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# WATER QUALITY

# OF

# THE SWATARA CREEK BASIN, PA.

By

E. F. McCarren, J. W. Wark, and J. R. George

Prepared by the U. S. Geological Survey
in
cooperation with the Pennsylvania
Department of Forests and Waters

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# WATER QUALITY OF THE SWATARA CREEK BASIN, PENNSYLVANIA

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## ABSTRACT

The Swatara Creek of the Susquehanna River Basin is the farthest downstream sub-basin that drains acid water (pH of 4.5 or less) from anthracite coal mines. The Swatara Creek drainage area includes 567 square miles of parts of Schuylkill, Berks, Lebanon, and Dauphin Counties in Pennsylvania.

To learn what environmental factors and dissolved constituents in water were influencing the quality of Swatara Creek, a reconnaissance of the basin was begun during the summer of 1958. Most of the surface streams and the wells adjacent to the principal tributaries of the Creek were sampled for chemical analysis. Effluents from aquifers underlying the basin were chemically analyzed because ground water is the basic source of supply to surface streams in the Swatara Creek basin. When there is little runoff during droughts, ground water has a dominating influence on the quality of surface water. Field tests showed that all ground water in the basin was non-acidic. However, several streams were acidic. Sources of acidity in these streams were traced to the overflow of impounded water in unworked coal mines.

Acidic mine effluents and washings from coal breakers were detected downstream in Swatara Creek as far as Harper Tavern, although the pH at Harper Tavern infrequently went below 6.0. Suspended-sediment sampling at this location showed the mean daily concentration ranged from 2 to 500 ppm. The concentration of suspended sediment is influenced by runoff and land use, and at Harper Tavern it consisted of natural sediments and coal wastes. The average daily suspended-sediment discharge there during the period May 8 to September 30, 1959, was 109 tons per day, and the computed annual suspended-sediment load, 450 tons per square mile.

Only moderate treatment would be required to restore the quality of Swatara Creek at Harper Tavern for many uses. Above Ravine, however, the quality of the Creek is generally acidic and, therefore, of limited usefulness to public supplies, industries and recreation.

In general, the quality of Swatara Creek improves after it mixes with water from the Upper Little and Lower Little Swatara Creeks, which converge with the main stream near Pine Grove. Jonestown is the first downstream location where Swatara Creek contains bicarbonate ion most of the time, and for the remaining downstream length of the stream, the concentration of bicarbonate progressively increases. Before the stream enters the Susquehanna River, chemical and diluting processes contributed by tributaries change the acidic calcium sulfate water, which characterizes the upper Swatara, to a calcium bicarbonate water.

A major tributary to Swatara Creek is Quittapahilla Creek, which drains a limestone region and has alkaline characteristics. Effluents from a sewage treatment plant are discharged into this stream west of Lebanon. Adjacent to the Creek are limestone quarries and during the recovery of limestone, ground water seeps into the mining areas. This water is pumped to upper levels and flows over the land surface into Quittapahilla Creek.

As compared with the 1940's, the quality of Swatara Creek is better today, and the water is suitable for more uses. In large part, this improvement is due to curtailment of anthracite coal mining and because of the controls imposed on new mines, stripping mines, and the related coal mining operations, by the Pennsylvania Sanitary Water Board. Thus, today (1962) smaller amounts of coal mine wastes are more effectively flushed and scoured away with each successive runoff during storms that affect the drainage basin. Natural processes neutralizing acid water in the stream by infiltration of alkaline ground water through springs and through the streambed are also indicated.

# INTRODUCTION

## Objectives and Scope

The dominant factors affecting water quality in the Swatara Creek drainage basin are land use, such as coal mining, and ground water effluents; particularly those ground water effluents of aquifers in limestone formations. These factors were the principal facets of water quality evaluation described in this report.

The study was prompted chiefly by two questions: How far downstream in Swatara Creek does acid water flow, and what are the concentrations of dissolved and suspended solids at selected sites throughout the drainage basin.

Twenty-eight locations were selected as sampling sites. Samples collected at these locations during periods of high and low flows were analyzed for the most common dissolved chemical constituents and physical properties of water. Water discharge, specific conductance, pH, temperature, and hardness were determined at the time of sampling. Measurements of stream discharge were made at many locations, and at different times, in order to compute the discharge of acid, dissolved solids, and suspended sediment under different conditions of flow.

