

Variations in the Chemical Character of the Susquehanna River at Harrisburg, Pennsylvania

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1779-B

Prepared in cooperation with the Pennsylvania Department of Forests and Waters and the Pennsylvania Department of Commerce



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PETER W. ANDERSON

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CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

VARIATIONS IN THE CHEMICAL CHARACTER OF THE SUSQUEHANNA RIVER AT HARRISBURG, PENNSYLVANIA

By PETER W. ANDERSON

ABSTRACT

The chemical quality of the Susquehanna River at Harrisburg is influenced by three major factors: streamflow, anthracite and bituminous coal-mine drainage, and geology. Water samples collected at Harrisburg near the west bank of the Susquehanna River and those of western tributaries that drain limestone terranes are similar in chemical quality. The water is alkaline and contains calcium, magnesium, and bicarbonate-ion concentrations typical of water drained from limestone. The chemical quality of water samples collected in the center of the river resembles the quality of the West Branch Susquehanna River, which has a dissolved-solids content of about 200 parts per million, and a sulfate-ion concentration that generally exceeds the bicarbonate-ion concentration. Samples collected near the east or Harrisburg bank show the effect of anthracite coal-mine drainage from the river's eastern tributaries. The pH of these samples ranges from 5.7 to 7.5, and sulfate is the predominate ion.

The dissolved-solids content of the river at the Harrisburg cross-section stations is inversely proportional to the streamflow. During periods of low riverflow, the dissolved-solids content approaches a maximum; during periods of high flow, the content is low.

The chemical composition of the river at the Harrisburg cross section indicates that water from the principal tributaries above Harrisburg does not mix sufficiently to lose its chemical-quality identity before reaching Harrisburg irrespective of the long distance involved, the many islands and bridge piers and the rough streambed. This lack of lateral mixing is probably due to the small depth-width ratio and the extreme width of the river.

INTRODUCTION

A reconnaissance of the Susquehanna River at Harrisburg in 1944 indicated a wide variation in chemical quality across the width of the river. Because a single sample would not be representative of the water quality of the river, the U.S. Geological Survey, the Pennsylvania Department of Forests and Waters, and the Pennsylvania Department of Commerce cooperated to investigate the variations in

chemical quality of the river from bank to bank. Samples generally were taken at six stations in the cross section on the Walnut Street bridge in Harrisburg.

PURPOSE AND SCOPE

This report describes the variations in chemical quality of the Susquehanna River at Harrisburg, discusses the causative factors involved, and shows how they influence the chemical character of the river. The Harrisburg location was selected for study because of its marked cross-section variation in chemical quality and because of the considerable interest in the chemical quality of the river water, shown by representatives in the fields of water management and public water supplies.

This report summarizes the data collected during the period 1944-60 at the Harrisburg location. Variations in the chemical quality across the river are described in terms of these data. A qualitative interpretation of the chemical analyses collected at several locations on the Susquehanna River main stem and its tributaries shows the effects of physiographic, hydrologic, and cultural environment on the chemical character of the river at Harrisburg.

LOCATION

The Susquehanna River originates in Otsego Lake in southeastern New York State, enters Pennsylvania near Lanesboro, Susquehanna County, reenters New York State near Great Bend, Pa., and then reenters Pennsylvania near Sayre, Bradford County. From the Pennsylvania-New York State line, the river flows southward through central Pennsylvania to the Chesapeake Bay. The drainage basin of the entire river is 27,655 square miles, three-fourths of it within Pennsylvania.

The cross-section sampling stations are on the Walnut Street bridge connecting the capital city of Harrisburg, Dauphin County, and the borough of Lemoyne, Cumberland County (fig. 1). Harrisburg is 69 miles from the mouth of the river and 353 miles from its headwaters. At the sampling station, City Island divides the river into east and west channels. At median flow the gross widths of the east and the west channels are 1,288 and 1,330 feet, respectively.

The Susquehanna River at the sampling station has a drainage area of 24,100 square miles. The median flow for the period 1891-1959 was about 20,000 cfs (cubic feet per second). A cross-section diagram of the east and west channels at the Walnut Street bridge shows the relative depth of the river at median flow (fig. 2). The depths at the cross-section sampling stations are shallow, ranging at median flow from 3.9 feet at station W. 1320 to 9.3 feet at station E. 600.

