	1.1	93	193	24	589	3.60	8
28	3-485	Kiskiminetas River at Vandergrift, Pa. (1,825).	5-21-65	1010	1,312	3.30	70	8.0	89	34	64	69	7.2	2.1	6.7	0	320	14	.00	1.6	224	224	74	778	3.40	5
29	3-160	Allegheny River at West Hickory, Pa. (3,660).	5-22-65	1605	3,516	9.0	69	10.4	116	----	----	----	.2	.19	.00	49	16	21	.00	.0	57	17	----	178	7.1	16
30	3-175	Tionesta Creek at Lynch, Pa. (233).	5-22-65	1435	217	8.6	61	10.6	107	----	----	----	.3	.23	.00	16	10	4.4	.00	.2	19	6	----	60	6.8	9
31	3-240	French Creek at Utica, Pa. (1,028).	5-23-65	1015	674	7.9	65	9.1	95	----	----	----	.3	.25	.00	82	19	6.9	.00	.4	85	18	----	191	7.1	17
32	3-205	Oil Creek at Rouseville, Pa. (300).	5-23-65	0905	186	8.2	65	10.0	105	----	----	----	.2	.24	.00	70	16	20	.00	.0	74	17	----	208	7.0	9
33	3-291.7	Toby Creek (near mouth) near Carman, Pa. (123).	5-22-65	0900	125	4.50	60	9.2	92	0	9.8	9.8	1.6	.25	2.5	0	155	3.5	.00	.5	143	143	20	348	4.6	3
34	3-295	Clarion River at Cooksburg, Pa. (807).	5-22-65	0730	878	6.6	59	8.7	86	----	----	----	.2	.09	.00	8	37	10	.00	.0	43	36	----	134	6.2	16
35	3-285	Clarion River at Johnsonburg, Pa. (204).	5-22-65	1250	202	5.6	72	4.6	52	0	9.8	20	1.0	.45	.62	16	79	124	.00	2.0	177	164	4.9	612	5.5	100
36	3-325	Redbank Creek at St. Charles, Pa. (528).	5-21-65	1705	267	7.3	67	9.0	98	----	----	----	.3	.05	.71	6	9.5	10	.00	.4	96	91	----	258	6.3	5
37	3-360	Mahoning Creek at Mahoning Creek Dam, Pa. (344).	5-21-65	1815	145	7.5	65	8.8	92	----	----	----	.4	.09	.08	30	112	12	.00	.2	115	90	----	328	6.7	5
38	3-365	Allegheny River at Kittanning, Pa. (8,973).	5-21-65	1335	9,860	7.9	67	10.6	116	----	----	----	.3	.12	.21	33	30	15	.00	.0	61	34	----	178	6.8	9
39	3-380	Crooked Creek at Idaho, Pa. (191).	5-21-65	1125	30	3.65	61	8.6	86	29	59	59	5.8	4.3	1.3	0	327	22	.00	.4	195	195	64	788	3.50	4
40	3-490	Buffalo Creek near Freeport, Pa. (137).	5-21-65	1525	21	7.8	67	9.4	103	----	----	----	.2	.05	.02	54	106	32	.00	.2	148	103	----	413	6.9	7

Ohio River basin

41	3-855	Charties Creek at Carnegie, Pa. (257).	5-17-65	0730	110	6.1	65	6.7	70	----	----	----	0.4	2.0	2.5	34	728	74	.00	4.2	495	467	----	1,590	6.6	10
42	3-1080	Raccoon Creek at Moffatts Mill, Pa. (178).	5-17-65	1145	52	4.05	67	8.5	93	15	93	110	15	.85	7.6	0	867	72	.00	7.8	712	712	100	1,520	3.80	4
43	3-860	Ohio River at Sewickley, Pa. (19,500).	5-17-65	0930	18,020	6.7	68	7.8	85	----	----	----	2.2	.11	.69	17	81	12	.00	1.5	80	66	----	255	6.6	10
44	3-1060.5	Slippery Rock Creek near Liberty, Pa. (159).	5-18-65	1030	65	6.6	64	8.3	87	----	----	----	.2	.16	1.8	8	181	14	.00	.8	186	180	----	432	6.3	5
45	3-1065	Slippery Rock Creek at Wartemburg, Pa. (398).	5-17-65	1340	155	7.8	66	8.6	92	----	----	----	.2	.14	.23	52	137	12	.00	.8	171	129	----	398	7.2	7
46	3-1060	Connoquenessing Creek at Hazen, Pa. (356).	5-18-65	0730	102	7.6	61	6.6	66	----	----	----	.3	.08	.45	62	154	49	.03	8.0	210	159	----	593	7.0	8
47	3-1035	Shenango River at Sharpsville, Pa. (588).	5-18-65	1715	324	7.5	66	7.6	81	----	----	----	.6	.95	.22	73	34	7.5	.00	1.3	90	30	----	217	7.0	12
48	3-1046.9	Neshannock Creek at Neshanneck Falls, Pa. (154).	5-18-65	1430	215	8.5	67	8.6	94	----	----	----	.2	.09	.04	68	69	5.5	.00	2.4	125	69	----	278	7.0	20
49	3-1075	Beaver River at Beaver Falls, Pa. (3,106).	5-17-65	----	1,246	7.3	75	5.6	66	----	----	----	.3	.05	.39	54	152	36	.00	3.5	189	145	----	534	6.7	15

Monongahela River basin

60	3-786.8	Casselman River at Myersdale, Pa. (172).	5-18-65	1900	82	3.35	72	7.5	86	25	44	49	3.4	4.8	1.4	0	138	4.0	.00	0.3	102	102	44	397	3.70	5
61	3-790	Casselman River at Markleton, Pa. (382).	5-18-65	1250	230	3.80	70	7.6	84	9.3	20	24	1.5	.60	1.3	0	133	5.0	.00	.4	122	122	24	337	4.15	3
62	3-800	Laurel Hill Creek at Ursina, Pa. (121).	5-18-65	0950	71	6.9	64	9.0	95	----	----	----	.4	.14	.00	15	12	2.6	.00	.7	23	11	----	60	6.9	3
63	3-810	Youghiogheny River below Confluence, Pa. (1,029).	5-18-65	0800	705	5.9	46	10.8	91	0	.5	2.4	.2	.08	.05	6	17	4.0	.00	3.0	22	17	----	68	6.9	2
64	3-831	Jacobs Creek near Jacobs Creek, Pa. (95).	5-17-65	1500	94	7.1	71	8.0	91	----	----	----	.25	.07	.64	37	122	12	.00	2.2	148	118	----	368	7.2	5

Table 6.—*Field determinations and laboratory analyses (in parts per million except as indicated) for stream samples, May 1965*—Continued