Instrumentation studies of Swatara Creek were made at several locations. An electrical conductivity instrument was installed at Middletown for measuring continuously, from July 30 to December 10, 1959, the variations of specific conductance. Other specific conductance studies of shorter duration, by instrumentation, were made of the Quittapahilla Creek at Syner.

On October 1, 1958, a daily sampling station was established at Harper Tavern to supplement data already obtained from previous studies. The chemical quality record of past studies of the Creek and the records of private agencies, whenever available, were reviewed and evaluated for correlation purposes.

Water samples from wells at 15 locations representing aquifers in different geologic formations were analyzed. These analyses were done principally to determine the chemical quality relationship existing between ground water in the area and that of nearby surface streams. Other analyses and data of ground water resources of the area were used also for reference and correlation purposes.

## Location of Swatara Creek Drainage Basin

The Swatara Creek drainage basin lies in parts of the Piedmont Plateau province of southeastern Pennsylvania and of the Valley and Ridge province in central Pennsylvania. Headwaters of the Creek rise in the Appalacian Mountains (fig. 1).

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Swatara Creek is a tributary to the Susquehanna River. Its source is in Broad Mountain, Foster Township, of Schuylkill County. It begins a southwesterly course from an elevation of 1,660 feet, flowing through Schuylkill, Lebanon, and Dauphin Counties, to the Susquehanna at Middletown, a distance of 69 miles. The mouth of Swatara Creek is approximately 45 river miles upstream from the Pennsylvania-Maryland State line and approximately 50 miles upstream from the Conowingo hydro-electric dam in Maryland.


FIGURE 1 .--SWATARA CREEK DRAINAGE BASIN, PA.

## Factors Affecting the Chemistry of Water

During the 1959 water year Swatara Creek at Harper Tavern carried approximately 37,000 tons of dissolved solids (table 11). This is approximately equivalent to 102 tons per square mile. Streams in the United States carry about 270,000,000 tons of dissolved material to the oceans annually. This is approximately equivalent to 90 tons per square mile. The total load carried by a stream depends upon the concentration of dissolved materials and the volume of water carrying them.

From source to mouth Swatara Creek flows over a varied terrain that includes sedimentary formations of coals, sandstones, conglomerates, shales, and limestones. These sedimentary rocks consist of material that has settled out of air or water. Soluble materials in these rocks often include calcium, magnesium, carbonate, sulfate, aluminum, iron, manganese, copper and phosphate. Insoluble materials in the stream may include some inorganic and organic matter. Both dissolved material and sediments are transported by Swatara Creek and its tributaries through processes of wear and deposition. The geology or composition of the earth over which streams flow, therefore, is reflected in the quality of water.

The value of surface water for various uses depends upon its chemical composition and the amount of concentration of dissolved solids and gases. For a small fraction of a second during its journey to earth, precipitation may be absolutely pure water. It begins to change in quality as it absorbs gases and washes solid matter from the air. As a universal solvent, water dissolves mineral matter on and below the earth's surface. Weathering of rocks results from leaching, hydration, and oxidation and reduction, often aided by bacteria and decaying plant and animal remains. Underground, water is in contact with rock for longer periods than is surface water and, therefore, generally it contains higher concentrations of solutes. Water transports these solutes and may even alter and convert them by chemical action to new materials, which may be deposited.

When water is used by man for industry, public water supply, sanitary purposes, irrigation, and recreation, additional solutes are dissolved. After use, water may be treated, but often it is returned untreated to streams of natural water. Identification of the solutes and of their quantities in water, together with determinations of pH, specific conductance, temperature, and color provide analytical data necessary for classifying water chemically, assessing its usefulness, and investigating the factors that significantly affect it.

## Significance of Chemical Analyses of Water

Many products manufactured by industries require process water that is free of particular solutes. To many industries the selection of a public water supply or raw water source of supply from wells or surface streams can have important influence on the quality of their manufactured products. Large withdrawals of water by industry for steam generation, as a coolant, and for other industrial uses, require that some water quality standards be maintained to assure efficient and low-cost operation of boilers, cooling systems, and process units.