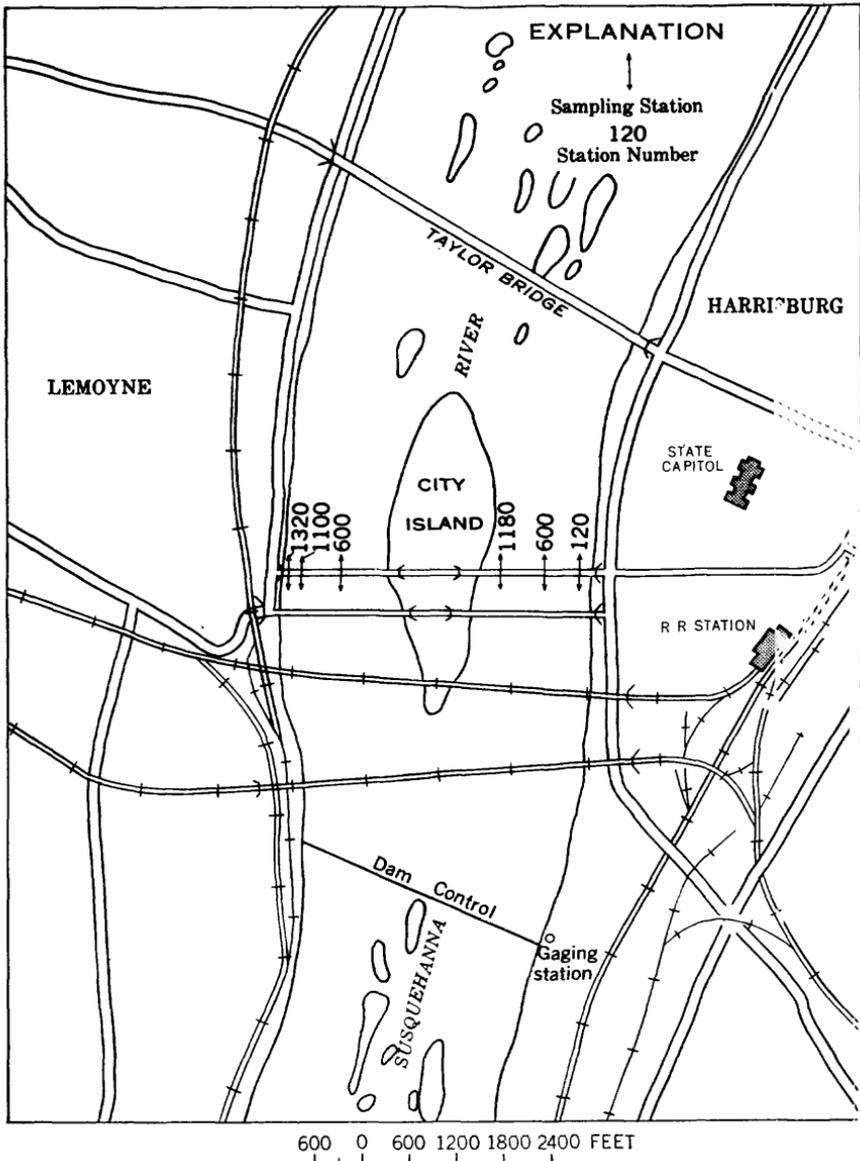


FIGURE 1.—Location of chemical quality cross-section sampling stations, Susquehanna River at Harrisburg, Pa.

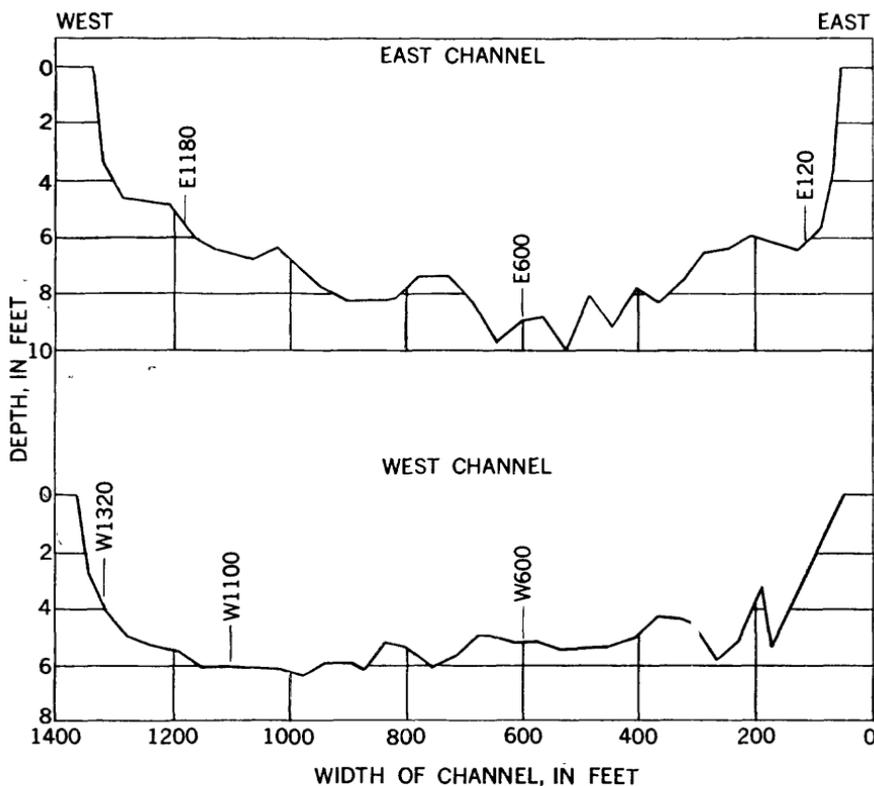


FIGURE 2.—Cross-section diagram of depth in the east and west channels of the Susquehanna River at Harrisburg, Pa., on October 31, 1958.

AVAILABLE DATA

From October 1944 to September 1946, the Susquehanna River was sampled from 1 to 3 times a month at each of 11 sampling sites on the Walnut Street bridge at Harrisburg. In October 1946, the number of sampling sites was reduced to six, three in each channel. In the east channel, samples were usually collected at 95, 575, and 1,155 feet from the east or Harrisburg bank, and in the west channel at 563, 1,063, and 1,283 feet from the west bank of City Island.