Appalachia map no.	USGS station	Stream sampling site and drainage area, in square miles (in parenthesis)	Date	Time	Field determination: Water discharge (cfs)	Field: pH	Field: Water temperature (°F)	Field: Dissolved oxygen: Concentration, ppm	Field: Dissolved oxygen: Percent saturation	Field: Acid concentration to indicate pH, (as H_2SO_4): 4.5	Acid conc.: 7.0	Acid conc.: 8.3	Laboratory analyses: Aluminum (Al)	Total iron (Fe)	Total manganese (Mn)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Phosphate (PO_4)	Nitrate (NO_3)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Potential free acidity to pH 8.3 as H_2SO_4	Specific conductance (micromhos at 25°C)	pH	Color
		Monongahela River basin—Continued																								
65	3–834	Sewickley Creek near Sutersville, Pa. (167).	5–17–65	1240	109	4.9	71	4.0	45	0	64	78	3.3	12	2.8	0	779	29	0.00	1.4	487	487	59	1,490	3.25	2
66	3–835	Youghiogheny River at Sutersville, Pa. (1,715).	5–17–65	1120	1,300	6.2	67	7.8	85	------	------	------	.2	1.8	.50	8	99	6.0	.00	1.5	88	82	-----	268	6.8	5
67	3–720	Dunkard Creek at Shannopin, Pa. (229).	5–21–65	1030	49	3.55	67	7.6	83	17	49	54	3.8	5.1	.88	0	363	22	.00	.6	209	209	39	849	3.60	4
68	3–725	Monongahela River at Greensboro, Pa. (4,407).	5–21–65	0805	860	3.65	68	7.9	86	17	34	39	2.0	.79	.87	0	204	4.3	.00	.3	142	142	49	511	3.70	5
69	3–730	South Fork Tenmile Creek at Jefferson, Pa. (180).	5–20–65	1500	48	7.3	72	8.8	101	------	------	------	.2	.08	.22	120	45	14	.24	1.7	129	31	-----	319	7.3	5
70	3–745	Redstone Creek at Waltersburg, Pa. (73.7).	5–20–65	1110	31	6.1	63	0	0	------	------	------	8.4	15	6.7	0	1,530	18	.00	.5	1,080	1,080	-----	2,410	3.80	4
71	3–750	Monongahela River at Charleroi, Pa. (5,213).	5–20–65	0830	2,720	4.5	69	9.5	106	0	9.8	15	.75	.12	.3	3	201	7.0	.00	1.2	147	145	9.8	487	5.0	5
72	3–849	Turtle Creek near (at mouth) Turtle Creek, Pa. (143).	5–17–65	0800	93	3.90	66	4.6	43	6.9	44	59	2.5	15	3.0	0	663	31	.00	2.8	439	439	34	1,350	3.50	3
73	3–394.7	Quemahoning Creek below Quemahoning Reservoir (97.8).	5–19–65	1100	1.42	4.6	66	8.4	89	------	24	29	1.5	.08	1.4	0	157	6.0	.00	1.6	149	149	20	373	4.85	3
74	3–394.2	Stony Creek above Confluence with Quemahoning Creek (145).	5–19–65	0820	69	3.70	62	8.7	90	11	24	29	1.9	.69	1.1	0	190	6.0	.00	.2	175	175	39	459	3.90	4
75	3–396	Shade Creek at Seanor, Pa. (96.8).	5–19–65	1300	111	3.40	67	7.8	85	25	39	44	1.5	3.5	1.4	0	128	2.0	.00	.1	100	100	44	385	3.70	3
76	3–410	Little Conemaugh River at East Conemaugh, Pa. (183).	5–19–65	1600	134	3.05	68	3.2	29	130	230	240	4.7	12	5.1	0	767	7.5	.00	2.0	511	511	230	1,640	2.80	4
		Delaware River basin																								
19	1–4690	Schuylkill River at Auburn, Pa. (160).	5–20–65	1300	134	4.35	70	7.9	88	0	15	20	1.1	0.18	4.6	0	332	10	0.00	0.8	308	308	9.8	690	4.8	4
20	1–4700	Little Schuylkill River at Drehersville, Pa. (122).	5–20–65	1500	99	3.85	71	8.2	93	9.8	29	34	3.4	.91	2.8	0	321	5.5	.00	4.7	285	285	29	676	4.05	4
21	1–4710	Tulpehocken Creek near Reading, Pa. (211).	5–21–65	1015	83	7.4	62	8.4	86	------	------	------	.3	.33	.03	165	32	12	.28	8.0	171	36	-----	375	7.5	9
22	1–4500	Pohopoco Creek near Parryville, Pa. (109).	5–20–65	1815	84	7.6	71	8.4	95	------	------	------	.6	.67	.00	13	5.9	4.0	.00	.4	15	5	-----	47	6.6	4
23	1–4510	Lehigh River at Walnutport, Pa. (889).	5–21–65	0915	900	7.1	61	8.3	83	------	------	------	.4	.27	.28	13	30	4.0	.00	.3	34	24	-----	106	6.8	5
		OHIO [See pl. 1 for map number]																								
55	3–1100	Yellow Creek near Hammondsville, Ohio (148).	5–23–65	1130	28.6	6.1	67	8.8	96	------	------	------	0.20	1.2	0.64	9	245	25	0.00	0.4	203	196	-----	601	6.4	4
56	3–1110	Cross Creek at Mingo Junction, Ohio (127).	5–23–65	0915	56	7.1	66	8.8	94	------	------	------	.2	.00	.78	110	616	17	.00	.4	700	610	-----	1,260	7.7	7
57	3–1115.5	Wheeling Creek at Brookside, Ohio (103).	5–22–65	1400	54.3	7.9	77	10	110	------	------	------	.8	.00	.63	149	1,160	13	0.00	.6	929	807	-----	2,090	8.0	3
58	3–1140	Captina Creek at Armstrong Mills, Ohio (135).	5–22–65	1045	30.5	7.9	68	9.4	102	------	------	------	.24	.01	.00	184	50	7.6	.00	.1	187	36	-----	391	8.0	5
59	3–1142.5	Sunfish Creek at Cameron, Ohio (98.8).	5–22–65	0730	25	7.5	63	8.8	109	------	------	------	.2	.18	.00	134	43	17	.00	.4	145	35	-----	338	7.8	3
80	3–1154	Little Muskingum River at Bloomfield, Ohio (210).	5–19–65	1245	56.7	7.8	69	7.2	80	------	------	------	.0	.00	.10	137	30	28	.03	.0	154	42	-----	368	7.7	4

81	----------	West Fork Duck Creek near Macksburg, Ohio (84.5).	5–19–65	1015	17.9	6.2	68	7.6	83	------	------	------	.1	.14	4.3	42	468	12	.00	.2	516	481	------	958	6.8	3
82	3–1158	Duck Creek at Stanleyville, Ohio (268).	5–19–65	0745	68.7	7.5	67	7.8	85	------	------	------	.1	.00	2.4	83	305	8.0	.00	.2	384	316	------	740	7.6	2
83	----------	Conotton Creek near New Cumberland, Ohio (162).	5–17–65	1300	96.5	7.6	62	6.7	69	------	------	------	.0	.06	.46	69	76	10	.00	.9	136	80	------	317	7.3	7
84	3–1245	Sugar Creek at Strasburg, Ohio (310).	5–17–65	1030	60.8	7.9	66	8.0	85	------	------	------	.0	.00	.90	127	213	17	.00	1.1	318	214	------	656	7.5	10
85	3–1275	Stillwater Creek at Uhrichsville, Ohio (367).	5–17–65	1500	12.8	7.6	65	8.6	91	------	------	------	.1	.02	.17	110	193	7.0	.01	.3	280	190	------	583	7.6	5
86	3–1390	Killbuck Creek at Killbuck, Ohio (466).	5–17–65	0810	148	7.6	64	6.1	64	------	------	------	.0	.02	.20	182	51	24	.19	2.4	230	81	------	467	7.6	6
87	3–1435	Wills Creek below Wills Creek Dam, Ohio (845).	5–17–65	1845	302	7.8	69	8.2	91	------	------	------	.1	.00	.34	112	130	10	.01	.1	211	119	------	478	7.8	5
88	3–1475	Licking River below Dillon Dam, Ohio (748).	5–18–65	0900	305	7.9	68	6.9	75	------	------	------	.1	.02	.13	169	60	22	.01	.9	203	64	------	454	7.7	7
89	3–1486	Moxahala Creek near Zanesville, Ohio (300).	5–18–65	1100	116	3.45	67	7.7	84	47	120	130	16	5.5	13	0	762	30	.00	.4	740	740	140	1,470	3.90	2
90	----------	Jonathan Creek near White Cottage, Ohio (162).	5–18–65	1345	51.5	6.9	68	7.7	84	------	------	------	.1	.04	6.0	65	338	28	.00	.3	410	357	------	833	7.2	2
91	----------	Jonathan Creek near Mount Perry, Ohio (115).	5–18–65	1515	34.2	8.3	71	8.6	98	------	------	------	.1	.00	.09	144	114	16	.02	.4	246	128	------	501	7.9	5
92	----------	Meigs Creek (near mouth) near Beverly, Ohio (136).	5–18–65	1815	56.4	8.1	71	7.5	85	------	------	------	.2	.00	.10	216	356	6.0	.01	.3	516	339	------	960	7.9	5
93	3–1575	Hocking River at Enterprise, Ohio (459).	5–20–65	0820	146	7.8	65	7.0	74	------	------	------	.0	.09	1.5	178	127	36	.22	.2	290	144	------	643	7.6	15
94	----------	Monday Creek near Greendale, Ohio (61.0).	5–20–65	1000	12.9	3.45	64	7.2	76	54	130	140	16	5.9	9.3	0	642	122	.01	.2	614	614	140	1,590	3.80	2
95	3–1582	Monday Creek at Doanville, Ohio (114).	5–20–65	1145	34.5	3.20	64	5.9	62	120	260	270	34	20	8.0	0	870	45	.00	1.0	660	660	300	1,850	3.30	3
96	3–1590	Sunday Creek near Glouster, Ohio (104).	5–20–65	1400	13.6	3.50	67	----	------	83	190	250	13	77	7.4	0	890	40	.00	2.3	660	660	250	2,180	3.20	5
97	3–1595.2	Federal Creek near Stewart, Ohio (136).	5–19–65	1815	19.5	8.0	70	8.0	89	------	------	------	.1	.66	.19	178	146	42	.00	.1	306	160	------	704	7.9	5
98	3–1595.5	Shade River at Keno, Ohio (160).	5–19–65	1630	53.6	6.7	68	7.5	82	------	------	------	.1	.02	2.7	22	169	13	.01	.8	192	174	------	448	7.0	10
99	3–2019	Raccoon Creek near Prattsville, Ohio (200).	5–20–65	1715	34.9	3.60	65	7.8	83	42	100	110	12	3.4	6.0	0	271	102	.00	.1	232	232	88	956	4.00	2
100	----------	Elk Fork near Oreton, Ohio (59.7).	5–21–65	0830	19.6	4.35	62	7.8	80	------	24	29	3.3	.74	2.9	2	149	10	.00	1.3	142	141	24	385	4.8	2
101	----------	Little Raccoon Creek near Vinton, Ohio (154).	5–21–65	1030	39.6	4.25	64	7.7	81	4.9	29	39	3.9	.44	2.7	0	148	6.0	.00	.3	122	122	29	378	4.5	2
102	3–2055	Symmes Creek at Getaway, Ohio (335).	5–21–65	1400	39.5	7.2	66	7.6	81	------	------	------	.1	.06	.75	44	59	29	.00	.4	107	71	------	313	7.3	5
103	3–2167	Little Scioto River at Sciotoville, Ohio (223).	5–21–65	1630	21.0	7.3	69	7.8	87	------	------	------	.1	.22	.11	38	36	13	.01	1.3	63	32	------	187	7.1	15
104	3–2315	Scioto River at Chillicothe, Ohio (3,849).	5–23–65	1315	948	7.7	74	3.1	36	------	------	------	.2	.36	.12	264	107	30	3.1	11	332	115	------	718	7.3	34
105	3–2340	Paint Creek near Bourneville, Ohio (807).	5–22–65	1445	374	8.2	70	6.8	76	------	------	------	.1	.00	.02	252	52	14	.18	10	282	75	------	543	7.7	8
106	----------	Salt Creek at Richmond Dale, Ohio (548).	5–23–65	1115	92.1	7.9	71	6.0	68	------	------	------	.1	.08	.14	120	34	9.0	.00	.9	134	36	------	302	7.5	5
107	3–2370.5	Sunfish Creek near Piketon, Ohio (144).	5–22–65	1730	24.1	7.5	72	6.8	77	------	------	------	.1	.12	.06	58	41	72	.00	.8	124	76	------	423	7.2	5
108	3–2375	Ohio Brush Creek near West Union, Ohio (387).	5–21–65	1900	37.3	8.2	72	7.4	84	------	------	------	.1	.00	.04	238	40	8.0	.00	.2	240	45	------	447	7.7	4
109	3–2385	Whiteoak Creek near Georgetown, Ohio (222).	5–22–65	0830	11.2	8.1	69	6.9	77	------	------	------	.1	.02	.06	220	52	12	.36	.4	236	56	------	474	7.8	5
110	3–2475	East Fork Little Miami River at Perintown, Ohio (476).	5–22–65	-----	49.6	8.4	74	7.6	88	------	------	------	.1	.00	.05	224	49	14	.02	.5	240	56	------	481	7.7	6