In general, industry is concerned with constituents of water that cause hardness. Calcium and magnesium are the principal hardness-causing cations, although other substances, such as aluminum, iron, manganese, strontium, zinc, and free acids also cause water hardness. Unless removed from the solution of water these water-hardness-inducing constituents cause a build-up of scale in boilers, hot water heaters, and pipes, a resulting economic loss due to poor heat transfer, increased fuel comsumption, and replacement of parts. In hard water, soap will not cleanse nor lather until the hardness-causing constituents are precipitated as the insoluble salts of fatty acids.

Recently, research teams in England have made statistical studies of the relation between hardness of water and the incidence of cardiovascular diseases. The British team suggests that ".....the softer the water supply, the higher the local death rate from cardiovascular disease." This relationship was first reported by Dr. Henry A. Schroeder of Dartmouth Medical School in Hanover, N. H., (Water Newsletter, 1961). Although the study indicates no conclusive evidence linking soft water with heart disease, the analyses for minerals in consumable water supplies provide basic data significant to more comprehensive studies by different agencies in the future. Studies relating the concentration of nitrate and fluoride in water to pathological chemistry have been reported (California Water Pollution Control Board, 1952).

Chemical analyses of water in the Swatara Creek basin, as reported in this study, represent determinations for the most common constituents dissolved in water. These constituents may affect potability of the water and make it objectionable for domestic supplies and industrial uses when their concentrations exceed established individual tolerances. Most public water supply systems have recognized the U. S. Public Health Service drinking water standards limiting the acceptable concentrations of elements and substances in water. Some of these standards are (U. S. Public Health Service, 1962):

| | Concentrations in Mg/l |
|---|---|
| Lead (Pb) | 0.05 |
| Fluoride (F) | 1.7 |
| Arsenic (As) | .05 |
| Selenium (Se) | .01 |
| Hexavalent Chromium (Cr) | .05 |
| Copper (Cu) | 1.0 |
| Iron (Fe) | .3 |
| Manganese (Mn) | .05 |
| Zinc (Zn) | 5.0 |
| Chloride (Cl) | 250 |
| Sulfate ($SO_4$) | 250 |
| Phenolic compounds ($C_6H_5OH$) | .001 |
| Total dissolved solids | 500 |
| Nitrate ($NO_3$) 1/ | 45 |

1/ In areas in which the nitrate content of water is known to exceed the listed concentration, the public should be warned of the potential dangers of using the water for infant feeding.

Several streams in the Swatara Creek basin are stocked with game fish by the Pennsylvania Fish Commission. It is significant, therefore, for the propagation of fish and other aquatic life, to know beforehand that Pennsylvania streams meet the following criteria established by the Pennsylvania Fish Commission:

| | |
|---|---|
| Dissolved oxygen | Not less than 5 ppm |
| pH | 6.7 - 8.6 |
| Specific conductance | 150 - 500 micromhos |
| Free carbon dioxide | Not over 3 cc/ liter |
| Suspended solids | Such that the millionth intensity for light penetration will not be less than 5 meters. |

## Factors Affecting Sediment Discharge and Sediment Characteristics of Water

The erosion, transportation, and deposition of solids by flowing water is a weathering process known as fluvial sedimentation. Heavy sediment loads in a stream are the most obvious result of soil destruction by wind and water erosion. Erosion begins when the raindrop strikes the ground and dislodges soil particles.

Rainfall that does not seep through the ground or has not yet reached a river, stream, lake or pond flows over the land producing sheet erosion. In rivers and streams, water performs a process of channel or scour erosion and acquires additional sediment through erosion of banks and channels. Much of the sediment is deposited along the way in varying amounts, filling in channels and forming bars. In times of flood, sediment may be deposited in large amounts over flood plains. Thus, deposition of sediment is the counterpart of erosion.

Not all sediment in streams is natural sediment. For example, in the upper Swatara fine coal is part of the sediment being transported and redeposited. To help identify the composition of sediment, particle size and density measurements were made. Identification of sediment helps engineers, soil conservationists, agronomists, and other earth scientists interpret the data for their own purposes. Interpretation of sediment data may be helpful to land management groups who may then be better informed about a cultivated area losing fertile soil by water erosion.