Chemical analyses of each sample consisted of the determination of color, pH, specific conductance, bicarbonate, sulfate, chloride, nitrate, and hardness. The results of these chemical analyses from 1944 to 1951 were reported by W. F. White (1947 and 1951) and N. H. Beamer (1953). These publications of the Pennsylvania Department of Commerce contain graphs and brief comments on the Harrisburg stations.

From October 1944 to September 1946, daily water samples were collected at the east channel station E. 1180. The water of this station

location was representative of the quality of raw water used by the former city waterworks on City Island. Temperature, pH, and specific conductance were measured on each sample. The daily samples for each month were composited into three 10-day samples, and a comprehensive analysis was made of each. The comprehensive analysis included the determination of color, pH, specific conductance, silica, iron, calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, fluoride, nitrate, dissolved solids, and hardness.

Results of the chemical-quality studies at the daily sampling station E. 1180 are summarized in a report entitled, "The Chemical Quality of Surface Water in Pennsylvania" (Durfor and Anderson, 1963). The tabulated summary of chemical analyses at this station is given in table 1. The table was prepared by the following methods: (1) frequency distributions of daily temperature, pH, and specific conductance values were determined; (2) relations were established between the specific conductance and the concentration of individual dissolved constituents of composite samples; and (3) on the basis of these empirical relations between specific conductance and ion concentration and the frequency distribution of specific conductance, the frequency distribution of several chemical constituents was estimated.

TABLE 1.—Percent of days in which physical and chemical properties were equalled or exceeded, Susquehanna River at Harrisburg, Pa., station E. 1180, October 1944 to September 1946

[Analyses by U.S. Geol. Survey]

	1 percent	10 percent	50 percent	90 percent	99 percent
Temperature (°F)-----	79	75	55	34	32
pH-----	7.5	7.2	6.9	6.6	6.2
Specific conductance (micromhos at 25 °C)-----	369	278	180	105	88
Chemical analyses in parts per million:					
Calcium (Ca)-----	40	30	20	12	10
Magnesium (Mg)-----	14	10	5.9	3.0	2.2
Sodium and potassium (Na + K)-----	14	10	6.1	3.0	1.4
Bicarbonate (HCO ₃)-----	48	40	26	18	16
Sulfate (SO ₄)-----	126	90	54	28	21
Chloride (Cl)-----	9.0	6.4	4.2	2.4	2.0
Residue on evaporation at 180 °C.-----	244	170	110	64	54
Calcium, magnesium hardness as CaCO ₃ -----	156	114	73	42	34

Compilations of the chemical-quality data collected in Pennsylvania since 1944 are published by the Geological Survey in the Water-Supply Paper series entitled "Quality of Surface Waters of the United States, Parts 1-4, North Atlantic Slope Basins to St. Lawrence River Basin." The chemical quality of the Susquehanna River at Harrisburg was discussed by W. F. White (1949) in a paper presented at a meeting of the Engineers' Society of Western Pennsylvania.

CHEMICAL CHARACTERISTICS

The principal dissolved constituents in the Susquehanna River water at Harrisburg are calcium, magnesium, sodium, silica, bicarbonate, sulfate, chloride, and nitrate. Smaller quantities of other constituents, such as potassium, iron, manganese, and fluoride are also present. The river water generally contains less than 200 ppm (parts per million) of dissolved solids at station E. 1180 and W. 1320 and less than 325 ppm at station E. 120. The dissolved-solids content was estimated from the specific conductance. For water from the Susquehanna River at Harrisburg, the dissolved-solids content is approximately 0.62 ± 0.02 of the specific conductance.

To demonstrate the variations in chemical quality from bank to bank, a tabulation of the maximum, average, and minimum observed values for specific conductance, pH, and chemical analyses, based on once-a-month sampling at the cross-section stations (October 1956 to September 1960), is presented in table 2. This period is chosen for tabulation because of the availability of consecutive monthly data.

The average sulfate and bicarbonate-ion concentrations compiled in table 2 are plotted in figure 3 to demonstrate the variations in concentration of these ions across the river. The bicarbonate ion decreases in concentration from 113 to 19 ppm in a west to east direction, and the sulfate ion increases in concentration from 24 to 131 ppm. The maximum hydrogen-ion concentration (pH) decreases from 8.5 to 7.5 (table 2). The hardness of water is low near the center of the river and increases toward the banks (table 2). The hardness near the east bank results from the presence of calcium sulfate. Near the west bank the hardness is the result of the presence of calcium bicarbonate.