MARYLAND

[See pl. 1 for map number]

Monongahela River basin

111	3–766	Bear Creek near Friendsville, Md. (48.9).	5–18–65	1055	27	8.5	60	9.8	98	------	------	------	0.0	0.03	0.00	23	8.4	4.0	0.06	-----	21	2	------	66	7.0	0
112	3–755	Youghiogheny River near Oakland, Md. (134).	5–18–65	1230	76	6.4	66	8.0	85	------	------	------	.2	.50	.15	12	28	1.5	.03	-----	28	18	------	92	6.7	0
113	3–780	Casselman River at Grantsville, Md. (62.5).	5–18–65	0935	35	7.5	64	6.5	68	------	------	------	.1	.20	.00	25	26	5.2	3.1	-----	42	22	------	122	6.2	5

Table 6.—*Field determinations and laboratory analyses (in parts per million except as indicated) for stream samples, May 1965*—Continued

Appalachia map no.	USGS station	Stream sampling site and drainage area, in square miles (in parenthesis)	Date	Time	Field determination: Water discharge (cfs)	Field determination: pH	Field determination: Water temperature (°F)	Field determination: Dissolved oxygen: Concentration, ppm	Field determination: Dissolved oxygen: Percent saturation	Field determination: Acid concentration to indicate pH, (as H_2SO_4): 4.5	Field determination: Acid concentration to indicate pH, (as H_2SO_4): 7.0	Field determination: Acid concentration to indicate pH, (as H_2SO_4): 8.3	Laboratory analyses: Aluminum (Al)	Laboratory analyses: Total iron (Fe)	Laboratory analyses: Total manganese (Mn)	Laboratory analyses: Bicarbonate (HCO_3)	Laboratory analyses: Sulfate (SO_4)	Laboratory analyses: Chloride (Cl)	Laboratory analyses: Phosphate (PO_4)	Laboratory analyses: Nitrate (NO_3)	Laboratory analyses: Hardness as $CaCO_3$: Calcium, magnesium	Laboratory analyses: Hardness as $CaCO_3$: Noncarbonate	Laboratory analyses: Potential free acidity to pH 8.3 as H_2SO_4	Laboratory analyses: Specific conductance (micromhos at 25°C)	Laboratory analyses: pH	Laboratory analyses: Color
		Potomac River basin																								
114	1–5950	North Branch Potomac River at Steyer, Md. (73.0).	5–18–65	1335	39	4.10	71	7.9	90	15	39	59	3.7	2.4	1.1	0	135	2.0	0.11	----	50	50	39	331	3.5	0
115	1–5955	North Branch Potomac at Kitzmiller, Md. (225).	5–18–65	1600	105	4.30	72	7.7	88	9.8	29	39	1.7	.40	.66	0	97	2.2	.07	----	76	76	-----	218	4.6	0
116	1–5975	Savage River below Savage River Dam near Bloomington, Md.(106).	5–18–65	1600	47	8.0	63	8.5	88	------	-----	-----	.0	.00	.00	20	13	2.0	.08	----	22	6	-----	66	7.2	5
117	1–6030	North Branch Potomac River near Cumberland, Md. (875).	5–18–65	1900	450	8.5	73	9.6	94	------	-----	-----	.0	.02	.16	64	122	14	.03	----	164	112	-----	378	7.4	5
118	1–5990	Georges Creek at Franklin, Md. (72.4).	5–18–65	1750	41	5.6	69	7.7	86	0	29	39	2.1	.25	1.5	2	374	4.0	.02	----	344	342	-----	685	4.7	0
119	1–6015	Wills Creek near Cumberland, Md. (247).	5–18–65	0750	152	7.9	59	9.6	94	------	-----	-----	.00	.00	.40	40	195	4.0	.04	----	232	199	-----	462	7.1	0
		WEST VIRGINIA [See pl. 1 for map number] Ohio River basin																								
77	03A–1113.00	Buffalo Creek at Wellsburg, W. Va. (161).	5–22–65	1800	40.2	7.7	73	7.9	91	------	-----	-----	0.25	0.07	0.00	167	137	13	0.00	0.8	256	119	-----	560	8.1	4
78	03A–1145.00	Middle Island Creek at Little, W. Va. (458).	5–21–65	1600	69.4	6.6	71	8.0	91	------	-----	-----	.2	.03	.00	48	20	17	.00	.6	57	18	-----	180	7.2	7
79	03A–1120.00	Wheeling Creek at Elm Grove, W. Va. (282).	5–22–65	1600	53.2	8.1	77	8.8	105	------	-----	-----	.6	.27	.09	134	74	8.0	.00	.1	171	61	-----	366	8.0	5
163	03A–1596.50	Sandy Creek at Silverton, W. Va. (119).	5–22–65	0730	5.06	7.2	68	8.0	87	------	-----	-----	.0	.03	.18	100	18	6.0	.02	.1	84	2	-----	221	7.4	12
169	03A–1598.20	Little Mill Creek at Millwood, W. Va. (12.0).	5–22–65	0830	.42	7.2	67	5.5	60	------	-----	-----	.1	.04	.22	167	23	7.5	.01	.1	140	3	-----	332	7.4	12
		Monongahela River basin																								
120	03A–0505.00	Tygart Valley River near Elkins, W. Va. (27.2).	5–20–65	0830	82	7.0	68	7.6	83	------	-----	-----	0.0	0.18	0.00	40	7.2	1.5	0.01	----	30	0	-----	81	7.2	5
121	03A–0508.00	Roaring Creek at Norton, W. Va. (29.2).	5–20–65	0930	14	4.10	60	8.0	80	15	54	59	3.3	2.3	1.3	0	93	.0	.03	----	54	54	44	311	3.5	0
122	03A–0520.00	Middle Fork at Audra, W. Va. (149).	5–20–65	1045	72	8.0	69	7.4	82	------	-----	-----	.0	.00	.00	14	7.6	.0	.06	----	9	0	-----	25	7.3	0
123	03A–0535.00	Buckhannon River at Hall, W. Va. (277).	5–20–65	1120	92	-----	72	7.8	90	------	-----	-----	1.1	.05	.84	0	66	2.0	.03	----	52	52	24	167	4.5	0
124	03A–0545.00	Tygart Valley River at Philippi, W. Va. (916).	5–20–65	1300	323	5.1	72	7.9	91	0	9.8	20	.1	.10	.22	2	44	.2	.03	----	40	38	-----	112	5.1	0
125	03A–0552.00	Sandy Creek at Claude, W. Va. (76.7).	5–22–65	1130	9.2	3.50	67	7.1	77	59	120	130	8.8	4.0	.70	0	158	.0	.03	----	66	66	93	522	3.2	0
126	03A–0562.00	Threefork Creek at Thorton, W. Va. (90.9).	5–22–65	1030	23.2	3.8	66	7.7	82	34	93	100	5.9	2.1	1.4	0	219	.0	.06	----	132	132	78	523	3.4	0
127	03A–0570.00	Tygart Valley River at Colfax, W. Va. (1,366).	5–21–65	1115	290	5.6	66	8.7	91	0	15	29	.5	.05	.28	1	41	1.1	.02	----	33	32	-----	110	4.7	0
128	03A–0580.00	West Fork River at Brownsville, W. Va. (102).	5–21–65	1840	18	7.5	74	4.3	50	------	-----	-----	.0	.06	.16	25	51	5.2	.01	----	74	54	-----	172	6.8	5
129	03A–0590.00	West Fork River at Clarksburg, W. Va. (384).	5–21–65	1720	88	8.2	71	8.2	93	------	-----	-----	.0	.05	.49	39	250	4.0	6.3	----	260	228	-----	555	7.0	5