Measured sediment discharge provides data for planning the storage capacities of dams and reservoirs because accumulation of sediment occupies space needed to store water. Suspended sediment may result in heavy damage to hydroelectric equipment by causing excessive wear on turbines. Most public water supplies in the Swatara Creek basin require treatment for sediment removal.

Although much of the eroded soil carried by surface streams never reaches the open sea, the quantities of suspended material carried by rivers and streams of the United States to the oceans may be as much as one billion tons annually (Gottschalk and Jones, 1955). The sediment carried out of a river basin to the oceans is the basin's sediment yield.

## Specific Electrical Conductance of Water

Continual recording electrical conductivity instruments were installed at selected locations along Swatara Creek. One of these instruments was operated at Middletown from July 30 to December 10, 1959. Other conductivity studies of shorter duration by instrument were made of the Quittapahilla Creek at Syner.

In water analyses the specific electrical conductance determination is used as a quick method for estimating the dissolved-solid content. Conductance is the reciprocal of the resistance water may have to an electrical current passing between two immersed electrodes. Because conductance is affected by temperature, a standard temperature of 25°C is specified in reported values.

When water is relatively pure and consequently low in dissolved solids, it resists the flow of electrical current. The unit used in measuring this resistance is the ohm. When water becomes more concentrated with dissolved solids, much of the dissolved material is soluble salts that dissociate into ions. These salts increase the capacity of water to conduct electricity. Because conductance increases with an increase of dissolved solids, it is a measurement that is preferred to the measurement of resistance. The unit of measuring conductance is the mho. Most natural waters have dissociated ions in concentrations less than one mho and, therefore, specific electrical conductivity of water is usually reported in micromhos.

Not all dissolved solids in water conduct electricity. For example, most silica in solution probably is in the nonionized form. Furthermore, the different types of ions in solution differ in their degree of dissociation, their mobility, and in their charge. Because of these conditions, and perhaps others, there is no direct relationship between dissolved solids and conductance. The preceding statement is supported by data such as those for the 1959 water year at Harper Tavern on Swatara Creek, where the dissolved solids ranged from 60 to 78 percent of conductance.

## Acknowledgments

The authors acknowledge with appreciation the cooperation of the Pennsylvania Bureau of Sanitary Engineers at Reading, Pa., in making available their records of chemical analyses and other useful information on Swatara Creek, and the U. S. Bureau of Mines at Schuylkill Haven, Pa., for helping to locate the overflow of acid mine water from unworked anthracite mines, for identifying water pools resulting from strip-mining operations, and for the release of general information important to this report. Appreciation is extended also to public water supply officials and various industries for volunteering information and making available their chemical quality records.

## SWATARA CREEK BASIN

### Historical Background and Regional Setting

Swatara Creek, "Swahatawro", is said to be derived from the Indian, "where we fed on eels". From the chronicles of our Colonial history and biographies of early Pennsylvanians, we learned that during the early part of our history the Swatara flowed clear and potable and abounded with spring runs of shad, which were caught in nets well above the mouth of Swatara Creek at Middletown. Along the banks several grain mills were established as the region's first business enterprises. The lands occupied by the early settlers along the Swatara were near a settlement of the Tulpehocken Indians. The occupation of these Indian lands without purchase caused much trouble, including the "Tulpehocken Massacre".

After the American Revolution, Swatara Creek attained political and economic significance as a future important link to an inland waterway system designed to connect Philadelphia and eastern Pennsylvania with Pittsburgh. Settlers of rural Pennsylvania west of the Schuylkill River were conscious of the disadvantages of being remote from the tidewater city of Philadelphia, which was then the center of political power and the capital of the State.

The inland waterway was to be created by making use of the Schuylkill River from Philadelphia to Tulpehocken Creek near Reading. The construction of a canal on the Tulpehocken would serve as a junction between the Tulpehocken, Quittapahilla, and Swatara Creeks, the latter leading to the Susquehanna River and thence to the Juniata River. The waterway was to continue along the Juniata and its branches to Poplar Run in old Huntingdon County. From Poplar Run, a portage of not more than 18 miles would have been necessary to cross the mountains to reach the Conemaugh, Kiskiminitas and Allegheny Rivers to Pittsburgh.