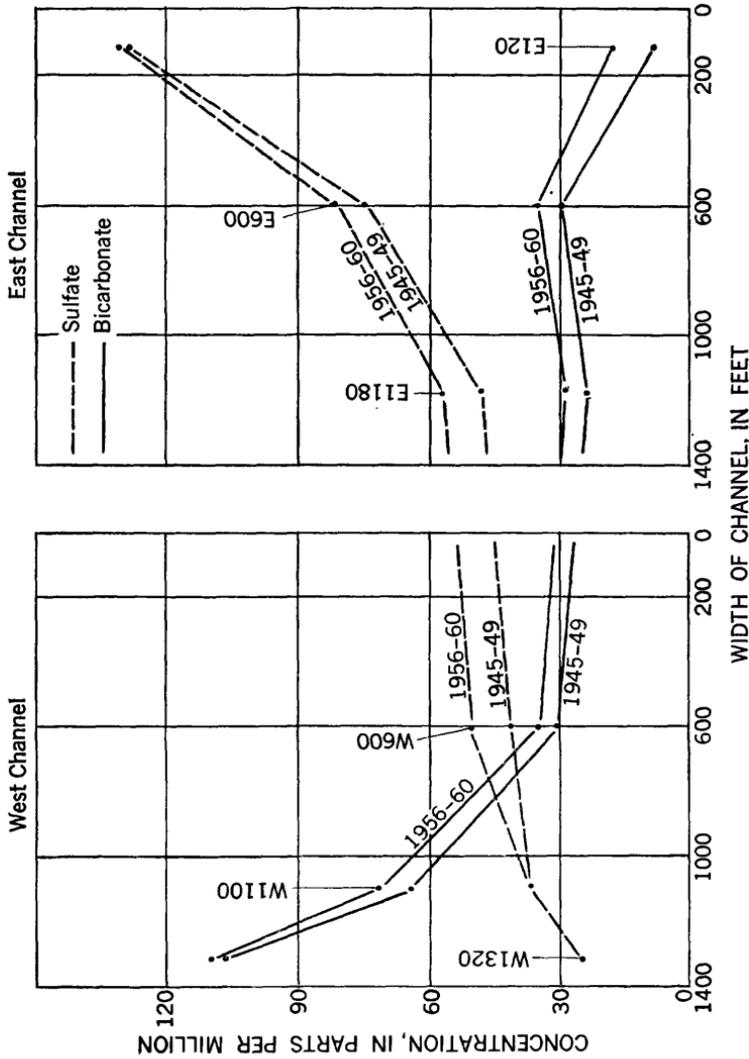


FIGURE 3.—Average bicarbonate- and sulfate-ion concentrations in Susquehanna River cross sections.

TABLE 2.—*Maximum, average, and minimum observed values for specific conductance, pH, and chemical analyses, Susquehanna River at Harrisburg, Pa., October 1956 to September 1960*

[Analyses by U.S. Geol. Survey. Based on once-a-month sampling]

	East channel								
	E. 120			E. 600			E. 1180		
	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum
Specific conductance (micromhos at 25°C).....	610	333	142	488	260	103	391	197	96
pH.....	7.5		5.7	8.2		6.0	8.6		6.1
Chemical analyses (parts per million):									
Carbonate (CO ₃).....	0	0	0	0	0	0	4	0	0
Bicarbonate (HCO ₃).....	34	19	5	56	36	16	64	30	8
Sulfate (SO ₄).....	301	131	36	229	83	23	127	58	20
Chloride (Cl).....	24	8.0	2.0	23	8.3	2.5	17	5.6	2.0
Nitrate (NO ₃).....	8.8	3.5	.6	4.7	2.4	.2	4.7	2.2	.7
Hardness as CaCO ₃ :									
Calcium, magnesium.....	264	139	54	186	103	38	172	77	38
Noncarbonate.....	256	124	28	171	74	23	120	52	10
	West channel								
	W. 600			W. 1100			W. 1320		
	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum
Specific conductance (micromhos at 25°C).....	396	192	92	377	220	109	350	255	113
pH.....	7.9		6.1	8.0		6.4	8.5		6.6
Chemical analyses (parts per million):									
Carbonate (CO ₃).....	0	0	0	0	0	0	4	0	0
Bicarbonate (HCO ₃).....	96	36	6	124	72	20	169	113	16
Sulfate (SO ₄).....	101	51	21	72	37	16	38	24	17
Chloride (Cl).....	21	5.9	.5	19	6.8	1.0	19	7.7	3.0
Nitrate (NO ₃).....	4.1	2.0	.5	5.7	3.0	.3	10	5.8	.2
Hardness as CaCO ₃ :									
Calcium, magnesium.....	152	75	35	136	87	40	160	114	40
Noncarbonate.....	95	45	5	73	28	13	32	22	10

A comparison of bicarbonate, and sulfate-ion concentrations plotted in figure 3 for the 4-year periods 1956-60 and 1945-49 indicates that the river water has changed little during the period of data collection. The mean discharge for the period 1956-60 (34,910 cfs) is slightly less than the mean discharge for the period 1945-49 (35,320 cfs). This slight difference in discharge accounts for the slightly lower bicarbonate and sulfate concentrations during the 1945-49 period.

The variations in specific conductance and, therefore, the dissolved-solids content from bank to bank are shown in figure 4. For both the high and the low discharge rates, the specific conductance is higher near the banks than in the center. The higher conductance values are near the east or Harrisburg bank for both discharge rates. A com-