130	03A–0595.00	Elk Creek at Quiet Dell, West Va. (84.6).	5–21–65	1630	18	3.70	68	8.2	89	29	69	83	4.6	1.0	3.2	0	922	8.0	.00	----	745	745	54	1,640	3.6	0
131	03A–0607.00	Tenmile Creek at Lumberport, W. Va. (125).	5–21–65	1510	29.3	3.70	68	7.2	78	34	78	88	1.6	9.3	2.4	0	700	5.0	.03	----	508	508	54	1,320	3.3	0
132	03A–0597.00	Simpson Creek at Meadowbrook, W. Va. (73.6)	5–22–65	0855	35	3.30	64	8.1	85	190	350	380	27	54	7.5	0	1,360	.0	.12	----	850	850	310	2,400	2.8	35
133	03A–0610.00	West Fork River at Enterprise, W. Va. (759).	5–21–65	1400	272	3.60	70	6.0	67	49	120	140	6.2	10	3.0	0	755	5.0	.00	----	560	560	88	1,420	3.2	0
134	03A–0613.25	Booth Creek at Monongah, W. Va. (44.4).	5–21–65	1310	6.9	5.4	66	7.6	81	0	29	39	2.0	.07	1.7	1	321	2.4	.00	----	296	295	-----	655	4.6	0
135	03A–0625.00	Decker Creek at Morgantown, W. Va. (63.2).	5–21–65	1000	15	4.6	64	7.1	75	0	78	93	6.4	11	1.2	0	274	4.0	.01	----	210	210	59	555	4.2	0
136	03A–0550.42	Laurel Creek near Philippi, W. Va. (45.6).	5–20–65	1415	2.4	8.2	72	8.1	93	------	-----	-----	.0	.13	.00	13	28	.5	.03	----	35	24	-----	90	6.9	5
Potomac River basin																										
137	01B–6085.00	South Branch Potomac River near Springfield, W. Va. (1,471)	5–19–65	0550	716	7.7	69	7.4	82	------	-----	-----	0.0	0.00	0.00	103	20	2.2	0.03	----	90	6	-----	182	7.8	7
138	01B–6165.00	Opequon Creek near Martinsburg, W. Va. (272)	5–19–65	0900	125	8.1	64	7.3	77	------	-----	-----	.0	.00	.00	286	28	10	.54	----	260	25	-----	462	7.9	5
139	-----------	Meadow Creek near Berkeley County line W. Va.	5–19–65	1045	9.6	8.0	62	9.0	93	------	-----	-----	.0	.17	.00	21	6.8	.5	.04	----	14	0	-----	47	7.3	5
140	01B–5953.00	Abram Creek near Oakmont, W. Va. (47.3).	5–18–65	1520	22	5.5	69	8.0	89	------	20	24	1.0	.10	.59	7	61	3.5	.11	----	57	51	-----	160	6.8	0
141	01B–5952.00	Stony River near Mount Storm, W. Va. (48.8).	5–22–65	1515	9.2	8.0	73	8.1	93	------	-----	-----	.0	.40	.00	15	8.8	1.4	.00	----	19	7	-----	47	7.0	10
142	03A–0650.00	Dry Fork at Hendrick, W. Va. (345).	5–20–65	1530	15	7.9	69	7.8	87	------	-----	-----	.0	.03	.00	28	6.0	.5	.03	----	26	3	-----	46	7.1	5
143	03A–0670.00	Blackwater River at Hendrick, W. Va. (140).	5–20–65	1600	54.1	4.8	67	8.1	88	0	29	39	2.4	.35	.37	0	72	.0	.00	----	53	53	24	175	4.0	0
144	03A–0700.00	Cheat River at Rowlesburg, W. Va. (972).	5–20–65	1830	482	7.6	74	7.7	90	------	-----	-----	.0	.02	.00	16	14	1.5	.06	----	24	11	-----	58	7.4	5
145	03A–0702.75	Muddy Creek near Ruthbelle, W. Va. (26.6).	5–21–65	0730	12.8	3.80	61	8.3	83	20	59	69	3.2	2.0	.78	0	116	.0	.02	----	80	80	39	336	3.7	0
146	03A–0705.00	Big Sandy Creek at Rockville, W. Va. (200).	5–21–65	0830	75	8.3	66	8.4	89	------	-----	-----	1.7	.80	.18	8	26	1.1	.02	----	32	25	-----	81	6.6	0
Kanawha River basin																										
147	03A–1890.00	Cherry River at Fenwick, W. Va. (150).	5–20–65	1320	72	7.4	67	8.8	96	------	-----	-----	0.1	0.09	0.03	17	17	0.5	0.02	0.2	21	7	-----	75	7.4	12
148	03A–1900.00	Meadow River at Mallen, W. Va. (287).	5–20–65	1115	107	7.3	68	8.2	89	------	-----	-----	.1	.07	.03	27	27	1.0	.02	.1	40	18	-----	115	7.2	7
149	03A–1930.00	Kanawha River at Kanawha Falls, W. Va. (8,367).	5–20–65	0930	5,070	7.4	72	8.3	94	------	-----	-----	.1	.06	.00	55	17	2.0	.02	.1	52	7	-----	138	7.2	5
150	03A–1932.30	Loop Creek at Robson, W. Va. (42.3).	5–20–65	0830	14.7	6.9	63	8.9	91	------	-----	-----	.1	.02	.82	20	368	4.0	.01	.3	374	357	-----	762	7.1	5
151	03A–1970.00	Elk River at Queen Shoals, W. Va. (1,147).	5–19–65	1330	287	7.2	72	7.8	88	------	-----	-----	.0	.05	.00	20	18	2.5	.01	.0	25	8	-----	84	7.2	3
152	03A–1982.00	Marsh Fork at Edwight, W. Va. (128).	5–17–65	1430	64.9	7.6	72	7.4	83	------	-----	-----	.2	.02	.17	53	114	4.0	.00	.4	96	52	-----	360	7.6	5
153	03A–1989.00	Pond Fork at Madison, W. Va. (138).	5–17–65	1145	64.3	7.3	74	8.2	95	------	-----	-----	.1	.03	.32	24	201	5.0	.00	.2	196	176	-----	490	7.2	4
154	03A–1990.00	Little Coal River at Danville, W. Va. (270).	5–17–65	1025	117	7.2	72	7.5	85	------	-----	-----	.1	.04	.21	31	188	7.0	.10	.5	159	134	-----	485	6.7	5
155	03A–1985.00	Big Coal River at Ashford, W. Va. (393).	5–17–65	0830	153	6.9	69	7.1	79	------	-----	-----	.1	.03	.05	30	116	6.0	.00	.7	118	94	-----	331	7.2	4
Guyandotte River basin																										
156	03A–2023.00	Guyandotte River at Pineville, W. Va. (261).	5–18–65	0930	214	8.3	67	8.0	88	------	-----	-----	0.3	0.04	0.05	162	128	4.0	0.01	0.1	121	0	-----	534	7.9	5
157	03A–2027.00	Clear Fork at Oceana, W. Va. (93.9).	5–18–65	1100	30.9	6.5	69	8.8	98	------	-----	-----	.0	.15	1.3	11	205	6.5	.02	.2	186	177	-----	480	6.4	5
158	03A–2037.00	Island Creek at Logan, W. Va. (103).	5–18–65	1430	44.9	6.3	76	8.0	95	------	-----	-----	.1	.60	1.1	100	638	14	.01	.3	392	310	-----	1,440	7.0	5
159	03A–2036.00	Guyandotte River at Logan, W. Va. (836).	5–18–65	1315	380	7.8	76	8.2	98	------	-----	-----	.1	.04	.05	95	135	7.5	.01	.1	125	47	-----	472	7.6	5

Table 6.—*Field determinations and laboratory analyses (in parts per million except as indicated) for stream samples, May 1965*—**Continued**

Appalachia map no.	USGS station	Stream sampling site and drainage area, in square miles (in parenthesis)	Date	Time	Field determination: Water discharge (cfs)	Field: pH	Field: Water temperature (°F)	Field: Dissolved oxygen: Concentration, ppm	Field: Dissolved oxygen: Percent saturation	Field: Acid concentration to indicate pH, (as H_2SO_4): 4.5	7.0	8.3	Laboratory analyses: Aluminum (Al)	Total iron (Fe)	Total manganese (Mn)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Phosphate (PO_4)	Nitrate (NO_3)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Potential free acidity to pH 8.3 as H_2SO_4	Specific conductance (micromhos at 25°C)	pH	Color
		Guyandotte River basin—Continued																								
160	03A–2040.00	Guyandotte River at Branchland, W. Va. (1,226).	5–19–65	1015	471	7.2	72	7.5	85	------	------	------	0.1	0.03	0.16	84	182	26	0.00	0.1	158	89	------	617	7.4	5
		Twelvepole Creek basin																								
161	03A–2068.00	East Fork Twelvepole Creek near East Lynn, W. Va. (139).	5–19–65	0900	33	7.1	68	7.5	82	------	------	------	0.0	0.12	0.10	20	20	5.0	0.00	0.1	29	12	------	93	6.8	5
162	03A–2065.80	West Fork Twelvepole Creek at Echo, W. Va. (109).	5–19–65	0815	21.5	7.1	66	7.0	75	------	------	------	.0	.21	.00	54	15	6.5	.01	.1	39	0	------	146	7.2	10
		Little Kanawha River basin																								
164	03A–1530.00	Steer Creek near Grantsville, W. Va. (166).	5–21–65	1130	12.0	7.5	71	7.8	89	------	------	------	0.0	0.10	0.03	40	13	2.5	0.01	0.1	40	7	------	105	7.3	12
165	03A–1550.00	Little Kanawha River at Palestine, W. Va. (1,515).	5–21–65	1315	315	7.5	73	8.2	94	------	------	------	.0	.04	.04	39	23	8.0	.01	.1	46	14	------	148	7.4	8
166	03A–1555.00	Hughes River at Cisko, W. Va. (452).	5–21–65	1430	64	7.6	70	8.5	95	------	------	------	.0	.10	.13	47	15	20	.04	.1	53	14	------	175	7.4	5
167	03A–1519.00	Lynch Run near Glenville, W. Va. (2.20).	5–21–65	0830	0.94	3.45	62	8.0	83	29	120	130	18	5.5	7.3	0	1,110	10	.02	.5	608	608	130	2,070	3.55	3
168	03A–1525.00	Leading Creek near Glenville, W. Va. (144).	5–21–65	1015	24.1	7.2	70	7.7	86	------	------	------	.2	.03	.09	45	49	12	.02	.1	84	47	------	230	7.2	5
170	03A–1775.00	Indian Creek at Indian Mills, W. Va. (189).	5–17–65	1745	51.7	8.2	74	7.6	88	------	------	------	.0	.03	.03	128	13	3.0	.04	.1	110	5	------	229	8.1	5
171	03A–1870.00	Gauley River at Camden on Gauley, W. Va. (236).	5–20–65	1430	85	7.6	72	7.6	87	------	------	------	.1	.08	.00	18	8.8	.5	.02	.1	15	0	------	56	6.7	5
		Big Sandy River basin																								
194	03A–2128.00	Tug Fork at Roderfield, W. Va. (208).	5–21–65	0730	558.	7.2	61	4.9	49	------	------	------	0.1	0.10	0.00	105	77	2.5	0.00	0.9	100	14	------	351	7.3	8
195	03A–2129.90	Dry Fork at Iaeger, W. Va. (228).	5–21–65	1000	130	6.8	68	5.2	56	------	------	------	.1	.08	.02	231	68	12	.00	.4	112	0	------	580	7.8	7
196	03A–2138.50	Pigeon Creek at Naugatuck, W. Va. (142).	5–21–65	1500	26.6	7.2	72	4.0	45	------	------	------	.0	.08	.12	55	334	13	.29	.5	204	159	------	843	7.1	3
197	03A–2140.00	Tug Fork near Kermit, W. Va. (1,185).	5–21–65	1700	468	8.0	75	6.4	75	------	------	------	.2	.18	.03	188	165	8.0	.01	.1	200	46	------	690	7.8	5
		KENTUCKY																								
		[See pl. 1 for map number]																								
		Big Sandy River basin																								
172	03A–2147.30	Rockcastle Creek at Clifford, Ky. (121).	5–21–65	1900	23.9	7.2	72	7.2	82	------	------	------	0.0	0.22	0.05	30	18	22	0.02	0.0	43	18	------	165	6.8	7
173	03A–2093.00	Russell Fork at Elkhorn City, Ky. (554).	5–20–65	1645	900	6.8	68	7.8	85	------	------	------	3.1	.06	.01	26	30	1.0	.02	.2	38	16	------	120	6.9	5
174	03A–2080.00	Levisa Fork at Fishtrap, Ky. (386).	5–20–65	1430	157	7.2	76	7.0	83	------	------	------	.1	.07	.00	50	173	8.0	.02	.1	183	142	------	471	7.3	3
175	03A–2094.60	Shelby Creek at Shelbiana, Ky. (110).	5–20–65	1200	76.8	7.4	71	7.7	88	------	------	------	.1	.04	.00	70	91	3.5	.74	11	114	56	------	324	7.3	3
176	03A–2097.00	Beaver Creek at Martin, Ky. (228).	5–20–65	0900	138	7.4	67	8.1	88	------	------	------	.1	.08	.16	62	104	7.0	.04	.8	104	53	------	359	7.0	8
177	03A–2097.00	Johns Creek near Van Lear, Ky. (206).	5–19–65	1615	27	7.4	74	9.0	105	------	------	------	.1	.15	.00	18	16	2.5	.02	.4	28	13	------	85	7.4	5