The canal movement in the United States began about 1823 when the historical Union Canal was conceived. The Union Canal, which was finished in 1827 and operated from 1828 to 1884, was about 80 miles long and connected the Schuylkill River near Reading with the Susquehanna River at Middletown. The Swatara supplied water to a feeder branch of the canal, which paralleled the creek from Pine Grove for nearly 7 miles. This feeder branch was navigable from nearby mines to Reading and Middletown and points along the way.

The Union Canal was divided into three sections: the eastern, the summit, and the western. The summit section crossed the limestone region of Lebanon County where excavation of the rock was necessary. During construction of the canal, engineers observed the weathering and solvent character of water on limestone. To form the canal bed, planks were lain throughout the limestone area. West of Lebanon, a tunnel 729 feet long, 18 feet wide, and 16 feet high was excavated through solid rock.

## Climate

The climate of the Swatara Creek basin is typical of the mild climate of Pennsylvania where few hours of extreme temperature have been recorded. Temperatures above 100°F have been recorded infrequently. Temperatures below freezing are not uncommon. Killing frosts usually occur in October and late April, although the record indicates they may occur as early as September or as late as May.

The growing season begins in April and ends in October. At Lebanon, the mean maximum and minimum daily temperatures for a 35-year record (1917-52) were 62.5°F and 41.5°F, respectively.

The range of mountains known as the Appalachian barrier has considerable influence upon local precipitation in the Swatara Creek drainage basin. The range directs eastwardly moving storms through Pennsylvania and also may divert the occasional storms originating from the West Indies in the Caribbean Sea. These storms, at times, reach hurricane proportions and are associated with copious rainfall. In the Swatara basin the average precipitation is 43 inches per year.

Precipitation is heaviest in the upper part of the Swatara Creek basin where the average for 1931-59 was about 47 inches.

Annual precipitation, 1931-59
(U. S. Weather Bureau)

| | Pine Grove (inches) | Lebanon (inches) | Middletown (inches) |
|---|---|---|---|
| Maximum | 63.3 | 55.7 | 50.1 |
| Minimum | 29.2 | 29.6 | 27.2 |
| Average | 46.7 | 43.9 | 40.8 |

Snowfalls occur generally from November through April--the heaviest usually during late February and early March. For 1959, precipitation at Pine Grove was 50.9 inches and at Lebanon 42.8 inches. At Pine Grove in October 1959, the 9.26 inches of rainfall was the heaviest for this month in the State.

Although precipitation is fairly uniform throughout the year in Pennsylvania, during the summer a large percentage of it is returned to the atmosphere by evapotranspiration. In Pennsylvania evaporation and transpiration losses range between 16.6 and 23.8 inches annually (Pennsylvania Industrial Development Bureau, 1958).

## Topography

The general physical character of Swatara Creek basin is divided between rugged ridge and valley terrain throughout the northern one-third of the basin and rolling to hilly terrain throughout the central and southern part. Elevations in the basin range from about 280 feet at Middletown to 1,720 feet at a point about 4 miles north of Tremont.

Several long, steep ridges trend northeasterly across the part of the basin above Inwood. Highly resistant, steeply dipping sandstones form ridges standing 800 to 1,000 feet above the adjacent narrow valleys. In this area of steep ridges the average gradient of Swatara Creek is 47 feet per mile as compared to an average gradient of 14 feet per mile for the entire length of channel.

South of Inwood, Swatara Creek meanders across a part of the "Great Valley". Bordered on the north by steep ridges and on the south by mountains, the valley has formed through the erosion of less resistant shales and limestones. The topography in this part of the basin is gently rolling to hilly and has much less relief.

## Geology

Rocks exposed in the Swatara Creek basin range in age from Cambrian to Triassic (Fig. 2). Except for rocks of Triassic age,

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Figure 2.--(Caption on next page) belongs near here.

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the strata appear in an orderly succession from older in the southern part of the basin to younger at the northern end. The Triassic rocks include shales and sandstones of the Gettysburg shale and intrusive diabase. Table 1 summarizes the lithology of geologic formations exposed throughout Swatara Creek basin.