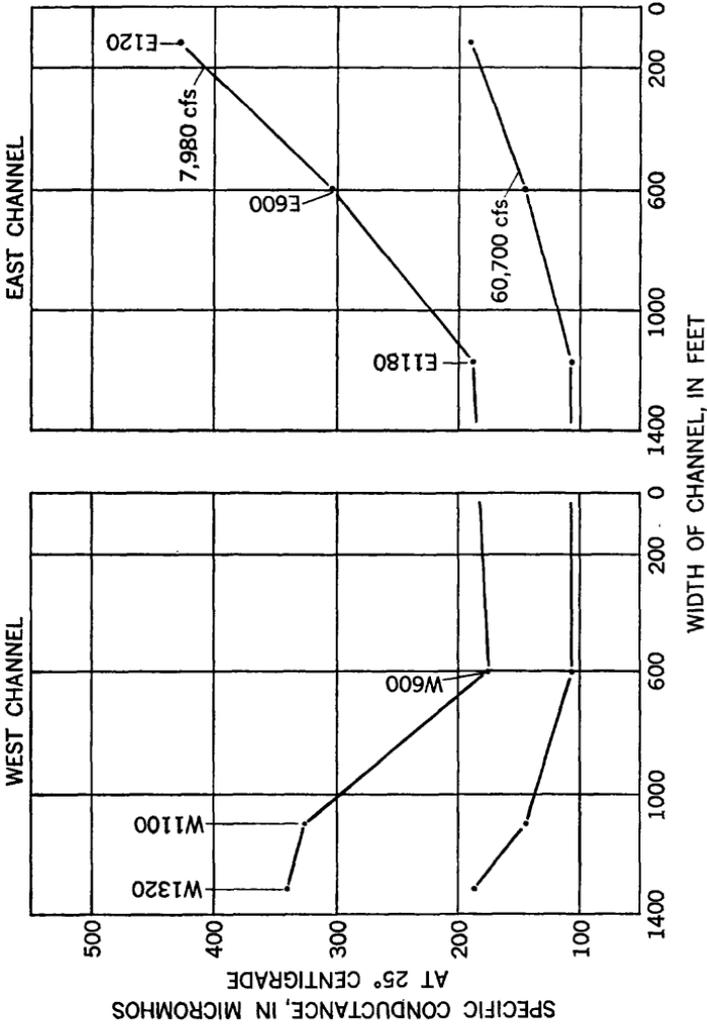


FIGURE 4.—Specific conductances in Susquehanna River at a high (Feb. 16, 1959) and a low (Oct. 15, 1958) discharge.

parison of the specific conductances compiled in table 2 indicates that this same relation occurs for maximum, average, and minimum observed values and, thus, probably occurs at most discharge rates.

ENVIRONMENT AND CHEMICAL QUALITY

The chemical character of the Susquehanna River at Harrisburg is influenced by three major factors: streamflow, anthracite and bituminous coal-mine drainage, and geology. Most of the tributaries draining into the west side of the river contain high concentrations of calcium and bicarbonate ions, in relation to other constituents. Many of the tributaries on the east side contain high concentrations of calcium and sulfate ions. The incomplete mixing of the calcium bicarbonate and calcium sulfate waters produces the cross-section variations at Harrisburg.

A map of the central Susquehanna River basin showing many of the tributaries and sampling points is presented in figure 5.

STREAMFLOW

Streamflow is composed of water that reaches the stream by direct overland flow and by ground-water inflow. After periods of moderate to heavy precipitation, the major part of the water flowing in a stream is the result of direct overland flow. Base flow is composed largely of ground-water inflow. During periods of base flow, the dissolved-solids content of the Susquehanna River is at a maximum, as the chemical quality of the river represents the effect of ground-water inflow and coal-mine drainage. As streamflow increases, the dissolved-solids content is lowered by dilution from direct runoff. The decrease in dissolved-solids content with increase in flow can be shown using the specific conductance of station E. 1187 as a measurement of the dissolved-solids content. During the period 1956-60, the maximum specific conductance, based on a once-a-month sampling, was 391 micromhos on September 16, 1957, and the discharge on this date was 3,580 cfs. On February 15, 1960, the specific conductance was 96 micromhos, and the discharge was 91,000 cfs.

COAL-MINE DRAINAGE

Several tributaries to the Susquehanna River, upstream from Harrisburg, receive coal-mine drainage. The headwaters of the West Branch Susquehanna and Juniata Rivers receive coal-mine drainage from the bituminous coal fields in western Pennsylvania. The Nescopeck, Catawissa, Shamokin, Mahanoy, and Manhantango Creeks and Lackawanna River receive coal-mine drainage from the anthracite coal fields in the northeastern part of the Commonwealth.