178	03A–2120.00	Paint Creek at Staffordville, Ky. (103).	5–19–65	1415	56	6.8	67	5.6	61	------	------	------	.1	.05	.17	34	15	322	.05	3.0	179	151	------	1,130	6.9	12
179	03A–2150.00	Big Sandy River at Louisa, Ky. (3,892).	5–22–65	0815	1,840	6.4	71	6.2	70	------	------	------	.1	.15	.05	79	107	12	.39	.4	122	58	------	398	7.2	5
180	03A–2155.00	Blaine Creek at Yatesville, Ky. (217).	5–22–65	1200	34	6.4	71	6.6	75	------	------	------	.1	.12	.34	35	28	575	.02	7.6	274	245	------	1,940	6.8	3
		Ohio River basin																								
181	03A–2164.00	Little Sandy River at Leon, Ky. (255).	5–17–65	1130	42.5	7.4	67	7.8	85	------	------	------	0.1	0.48	0.26	60	29	30	0.02	0.2	87	38	------	263	7.3	8
182	03A–2164.80	Little Fork near Grayson, Ky. (132).	5–17–65	0900	27.2	7.1	68	7.6	83	------	------	------	.1	.32	.28	38	33	3.0	.04	.4	54	23	------	154	7.0	5
183	03A–2170.00	Tygarts Creek near Greenup, Ky. (242).	5–22–65	1845	30	8.3	71	7.2	82	------	------	------	.0	.07	.17	94	25	4.0	.01	.2	102	25	------	223	7.4	3
184	03A–2372.61	Kinniconick Creek at Garrison, Ky. (245).	5–22–65	1645	17.7	6.6	78	7.4	90	------	------	------	.0	.39	.05	22	15	3.0	.02	.1	30	12	------	85	6.8	8
		Licking River basin																								
185	03A–2485.00	Licking River near Salyersville, Ky. (140).	5–19–65	1130	73.6	6.7	69	7.5	83	------	------	------	0.0	0.36	0.20	38	14	66	0.84	0.6	71	40	------	324	6.8	8
186	03A–2487.00	Elk Fork at West Liberty, Ky. (78.6).	5–19–65	0945	68.9	7.0	66	5.5	58	------	------	------	.1	.18	.15	37	18	.5	.02	.8	49	18	------	111	7.3	18
187	03A–2489.00	North Fork Licking River at Bangor, Ky. (100).	5–17–65	1600	16.9	7.0	71	7.3	83	------	------	------	.1	1.6	.07	62	12	3.0	.02	.2	62	11	------	140	7.2	7
188	03A–2495.00	Licking River at Farmers, Ky. (831).	5–17–65	1715	234	7.1	75	8.0	94	------	------	------	.0	.47	.11	50	14	20	.02	.0	56	15	------	177	6.9	10
		Kentucky River basin																								
189	03A–2785.00	Troublesome Creek at Noble, Ky. (177).	5–18–65	1445	34	7.4	72	6.8	77	------	------	------	0.0	0.17	0.08	24	66	11	0.00	0.1	89	70	------	235	6.9	7
190	03A–2792.00	Lost Creek at Lost Creek, Ky. (42).	5–18–65	1930	100	7.8	68	7.6	83	------	------	------	.1	.32	.03	28	52	.5	.01	.4	73	50	------	175	6.6	10
191	03A–2797.00	Quicksand Creek at Quicksand, Ky. (203).	5–18–65	1800	52.4	6.7	68	5.9	64	------	------	------	.0	.37	.10	36	19	4.0	.05	.1	42	12	------	112	6.9	5
192	03A–2800.00	North Fork Kentucky River at Jackson, Ky. (1,101).	5–18–65	1130	125	7.0	74	7.7	90	------	------	------	.0	.11	.06	48	145	5.0	.00	.0	157	118	------	410	7.2	3
193	03A–2835.00	Red River at Clay City, Ky. (362).	5–18–65	0830	95.8	7.1	69	6.4	70	------	------	------	.0	.44	.14	63	13	59	.01	.1	90	38	------	329	7.1	15
198	03A–2806.00	Middle Fork Kentucky River near Hyden, Ky. (202).	5–18–65	1500	28.4	7.6	74	8.1	93	------	------	------	.1	.07	.03	29	9.2	2.2	.0	.1	33	6	------	66	7.3	7
199	03A–2809.05	Long Creek near Buckhorn, Ky. (6.6).	5–19–65	0930	5.13	7.7	65	8.2	86	------	------	------	.1	.05	.04	30	15	2.0	.0	.4	36	12	------	82	7.3	13
200	03A–2810.00	Middle Fork Kentucky at Tallega, Ky. (537).	5–19–65	1145	395	7.3	66	7.5	80	------	------	------	.1	.11	.05	23	15	16	.0	.5	37	18	------	130	7.0	14
201	03A–2810.00	South Fork Kentucky River at Booneville, Ky. (722).	5–19–65	1150	140	7.3	72	7.8	88	------	------	------	.1	.18	.08	30	30	6.8	.0	.2	48	24	------	143	7.2	8
202	03A–2822.00	Station Camp Creek near Irvine, Ky. (217).	5–19–65	1430	160	7.5	68	6.7	73	------	------	------	.1	.06	.08	103	20	4.8	.0	.9	104	20	------	215	7.5	12
203	03A–2840.00	Kentucky River at lock 10, near Winchester, Ky. (3,955).	5–19–65	1605	2,100	7.7	72	6.2	70	------	------	------	.0	.04	.18	55	33	19	.0	.2	78	33	------	215	7.4	9
204	------------	Silver Creek near mouth.	5–20–65	0930	3.3	8.2	71	7.5	83	------	------	------	.1	.02	.00	180	27	5.8	.0	.1	174	26	------	325	7.9	8
216	03A–2773.40	North Fork Kentucky River at Blackey, Ky. (135).	5–18–65	1030	39.6	8.2	70	7.8	87	------	------	------	.1	.02	.06	157	211	6.0	.0	.6	224	95	------	630	8.1	7
217	03A–2773.60	Rockhouse Creek near Letcher, Ky. (51.5).	5–17–65	1400	10.4	8.2	74	8.4	97	------	------	------	.2	.30	.15	56	243	8.8	.0	.1	180	134	------	576	7.6	8
218	03A–2773.80	Line Fork near Ulvah, Ky. (64).	5–18–65	1130	11.5	8.2	72	7.9	89	------	------	------	.1	.09	.02	69	50	3.0	.0	1.1	102	45	------	235	7.4	6
219	03A–2774.10	Leatherwood Creek at Cornettsville, Ky. (49.7).	5–17–65	1700	15.5	7.9	74	7.7	89	------	------	------	.2	.05	.03	73	113	5.0	.0	.6	160	100	------	372	7.5	5
220	03A–2774.20	Maces Creek at Viper, Ky. (29).	5–18–65	1300	6.37	7.5	72	7.5	85	------	------	------	.2	.04	.48	32	68	9.4	.0	.0	94	68	------	230	7.0	6
221	03A–2774.55	Yellow Creek at Sassafrass, Ky. (2.70).	5–17–65	1100	.79	3.00	74	5.6	65	230	330	360	44	35	4.7	0	814	5.0	.0	2.6	530	530	3.80	1,680	2.8	8
222	03A–2774.45	Irishmans Creek at Ambergey, Ky. (10).	5–17–65	1215	.67	5.0	73	7.5	86	0	15	20	2.7	.36	.58	2	139	1.8	.0	.4	131	129	------	305	4.8	5
223	03A–2774.40	Carr Fork at Cody, Ky. (42.6).	5–18–65	0900	7.90	6.2	65	7.5	79	------	------	------	.1	.03	.09	93	171	3.4	.0	.5	110	34	------	493	7.6	7
224	03A–2774.80	Carr Fork near Hazard, Ky. (85.5).	5–17–65	1000	24.5	6.3	64	8.0	84	------	------	------	.8	.72	.43	70	218	3.0	.0	.4	162	104	------	550	7.7	5
225	03A–2775.00	North Fork Kentucky River at Hazard, Ky. (466).	5–17–65	0810	102	7.9	71	7.0	79	------	------	------	.2	.37	.05	95	168	5.2	.0	.2	176	98	------	475	7.6	7
226	03A–2775.20	Lotts Creek near Hazard, Ky. (27.8).	5–18–65	1700	100	6.1	68	7.5	82	------	------	------	.2	.02	2.1	23	399	3.4	.0	2.1	404	385	------	740	6.8	6