The drainage area above Ravine is underlain primarily by sedimentary rocks of Pennsylvanian age. These strata consist of shale, sandstone, conglomerate, and several veins of workable anthracite coal. The oldest member of Pennsylvanian age is exposed along Swatara Creek about three-quarters of a mile south of Tremont.

The area from Tremont to Swatara Gap at Inwood is underlain by an alternating succession of sandstone, shale, and conglomerate of Silurian, Devonian, and Mississippian age. These strata, together with those of Pennsylvanian age, characterize the steep ridges and narrow valleys typical of the Valley and Ridge province that extends across central Pennsylvania into Maryland, Virginia, and West Virginia.

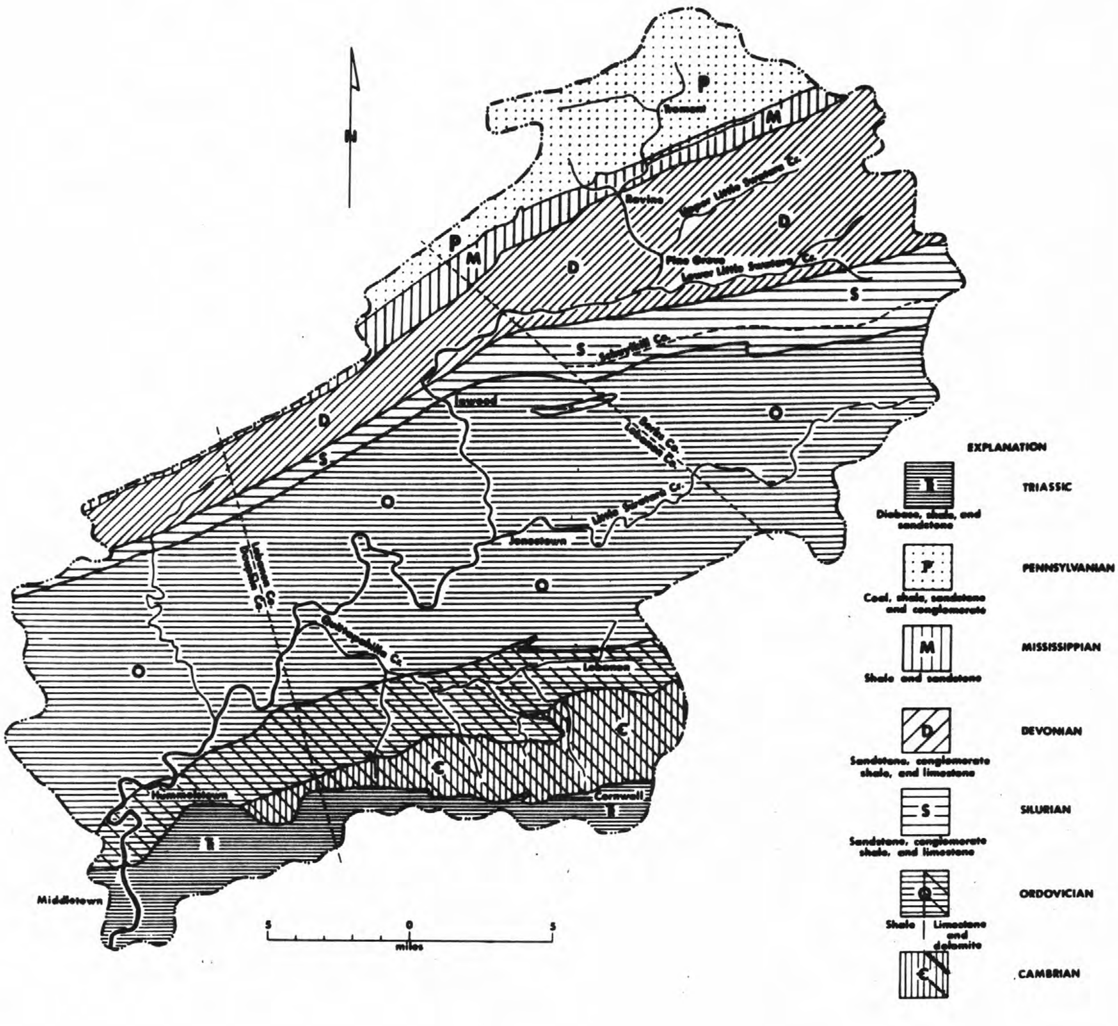


Figure 2.--Generalized geologic map of Swatara Creek basin, Pa.