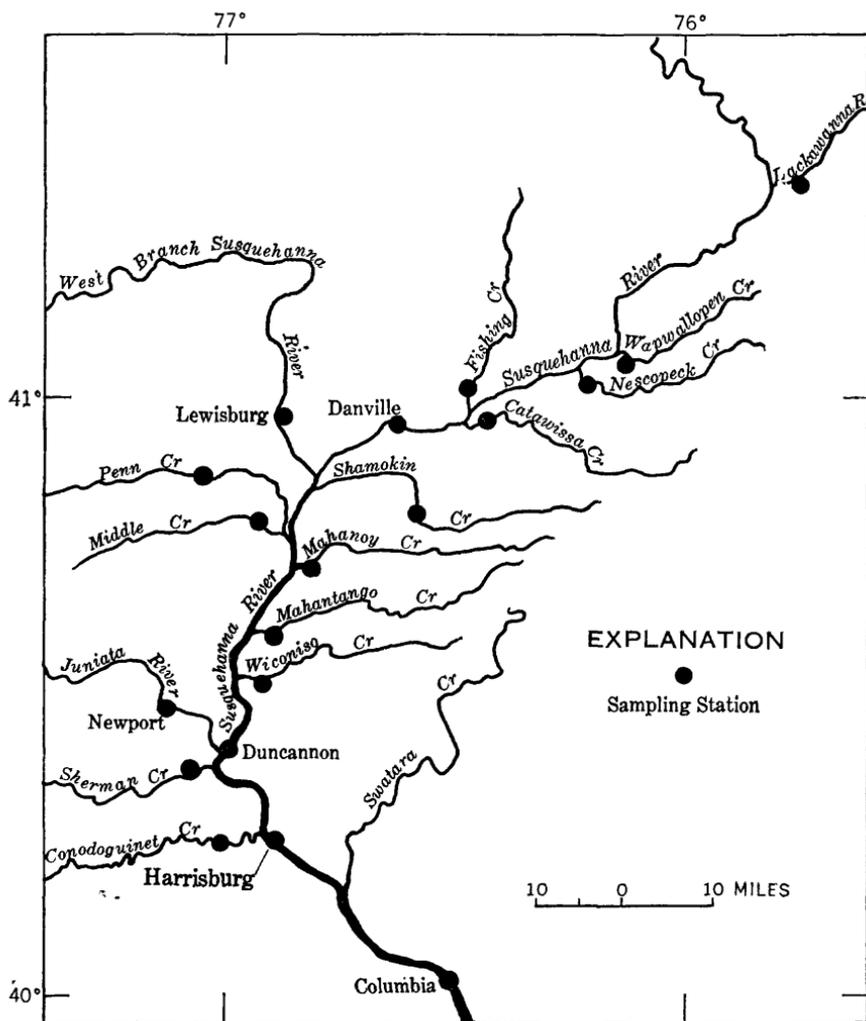


FIGURE 5.—Map of the central Susquehanna River basin.

The chemical quality of streams receiving water drained from coal mines are strongly influenced by the composition and concentration of the coal-mine drainage. As shown by analyses of mine effluents from the anthracite coal fields in table 3, coal-mine effluents are low in pH (below 5.0) and high in iron (above 1.0 ppm), manganese, aluminum, sulfate, and free sulfuric acid content. Accordingly, the dissolved-solids contents of the tributaries draining the anthracite coal regions range between 100 and 3,000 ppm, depending on the amount and concentration of coal-mine effluents that are pumped or seep into the streams in relation to their total flow.

TABLE 3.—Physical and chemical character of mine drainage from anthracite coal fields

[Analyses by U.S. Geol. Survey. Samples collected June 25, 1959]

	Mine A	Mine B	Mine C	Mine D	Mine E
Specific conductance (micromhos at 25°C)-----	533	1, 080	864	1, 200	400
pH-----	3. 60	2. 95	2. 95	3. 00	3. 75
Color-----	1	1	2	1	2
Chemical analyses (parts per million):					
Silica (SiO ₂)-----	13	16	15	17	15
Aluminum (Al)-----	. 5	5. 6	1. 9	10	1. 1
Iron (Fe) ¹ -----	9. 0	9. 2	10	9. 6	2. 3
Manganese (Mn) ¹ -----	2. 9	4. 9	2. 5	5. 8	-----
Calcium (Ca)-----	41	61	39	80	21
Magnesium (Mg)-----	24	48	31	56	23
Sodium (Na)-----	2. 0	2. 0	1. 4	1. 4	1. 4
Potassium (K)-----	1. 8	1. 5	1. 2	1. 5	1. 8
Bicarbonate (HCO ₃)-----	0	0	0	0	0
Sulfate (SO ₄)-----	214	427	280	516	158
Chloride (Cl)-----	1. 2	3. 2	. 6	1. 6	. 6
Fluoride (F)-----	. 3	. 3	. 3	. 4	. 3
Nitrate (NO ₃)-----	. 3	. 4	. 2	. 3	. 1
Residue on evaporation at 180°C-----	332	671	446	821	252
Calcium, magnesium hardness as CaCO ₃ -----	201	350	225	430	147
Total acidity as H ₂ SO ₄ -----	59	108	69	132	15

¹ At time of sampling.

Chemical analyses of water from the principal tributaries to the Susquehanna River above the Harrisburg station are given in table 4. The tributaries were usually sampled near their confluence with the Susquehanna River. The sampling locations are plotted on the map of the Susquehanna River basin (fig. 5). The bicarbonate-ion concentrations of the eastern tributaries range from 0 to 28 ppm, and the sulfate-ion concentrations range from 10 to 925 ppm. The concentrations of bicarbonate ion in the western tributaries range from 12 to 160 ppm and of sulfate ion from 8.6 to 65 ppm.

Bar diagrams of sulfate and bicarbonate-ion concentrations (fig. 6) show that, with the exception of Wapwallopen Creek, the sulfate-ion concentration exceeds the bicarbonate-ion concentration for each of the eastern tributaries. The sulfate-ion concentration exceeds the bicarbonate-ion concentration in only one of the western tributaries, the West Branch Susquehanna River. Coal-mine drainage caused this high sulfate-low bicarbonate relation in these streams.