Table 6.—*Field determinations and laboratory analyses (in parts per million except as indicated) for stream samples, May 1965*—**Continued**

Appalachia map no.	USGS station	Stream sampling site and drainage area, in square miles (in parenthesis)	Date	Time	Field determination: Water discharge (cfs)	pH	Water temperature (°F)	Dissolved oxygen: Concentration, ppm	Dissolved oxygen: Percent saturation	Acid concentration to indicate pH, (as H_2SO_4): 4.5	7.0	8.3	Laboratory analyses: Aluminum (Al)	Total iron (Fe)	Total manganese (Mn)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Phosphate (PO_4)	Nitrate (NO_3)	Hardness as $CaCO_3$: Calcium, magnesium	Noncarbonate	Potential free acidity to pH 8.3 as H_2SO_4	Specific conductance (micromhos at 25°C)	pH	Color
		Kentucky River basin—Continued																								
		Green River basin																								
205	-----------	Green River at Liberty, Ky.	5–20–65	1210	17.1	7.8	71	6.4	72	-----	-----	-----	0.0	0.02	0.03	106	21	4.5	0.0	1.2	107	20	-----	230	7.4	7
206	03A–2070.00	Russell Creek near Columbia, Ky. (188).	5–20–65	1415	67.1	8.5	72	8.0	91	-----	-----	-----	.0	.04	.02	109	14	4.0	.0	2.3	104	14	-----	218	7.4	10
		Cumberland River basin																								
207	03B–4010.00	Cumberland River near Harlan, Ky. (374).	5–22–65	1035	250	8.3	71	7.0	79	-----	-----	-----	0.1	0.11	0.06	136	59	3.6	0.0	0.6	78	0	-----	330	7.9	9
208	03B–4024.90	Straight Creek at mouth at Pineville, Ky. (93.0).	5–22–65	0920	21.1	7.9	69	7.0	88	-----	-----	-----	.3	.04	.5	28	165	16	.0	1.0	126	104	-----	465	7.3	9
209	03B–4035.00	Cumberland River at Barbourville, Ky. (960).	5–22–65	0815	420	7.4	72	7.2	82	-----	-----	-----	.2	.05	.04	108	66	6.2	.0	.3	82	0	-----	310	7.9	8
210	03B–4042.00	Jellico Creek near Williamsburg, Ky. (103).	5–21–65	1245	20.3	7.2	72	7.8	88	-----	-----	-----	.1	.19	.13	18	29	1.0	.0	.0	40	26	-----	110	7.1	5
211	03B–4045.00	Cumberland River at Cumberland Falls, Ky. (1,977).	5–21–65	1515	960	8.2	77	7.3	87	-----	-----	-----	.0	.04	.01	73	66	5.0	.0	.7	76	16	-----	285	7.4	5
212	03B–4105.90	Rock Creek near Yamacraw, Ky. (60).	5–21–65	1145	19.4	7.7	68	8.3	91	-----	-----	-----	.1	.00	.2	26	71	2.0	.0	1.1	68	46	-----	190	7.1	4
213	03B–4109.00	Little South Fork near Coopersville, Ky. (98.4).	5–21–65	1020	30	8.2	69	7.6	85	-----	-----	-----	.2	.01	.01	152	58	54	.0	.7	184	60	-----	535	7.8	5
214	03B–4140.00	Cumberland River near Rowena, Ky. (5,790).	5–20–65	1620	4,400	8.5	48	9.8	85	-----	-----	-----	.1	.07	.08	42	21	2.2	.0	.7	54	19	-----	125	7.1	6
215	03B–4065.00	Rockcastle River at Billows, Ky. (604).	5–21–65	1700	148	7.3	73	8.4	97	-----	-----	-----	.0	.02	.02	70	28	3.0	.0	1.1	72	15	-----	160	7.4	5
276	-----------	Clear Fork near Saxton, Ky.	5–18–65	0830	94.9	7.3	70	6.8	76	-----	-----	-----	.2	.00	.3	65	114	1.6	.00	.4	102	49	-----	338	7.6	3
		VIRGINIA																								
		[See pl. 1 for map number]																								
		Big Sandy River basin																								
227	3–2075	Levisa Fork near Grundy, Va. (235).	5–18–65	1015	69	8.1	69	9.0	100	-----	-----	-----	0.4	0.01	0.08	35	130	5.0	0.0	0.8	144	115	-----	362	7.1	5
228	3–2085	Russell Fork at Haysi, Va. (286).	5–18–65	1130	184	7.6	68	7.9	86	-----	-----	-----	.1	.02	.02	51	52	2.0	.0	.7	56	14	-----	205	7.3	10
229	3–2092	Russell Fork at Bartlick, Va. (526).	5–18–65	1340	225	7.6	71	8.0	91	-----	-----	-----	.1	.01	.01	36	66	2.0	.0	.8	62	32	-----	205	7.2	10
230	3–2090	Pound River near Haysi, Va. (212).	5–18–65	1300	34	7.6	70	8.5	95	-----	-----	-----	.0	.01	.05	16	107	3.0	.0	1.0	102	89	-----	265	6.9	5
231	3–2089.50	Cranesnest River near Clintwood, Va. (66).	5–18–65	1620	90	6.9	68	8.4	92	-----	-----	-----	.1	.02	.4	16	199	1.2	.0	.3	196	183	-----	485	6.6	6
232	3–2089	Pound River near Georges Fork, Va. (86).	5–18–65	1715	70	7.1	69	8.2	91	-----	-----	-----	.4	.01	.4	12	196	4.5	.0	.9	186	176	-----	455	6.3	10
233	3–2083	McClure River at Clinchco, Va.	5–18–65	1445	130	8.0	67	7.5	82	-----	-----	-----	.1	.00	.03	84	91	2.6	.0	.6	110	40	-----	345	7.2	8
234	-----------	Dismal River near Grundy, Va.	5–18–65	0905	34.9	7.8	65	9.0	96	-----	-----	-----	.2	.02	.4	37	149	4.5	.0	.6	154	124	-----	397	7.3	5
		Tennessee River basin																								
235	3–5245	Guest River at Coaburn, Va. (87.3).	5–19–65	0850	226	7.5	63	8.0	82	-----	-----	-----	0.1	0.02	0.01	34	67	3.0	0.0	1.2	78	50	-----	210	6.7	7
236	3–5295	Powell River at Big Stone Gap, Va. (112).	5–19–65	1000	198	8.0	64	8.5	89	-----	-----	-----	.1	.01	.08	61	79	.8	.0	.3	94	44	-----	301	6.9	8

237	3–5315	Powell River near Jonesville, Va. (319).	5–19–65	1130	768	8.2	69	7.8	87	------	-----	-----	.3	.01	.01	105	51	2.0	.0	1.0	108	22	-----	285	7.4	5
238	3–5305	North Fork Powell River at Pennington Gap, Va. (75).	5–19–65	1040	708	7.4	63	9.0	92	------	-----	-----	.1	.02	.05	15	17	.1	.0	.4	22	9	-----	73	6.4	10
239	3–5215	Clinch River at Richlands, Va. (139).	5–17–65	1830	90	8.7	69	8.5	95	------	-----	-----	.1	.04	.04	120	9.8	6.7	.0	4.6	109	10	-----	250	7.6	7
240	3–5240	Clinch River at Cleveland, Va. (528).	5–19–65	0730	1,520	8.0	61	8.5	85	------	-----	-----	.1	.02	.04	115	10	.5	.0	2.9	106	12	-----	230	7.0	10
241	3–5217	Coal Creek at Raven, Va. (6.25).	5–18–65	0700	4.22	7.9	60	7.8	78	------	-----	-----	.1	.09	.05	66	53	3.8	.0	.4	92	38	-----	248	7.2	8
242	3–5260	Copper Creek near Gate City, Va. (106).	5–19–65	1400	656	8.3	66	8.2	88	------	-----	-----	.1	.02	.04	169	7.2	.6	.0	1.7	144	6	-----	290	7.4	8
243	3–4880	North Fork Holston River near Saltville, Va. (222).	5–17–65	1545	180	6.9	69	8.4	9.3	------	-----	-----	.1	.05	.04	92	8.4	1.2	.0	1.1	82	6	-----	178	7.4	10

James River basin

244	2–195	James River at Buchanan, Va. (2,084).	5–17–65	1035	1,530	7.8	71	7.8	88	------	-----	-----	0.1	0.10	.01	80	22	9.8	0.0	0.2	76	10	-----	217	7.3	15

TENNESSEE

[See pl. 1 for map number]