Table 1.--Summary of exposed rock formations in Swatara Creek basin, Pa.

| Age | | | Group or formation | Lithology |
|---|---|---|---|---|
| Mesozoic | Triassic | | Diabase | Dark gray medium-grained igneous intrusive. |
| Mesozoic | Triassic | | Gettysburg Shale | Red to brown, fine to coarse grained quartzose sandstone, interbedded with red shales and local conglomerates. |
| Paleozoic | Carboniferous | Pennsylvanian | Post-Pottsville rocks | Brown and gray sandstone and shale, and some conglomerate and several workable coals. |
| Paleozoic | Carboniferous | Pennsylvanian | Pottsville Formation | Light-gray to white sandstone and conglomerate and some workable coals. |
| Paleozoic | Carboniferous | Pennsylvanian | Mauch Chuck Formation | Chiefly red and green shale and gray sandstone. |
| Paleozoic | Carboniferous | Mississippian | Pocono Formation | Massive, thick-bedded sandstone and some shale. |
| Paleozoic | Carboniferous / Devonian | Mississippian / Upper | Catskill Formation | Chiefly red to brown shale and sandstone; tongues of gray and green sandstones. |
| Paleozoic | Devonian | Middle | Hamilton Group | Fossiliferous, dark gray shale and sandstone. |
| Paleozoic | Devonian | Middle | Marcellus Shale | Shale, black, carbonaceous. |
| Paleozoic | Devonian | Middle | Onondaga Limestone | Dark argillaceous limestone and dark, thin-bedded shale. |
| Paleozoic | Devonian | Lower | Oriskany Group | Coarse sandstone grading into fine pebbly conglomerate. |
| Paleozoic | Silurian | | Bloomsburg Red Beds | Red thin- to thick-bedded shale; local sandstones and some thin limestones. |
| Paleozoic | Silurian | | McKenzie Formation | Gray thin-bedded shale interbedded with thin fossiliferous limestone. |
| Paleozoic | Silurian | | Clinton Formation | Red and green sandstone and shale, some white quartzitic sandstone. |
| Paleozoic | Silurian | | Tuscarora Sandstone | Gray, medium- to thick-bedded quartzitic sandstone and conglomerate. |
| Paleozoic | Ordovician | | Martinsburg Shale | Light- to dark-gray shale grading into sandstone; interbedded red shale, gray to brown sandstone and some thin limestone; scattered diorite intrusives and andesite lavas in Lebanon County. |
| Paleozoic | Ordovician | | Leesport Limestone | Limestone, thin-bedded, dark, slaty, and argillaceous. |
| Paleozoic | Ordovician | | Stones River Limestone | Limestone, thin-bedded, pure, dove-colored. |
| Paleozoic | Ordovician | | Beekmantown Group | Thick- and thin-bedded dolomite and dolomitic limestone interbedded with limestone and stringers of chert. |
| Paleozoic | Cambrian | | Conococheaque Limestone | Limestone and dolomite, thin-bedded, gray, sandy in lower part. |

From Swatara Gap to Hummelstown, Swatara Creek meanders across the Martinsburg shale of Ordovician age. This formation, which is mostly a soft shale with some small, scattered exposures of sandstone, limestone, diorite, and andesite, is exposed throughout 45 percent of the basin.

A belt of limestone and dolomite of Cambrian and Ordovician age trends northeast across the southern part of the basin. The exposures are nearly 7 miles wide at Lebanon but narrow to about 2 miles at Hummelstown. The limestone and dolomite underlie about 15 percent of the entire basin and make up 75 percent of the rocks exposed throughout the Quittapahilla Creek drainage area.

The extreme southern part of the basin is underlain by intrusive diabase or sandstone and shale of Triassic age.

## Ground Water

When ground water mixes with surface water through seepage and springs, the chemical quality of the ground water may dominate the quality of the stream into which it seeps. This condition is most likely to occur during periods of little precipitation and runoff, a time when streamflow is maintained largely by ground-water effluent. These effluents often contain high concentrations of solutes dissolved from underground rocks and soils.