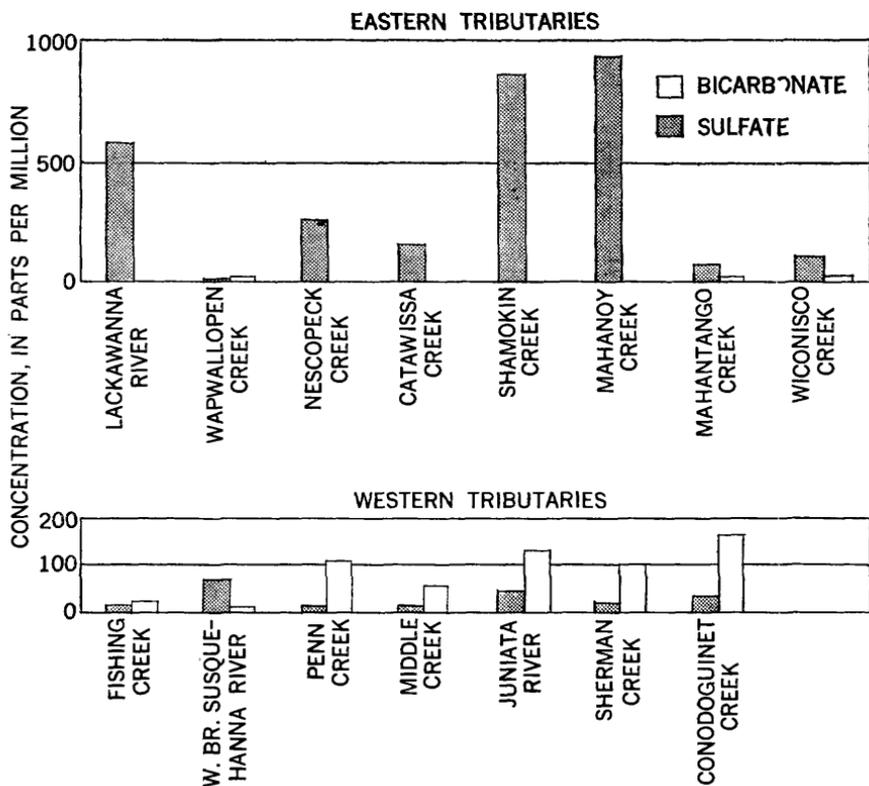


FIGURE 6.—Sulfate- and bicarbonate-ion concentrations in the principal tributaries of the Susquehanna River.

TABLE 4.—*Chemical analyses, in parts per million, at sampling stations in the Susquehanna River basin, Pennsylvania*

[Analyses by U.S. Geol. Survey]

Stream	Date	Bicarbonate (HCO ₃)	Sulfate (SO ₄)	Hardness as CaCO ₃		Specific conductance (micro-mhos at 25°C)	pH
				Calcium, magnesium	Non-carbonate		
Lackawanna River.....	8-25-60	0	573	530	530	1,080	3.75
Wapwallopen Creek.....	6-23-50	16	10	18	5	47	6.6
Nescopeck Creek.....	6-23-50	0	262	154	154	650	3.90
Fishing Creek.....	10-11-57	20	12	22	6	73	6.2
Catawissa Creek.....	10-22-59	0	150	87	87	349	3.95
West Branch Susquehanna River.....	8-9-60	12	65	72	62	189	6.4
Shamokin Creek.....	10-7-59	0	853	700	700	1,730	3.00
Penn Creek.....	10-8-59	103	12	86	2	195	7.4
Middle Creek.....	4-19-60	56	8.6	50	4	120	8.0
Mahanoy Creek.....	6-23-50	0	925	709	709	1,620	3.90
Mahantango Creek.....	6-23-50	6	62	108	61	179	4.9
Wiconisco Creek.....	10-23-59	28	102	128	115	299	6.4
Juniata River.....	8-1-60	126	43	136	33	315	7.6
Sherman Creek.....	10-21-59	99	16	97	16	198	7.1
Conodoguinet Creek.....	10-12-57	160	27	136	5	350	7.2

Chemical analyses of water samples from cross-section locations on the Susquehanna River above and below Harrisburg are tabulated in table 5. These samples were collected during a low discharge (14,800 cfs at Harrisburg) so that the variation in chemical character of the cross section would be maximized.

The chemical analyses of water samples from cross-section locations on the Susquehanna River at Danville and near Duncannon (table 5) show the effect of mine drainage from the Lackawanna River and the Nescopeck, Catawissa, Shamokin, Mahanoy, Mahantango Creeks. The sulfate-ion concentration increases in a west to east direction. This increase is further evidence of the pattern of higher sulfate-ion concentrations and lower pH's on the east side of the cross sections as a result of the coal-mine drainage from the anthracite coal fields into the eastern tributaries (fig. 6) of the Susquehanna River. The pattern is retained in the east channel stations of the Harrisburg cross sections (fig. 3).

TABLE 5.—*Chemical analyses, in parts per million, at cross-section sampling locations on the Susquehanna River in Pennsylvania, collected July 19, 1961*

[Analyses by U.S. Geol. Survey]

Station	Bicar- bonate (HCO ₃)	Sulfate (SO ₄)	Hardness as CaCO ₃		Specific conduct- ance (micro- mhos at 25°C)	pH
			Calcium mag- nesium	Non- carbonate		
Danville:						
West side.....	62	69	120	69	290	7.2
West center.....	67	82	132	76	317	7.2
Center.....	62	85	136	85	332	7.2
East center.....	58	90	134	87	328	7.5
East side.....	50	91	128	87	310	7.1
Duncannon:						
West side.....	36	54	80	51	196	7.2
West center.....	29	67	94	70	228	6.7
Center.....	58	69	118	71	291	7.1
East center.....	65	80	130	77	329	7.1
East side.....	20	206	220	204	493	6.7
Harrisburg:						
West 1320.....	156	19	160	32	313	7.9
West 1100.....	94	33	106	29	241	7.8
West 600.....	44	52	84	48	201	7.3
East 1180.....	34	66	88	60	217	7.1
East 600.....	59	82	124	76	302	7.1
East 120.....	34	140	168	140	399	6.9
Columbia:						
West side.....	73	50	106	46	253	7.3
West center.....	69	52	104	48	251	7.2
Center.....	60	66	112	63	267	7.5
East center.....	56	82	128	82	296	7.2
East side.....	61	93	144	94	335	7.0