Tennessee River basin

256	3–4955	Holston River near Knoxville, Tenn. (3,747).	5–17–65	0845	7,000	7.9	61	9.1	91	------	-----	-----	0.0	0.63	0.02	113	23	72	0.02	3.7	166	73	-----	480	8.0	3
257	3–5382.25	Poplar Creek near Oak Ridge, Tenn. (82.5).	5–17–65	1020	32	7.6	68	7.4	80	------	-----	-----	.1	.00	.3	110	30	1.6	.00	.8	113	22	-----	240	8.1	8
258	3–5397.3	White Creek near mouth near Frankfort, Tenn. (75).	5–22–65	1030	87.9	6.9	68	8.0	87	------	-----	-----	.2	.10	.00	12	1.8	.6	.00	.1	11	0	-----	27	6.7	3
259	3–5397.8	Clear Creek near mouth at Howard Mill, Tenn. (170).	5–22–65	1410	90	7.0	74	8.2	95	------	-----	-----	.2	.06	.00	10	5.6	.7	.00	.1	10	2	-----	30	6.9	1
260	3–5397	Obed River 0.1 mile below Daddys Creek near Frankfort, Tenn. (331).	5–22–65	1220	143	7.4	72	8.5	97	------	-----	-----	.2	.10	.00	18	2.6	1.3	.01	.2	15	0	-----	40	7.0	6
261	3–5340	Coal Creek at Lake City, Tenn. (24.5).	5–17–65	1400	11.1	8.4	68	8.2	89	------	-----	-----	.6	.78	.01	142	119	3.4	.00	.7	84	0	-----	478	8.3	3
262	3–5385	Emory River near Wartburg, Tenn. (83.2).	5–22–65	1630	53.1	6.8	69	7.0	70	------	-----	-----	.1	.10	.03	15	8.6	.8	.00	.1	17	5	-----	48	6.9	4
263	3–5396	Daddys Creek near Hebbertsburg, Tenn. (139).	5–22–65	0750	102	7.2	67	7.8	85	------	-----	-----	.2	.03	.01	16	3.2	.8	.00	.2	14	2	-----	37	7.2	11
264	3–5398	Obed River near Lancing Tenn. (518).	5–23–65	1535	420	7.2	72	7.8	89	------	-----	-----	.2	.00	.00	13	3.8	1.1	.00	.1	12	2	-----	34	7.1	8
265	3–5398.3	Island Creek near mouth near Catoosa, Tenn. (50).	5–23–65	1300	4.0	6.4	69	7.7	85	------	-----	-----	.1	.00	.01	5	11	.7	.00	.0	10	6	-----	30	6.6	6
266	3–5398.6	Crooked Fork Creek near Wartburg, Tenn. (75).	5–23–65	1045	10.0	4.6	67	6.9	75	------	15	15	.8	.21	2.2	----	162	2.4	.00	.6	142	---	9.8	377	5.2	1
267	3–5405	Emory River at Oakdale, Tenn. (764).	5–23–65	0910	396	7.1	72	7.6	86	------	-----	-----	.2	.00	.00	16	10	1.1	.00	.0	20	8	-----	56	7.2	8
268	3–5425	Piney River at Spring City, Tenn. (95.9).	5–21–65	1640	101	7.3	71	8.2	93	------	-----	-----	.2	.03	.00	14	3.4	.6	.00	.1	12	0	-----	32	7.0	2
269	3–5595	Ocoee River at Copperhill, Tenn. (352).	5–25–65	0820	290	7.0	52	9.5	86	------	-----	-----	.1	.03	.00	10	1.2	.6	.00	.0	7	0	-----	23	6.8	3
270	3–5675	South Chickamauga Creek near Chickamauga, Tenn. (428).	5–25–65	1100	230	7.8	71	5.0	57	------	-----	-----	.1	.02	.01	145	9.4	3.2	.53	.9	117	0	-----	256	7.9	7
271	3–5706	Sequatchie River Pikeville, Tenn. (86.2).	5–24–65	0835	479	7.7	65	8.0	84	------	-----	-----	.2	.02	.00	91	5.0	1.1	.01	1.4	78	4	-----	158	7.6	4
272	3–5707.5	Big Brush Creek near Dunlap, Tenn. (47.7).	5–24–65	1015	38.8	6.9	68	7.9	86	------	-----	-----	.2	.09	.02	14	3.6	.6	.00	.0	11	0	-----	31	7.0	2
273	3–5710	Sequatchie River near Whitwell, Tenn. (384).	5–24–65	1150	620	7.6	68	7.7	84	------	-----	-----	.2	.02	.00	68	5.0	1.1	.00	1.1	59	4	-----	125	7.7	4
274	3–5715	Little Sequatchie River at Sequatchie, Tenn. (116).	5–24–65	1335	26.2	7.8	70	8.7	97	------	-----	-----	.2	.01	.01	60	26	.7	.01	.0	70	21	-----	159	7.4	1
275	3–5320	Powell River near Arthur, Tenn. (685).	5–17–65	1650	400	8.2	74	7.9	92	------	-----	-----	.1	.00	.00	132	27	1.1	.00	.6	119	9	-----	265	8.3	8

Cumberland River basin

277	3–4082	Brimstone Creek near Robbins, Tenn. (48.7).	5–18–65	1415	26.9	7.0	68	6.0	65	------	-----	-----	0.1	0.02	0.5	26	48	7.5	0.00	0.5	52	30	-----	171	7.0	4
278	3–4085	New River at New River, Tenn. (382).	5–18–65	1030	68	7.0	72	7.4	84	------	-----	-----	.1	.00	.6	16	84	1.3	.00	.0	76	62	-----	228	7.0	5
279	3–4095	Clear Fork near Robbins, Tenn. (272).	5–18–65	1150	62	7.1	70	8.0	89	------	-----	-----	.1	.03	.04	13	5.4	1.1	.00	.0	12	1	-----	37	7.0	9
280	3–4088	Clear Fork above Crooked Creek near Burrsville, Tenn. (87.9).	5–18–65	1620	28.4	7.1	69	7.7	86	------	-----	-----	.2	.05	.02	11	4.4	.8	.00	.2	8	0	-----	24	6.9	7

Table 6.—*Field determinations and laboratory analyses (in parts per million except as indicated) for stream samples, May 1965*—Continued

Appalachia map no.	USGS station	Stream sampling site and drainage area, in square miles (in parenthesis)	Date	Time	Field determination: Water discharge (cfs)	Field: pH	Field: Water temperature (°F)	Field: Dissolved oxygen: Concentration, ppm	Field: Dissolved oxygen: Percent saturation	Field: Acid concentration to indicate pH, (as H_2SO_4): 4.5	7.0	8.3	Laboratory analyses: Aluminum (Al)	Total iron (Fe)	Total manganese (Mn)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Phosphate (PO_4)	Nitrate (NO_3)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Potential free acidity to pH 8.3 as H_2SO_4	Specific conductance (micromhos at 25°C)	pH	Color
		Cumberland River basin—Continued																								
282	3–4144	East Fork Obey River at mouth of Hurricane Creek near Clarkrange, Tenn. (90.4).	5–19–65	1700	0.30	7.9	75	7.9	93	------	------	------	0.1	0.00	0.00	65	14	0.8	0.00	0.0	60	8	------	130	7.9	4
283	3–4144.7	Buffalo Cove Creek near mouth near Boatland, Tenn. (23.4).	5–19–65	1730	15.2	7.7	53	10.2	94	------	------	------	.2	.98	.00	93	33	1.3	.00	.6	101	24	------	214	7.8	3
284	3–4145	East Fork Obey River near Jamestown, Tenn. (202).	5–19–65	0850	190	6.4	61	9.1	91	------	------	------	.1	.02	.8	15	107	1.7	.00	1.0	119	107	------	274	6.8	4
285	3–4150	West Fork Obey River near Alpine, Tenn. (115).	5–19–65	1000	60.9	7.8	65	8.4	89	------	------	------	.2	.00	.4	73	52	.8	.00	.5	111	50	------	235	7.9	7
285A	3–4185	Caney Fork at Clifty, Tenn. (111).	5–20–65	1000	94.4	6.6	66	7.8	83	------	------	------	.1	.03	.3	7	18	1.1	.00	4.4	18	12	------	53	6.5	3
287	3–4192	Cane Creek near Spencer, Tenn. (134).	5–21–65	0945	10.6	7.5	60	9.0	90	------	------	------	.1	.06	.00	24	8.2	1.0	.00	.1	22	2	------	55	7.5	10
288	3–4200	Calfkiller River below Sparta, Tenn. (175).	5–20–65	1425	155	8.1	68	8.3	90	------	------	------	.2	.02	.00	120	11	1.9	.00	1.6	107	8	------	220	7.9	4
289	3–4202	Collins River near Steppsville, Tenn. (174).	5–21–65	0730	66.7	7.7	56	8.9	85	------	------	------	.1	.13	.00	62	17	1.3	.00	.4	62	10	------	134	7.7	5
290	3–4250	Cumberland River at Carthage, Tenn. (10,700).	5–20–65	1325	16,800	7.8	58	8.7	87	------	------	------	.2	.02	.00	66	23	2.2	.00	.4	72	18	------	164	7.5	3
		NORTH CAROLINA [See pl. 1 for map number] Tennessee River basin																								
250	3–5485	Hiwassee River above Murphy, N.C. (406).	5–20–65	1445	405	7.4	59	7.0	69	------	------	------	0.1	0.04	0.02	12	6.0	0.5	0.0	1.6	7	0	------	23	6.8	7
251	3–5030	Little Tennessee River at Needmore, N.C. (436).	5–20–65	1315	890	7.2	68	8.6	94	------	------	------	.1	.09	.02	13	2.6	.2	.0	.1	6	0	------	27	6.5	8
252	3–4430	French Broad River at Blantyre, N.C. (296).	5–20–65	0900	729	6.9	63	4.9	50	------	------	------	.2	.14	.01	24	23	4.3	.0	1.0	15	0	------	120	6.4	45
253	3–4535	French Broad River at Marshall, N.C. (1,332).	5–19–65	1830	2,360	7.4	72	7.6	86	------	------	------	.1	.03	.00	23	18	2.9	.1	.5	15	0	------	106	6.4	18
		Santee River basin																								
254	2–1515	Broad River near Boiling Springs, N.C. (864).	5–21–65	1905	1,280	7.5	77	7.8	93	------	------	------	0.0	0.06	0.02	18	4.0	2.0	0.0	1.2	11	0	------	39	6.7	7
		Kanawha River basin																								
255	3–1610	South Fork New River near Jefferson, N.C. (207).	5–22–65	0900	475	7.5	67	8.2	88	------	------	------	0.1	0.11	0.02	15	2.0	0.6	0.5	0.2	10	0	------	34	6.4	8
		GEORGIA [See pl. 1 for map number] Mobile River basin																								
245	2–3835	Coosawattee River at Pine Chapel, Ga. (856).	5–21–65	0745	1,510	7.8	71	7.7	87	------	------	------	0.1	0.03	0.02	28	3.2	2.4	0	0.2	22	0	------	60	6.7	7
246	2–3870	Conasauga River at Tilton, Ga. (682).	5–21–65	0640	412	7.7	72	5.7	65	------	------	------	.1	.07	.00	87	7.6	25	.8	.3	72	1	------	250	7.0	17
		Tennessee River basin																								
247	3–5535	Nottely River at Nottely Dam, near Ivylog, Ga. (215).	5–20–65	1605	1,420	6.5	47	8.7	73	------	------	------	0.1	0.08	0.02	10	2.0	1.0	0.0	0.7	6	0	------	22	6.6	7

248	3–5590	Toccoa River near Blue Ridge, Ga. (233).	5–20–65	1730	18	6.2	56	8.9	84	-----	-----	-----	.1	.01	.00	9	1.6	.4	.0	.2	6	0	-----	20	6.6	5
249	3–5667	South Chickamauga Creek at Ringgold, Ga. (169).	5–21–65	0930	85	8.2	67	7.6	83	-----	-----	-----	.0	.02	.02	136	18	7.0	.0	1.0	130	18	-----	275	7.4	5

ALABAMA

[See pl. 1 for map number]

Mobile River basin

291	2–4005	Coosa River at Gadsden, Ala. (5,800).	5–17–65	1535	2,070	7.4	77	6.8	81	-----	-----	-----	0.1	0.03	0.00	56	5.8	3.4	0.0	0.2	48	2	-----	120	6.9	5
292	2–4010	Big Wills Creek near Crudup, Ala. (185).	5–17–65	1730	200	7.4	69	8.0	89	-----	-----	-----	.1	.05	.04	135	.8	4.8	.0	.7	118	7	-----	234	7.1	5
293	2–4015	Big Canoe Creek near Gadsden, Ala. (256).	5–18–65	0640	72	7.7	71	7.5	85	-----	-----	-----	.1	.01	.04	123	2.4	2.7	.0	.2	108	7	-----	212	7.3	5
294	2–4044	Choccolocco Creek at Jackson Shoals, near Lincoln, Ala. (484).	5–18–65	0825	335	7.8	72	8.2	93	-----	-----	-----	.2	.03	.00	110	13	26	1.5	.6	101	11	-----	289	7.1	5
295	2–4055	Kelly Creek near Vincent, Ala. (192).	5–18–65	0930	25	7.3	71	7.2	82	-----	-----	-----	.1	.03	.05	50	.2	2.7	.0	.2	40	0	-----	94	6.9	5
296	2–4080.10	Yellowleaf Creek below Lay Dam near Clanton, Ala. (32).	5–18–65	1230	3.44	7.2	74	7.1	82	-----	-----	-----	.2	.32	.25	20	.6	3.2	.0	.3	15	0	-----	524	6.2	15
297	2–4120	Tallapoosa River near Heflin, Ala. (444).	5–17–65	1330	430	7.3	69	8.1	90	-----	-----	-----	.1	.01	.01	16	.0	1.8	.0	.2	12	0	-----	36	6.7	10
298	2–4145	Tallapoosa River at Wadley, Ala. (1,660).	5–17–65	1135	1,660	8.7	76	8.0	95	-----	-----	-----	.1	.03	.00	14	.0	3.2	.2	.2	9	0	-----	37	6.3	15
299	2–4150	Hillabee Creek near Hackneyville, Ala. (196).	5–17–65	0955	150	7.5	67	6.3	69	-----	-----	-----	.0	.05	.03	22	.2	2.3	.0	.2	11	0	-----	47	7.0	15
300	2–4235	Cahaba River at Helena, Ala. (400).	5–18–65	1715	58	7.4	76	7.6	91	-----	-----	-----	.1	.01	.03	125	6.2	3.5	.1	.3	110	8	-----	228	7.2	10
301	2–4240	Cahaba River at Centreville, Ala. (1,029).	5–18–65	1530	315	7.4	78	8.4	102	-----	-----	-----	.1	.03	.00	122	15	3.7	.1	.2	107	7	-----	236	7.4	15
302	2–4420	Luxapalila Creek near Fayette, Ala. (127).	5–21–65	0915	90	6.3	68	8.3	91	-----	-----	-----	.0	.01	.15	11	.0	2.4	.1	.4	9	0	-----	34	6.4	5
303	2–4465	Sipsey River near Elrod, Ala. (518).	5–21–65	0745	135	6.7	72	7.5	85	-----	-----	-----	.1	.00	.15	23	6.4	2.6	.1	.2	18	0	-----	64	6.8	20
304	2–4500	Mulberry Fork near Garden City, Ala. (368).	5–20–65	1100	165	7.8	77	7.6	91	-----	-----	-----	.1	.03	.02	44	3.9	4.6	1.1	1.4	37	1	-----	102	6.9	10
305	2–4530	Blackwater Creek near Manchester, Ala. (188).	5–20–65	1425	38	7.2	78	7.9	86	-----	-----	-----	.1	.18	.02	20	21	1.7	.0	.2	30	14	-----	88	7.0	20
306	2–4540	Lost Creek near Oakman, Ala. (130).	5–20–65	1535	25	7.2	74	7.2	83	-----	-----	-----	.1	.02	.05	54	48	2.9	.0	.2	60	16	-----	211	7.0	10
308	2–4542	Wolf Creek near Oakman, Ala. (89.1).	5–20–65	1700	7.0	6.7	72	7.2	82	-----	-----	-----	.1	.03	.25	35	136	1.8	.0	.2	90	61	-----	371	6.9	15
309	2–4550	Locust Fork near Cleveland, Ala. (309).	5–20–65	0715	64	7.6	74	7.0	81	-----	-----	-----	.1	.02	.03	52	9.4	4.0	.0	.9	52	9	-----	124	7.0	10
310	2–4565	Locust Fork at Sayre, Ala. (887).	5–20–65	1310	188	7.0	77	6.8	81	-----	-----	-----	.1	.00	.30	53	40	6.9	.0	.4	74	31	-----	191	7.0	10
311	2–4635	Hurricane Creek near Holt, Ala. (108).	5–21–65	1320	38	4.9	77	7.4	88	0	4.9	7.4	.5	.06	2.5	11	61	2.7	.0	.2	60	51	-----	174	6.4	5
312	2–4645	North River near Tuscaloosa, Ala. (366).	5–21–65	1055	70	6.8	75	7.6	89	-----	-----	-----	.1	.03	.05	17	.6	2.7	.0	.2	12	0	-----	44	6.7	10
313	2–4650	Black Warrior River at Tuscaloosa, Ala. (4,828).	5–21–65	0645	1,450	7.1	76	6.0	70	-----	-----	-----	.1	.01	.10	31	7.2	3.7	.0	.0	36	11	-----	135	6.9	10
320	2–4222	Middle Fork Mulberry Creek near Maplesville, Ala. (40).	5–18–65	1400	22.2	7.2	72	7.3	83	-----	-----	-----	.0	.03	.11	14	.0	2.2	.0	.2	12	1	-----	38	6.4	5

Tennessee River basin

314	3–5729	Town Creek near Geraldine, Ala. (141).	5–19–65	0825	15	7.4	71	7.5	85	-----	-----	-----	0.1	0.03	0.04	14	2.2	3.9	0.0	0.4	13	2	-----	45	6.6	10
315	3–5745	Paint Rock River near Woodville, Ala. (320).	5–19–65	1000	690	7.3	68	6.3	69	-----	-----	-----	.7	.20	.11	74	6.2	2.3	.0	.9	68	7	-----	148	6.8	20
316	3–5750	Flint River near Chase, Ala. (342).	5–19–65	1115	180	7.4	71	8.0	91	-----	-----	-----	.1	.01	.01	67	2.2	2.1	.0	2.3	58	3	-----	129	6.5	10
317	3–5853	Sugar Creek near Good Springs, Ala. (152).	5–19–65	1340	105	7.4	70	7.5	83	-----	-----	-----	.0	.01	.04	56	.2	1.6	.0	.7	46	0	-----	105	6.8	10
318	3–5895	Tennessee River at Florence, Ala. (30,810).	5–19–65	1515	61,000	7.6	72	6.8	77	-----	-----	-----	.1	.01	.01	60	8.4	3.7	.0	.6	58	9	-----	134	7.0	10
319	3–5925	Bear Creek at Bishop, Ala. (667).	5–19–65	1700	225	7.4	71	7.4	84	-----	-----	-----	.1	.00	.20	46	2.8	2.7	.2	.4	41	3	-----	96	6.9	10

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