The effect of coal-mine drainage (high sulfate concentrations and low pH) from the bituminous coal fields in western Pennsylvania on the chemical quality of the Susquehanna River at Harrisburg is not so pronounced as is the effect of the anthracite fields on eastern tributaries. Neutralization and dilution of streams draining the bituminous coal fields by tributaries draining limestone and dolomite regions in south-central Pennsylvania retard the effect of acid mine drainage.

The effect of coal-mine drainage on the chemical quality of water is more pronounced on the West Branch Susquehanna River than on the Juniata River (table 4). At the Lewisburg sampling station (fig. 5) on the West Branch Susquehanna River, the concentration of the sulfate ion generally exceeds the bicarbonate ion, but at the Newport sampling station on the Juniata River the bicarbonate ion exceeds the sulfate ion (table 4). Durfor and Anderson (1963) reported that for the period 1944-52 the average sulfate-ion concentration at the Lewisburg station was 50 ppm, although the average bicarbonate-ion concentration was 10 ppm. For the same

period, the average sulfate-ion concentration at the Newport station was 41 ppm, though the average bicarbonate-ion concentration was 72 ppm.

GEOLOGIC INFLUENCES

Both the eastern and the western tributaries of the Susquehanna River in the vicinity of Harrisburg are underlain by limestone and dolomite formations and by glacial-drift deposits. Each geologic environment influences the chemical character of the stream. The limestone and dolomite influence the chemical quality because of their position in valley bottoms and their soluble nature. The glacial-drift deposits blanket the uplands in northeastern Pennsylvania. Many of the streams draining the glaciated part flow over buried valleys filled with glacial-outwash deposits. These deposits are permeable and are hydraulically connected to underlying formations.

With few exceptions, calcium-bicarbonate type of water predominates in the tributaries draining into the west side of the Susquehanna River. These tributaries drain regions underlain by limestone and dolomite formations or by glacial-drift deposits. Hence, streams draining these regions are generally alkaline (pH 6.0–8.5) and high in calcium, magnesium, and bicarbonate-ion concentration, in relation to other constituents. Concentrations of calcium, magnesium, and bicarbonate ions and pH are lower in streams draining the glacial-drift areas in the northern part of the basin than in the limestone terranes. Chemical analyses of several western tributaries are presented in table 4 to show chemical quality of the streams draining into the west side of the Susquehanna River above Harrisburg. Figure 6 is a graphical illustration of the sulfate and bicarbonate-ion concentrations for the various tributaries named in table 4.

The bicarbonate-ion concentration at the Harrisburg station W. 1320 is considerably higher (156 ppm) than the concentrations at the west side stations at Danville (62 ppm) or near Duncannon (36 ppm). The Duncannon station is just above the confluence of the Juniata River. The higher bicarbonate-ion concentrations at station W. 1320 may be due to the high concentration of bicarbonate in the water of the Juniata River and the Conodoguinet Creek (fig. 4).

Most of the tributaries that drain into the east side of the river receive coal-mine drainage, and geologic influences do not predominate. Wapwallopen Creek, an exception, drains an area of glacial drift overlying sandstone and shale but does not receive coal-mine drainage. It is low in dissolved solids and generally is higher in bicarbonate-ion concentration than in sulfate-ion concentration (fig. 6).

CONCLUSIONS

The chemical quality of cross-section samples collected near the west bank at Harrisburg closely resembles the water of the Juniata River and Conodoguinet Creek, which drain the limestone terranes to the west of the Susquehanna River. These streams tend to entrain along the west bank of the Susquehanna River and to carry water high in pH and in calcium, magnesium, and bicarbonate-ion concentrations.

Water in the center of the Harrisburg station generally resembles the chemical character of the West Branch Susquehanna River, as its dissolved-solids content is low in relation to other sections of the river, and its sulfate-ion concentration generally exceeds the bicarbonate-ion concentration.

Water sampled near the east or Harrisburg bank shows the influence of coal-mine drainage. River water from east channel station E. 120 is high in sulfate-ion concentration (36-301 ppm) and ranges in pH from slightly acid to slightly alkaline (5.7-7.5).

Although the long distance involved, the many islands and bridge piers, and the rocky streambeds favor mixing of the Susquehanna River flow, the chemical composition of water at the Harrisburg cross section indicates that the principal tributaries above Harrisburg do not intermix sufficiently to lose their identity before reaching Harrisburg. In fact, the cross-section variations in chemical composition of the water at the Harrisburg station are retained at Columbia, several miles downstream from the Harrisburg station. This lack of lateral mixing probably is due to the very small depth-width ratio and also to the extreme width of the river. The river at median flow at the Harrisburg sampling station ranges between 3.9 and 9.3 feet deep and is approximately 3,000 feet or slightly more than half a mile wide.

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