Much of the lower part of the Swatara drainage basin is noted for its high quality limestone. Ground water filtering through the earth to these formations flows through fissures, dissolves limestone, and enlarges the passages of flow. Because of the larger passages in limestone aquifers water can move more rapidly through it than through most other aquifers. The fissured limestone is permeable and generally has a high capacity for underground storage of water and thus permits ready infiltration of precipitation. This ground water maintains the flow in some streams that contain high concentrations of solutes.

In the Swatara Creek basin, ground water in limestone or dolomite is a calcium bicarbonate type, high in dissolved solids (wells 6 and 7, table 2). Water from the Martinsburg Shale is also a calcium bicarbonate type but generally is lower in dissolved solids than water from limestone or dolomite (wells 3, 4, 8, and 9).

The sandstone formations consist mostly of materials not readily soluble, and, therefore, the water in these formations contains less dissolved solids than water in limestone or dolomite (wells 1 and 2, table 2). Average analyses of ground water from three principal lithologic types in the Swatara basin are shown in (figure 3.) Chemical analyses of ground water from wells located throughout the basin are

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Figure 3.--(Caption on next page) belongs near here.

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reported in table 2. Locations of the sampling sites are shown on figure 1.

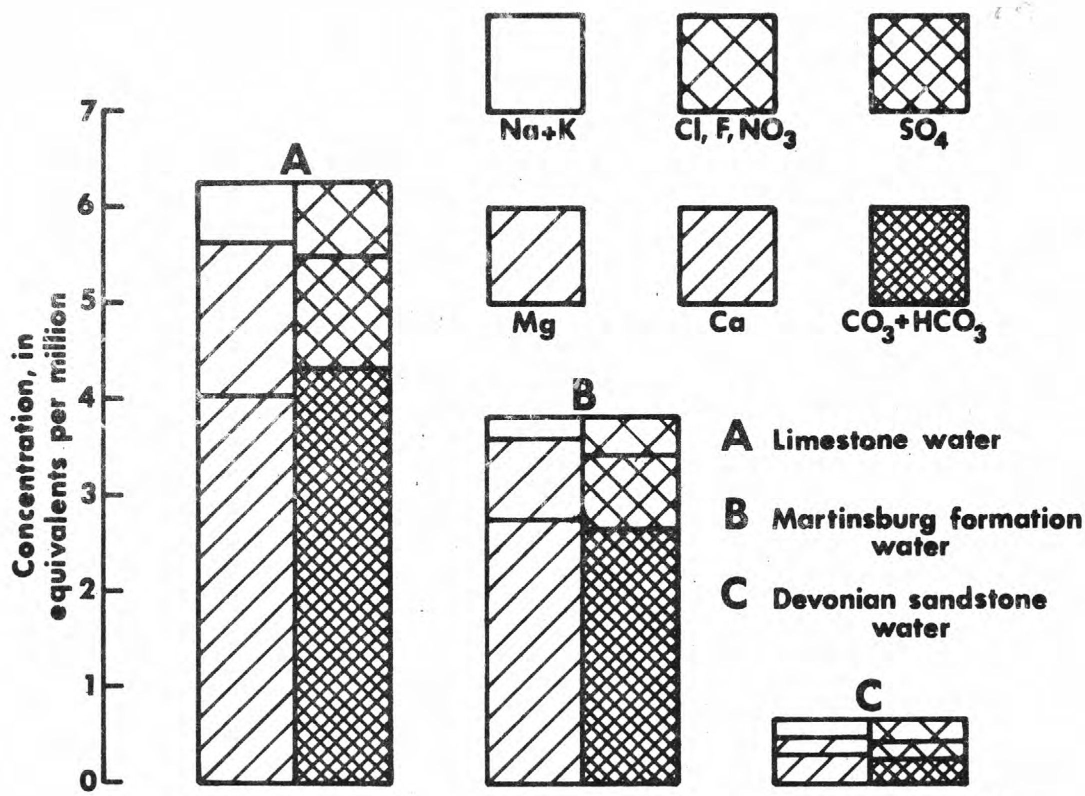


Figure 3.--Typical analyses of ground water from three principal lithologic types in Swatara Creek basin, Pa.

Table 2.--Chemical analyses of ground water, Swatara Creek Basin, Pa., 1959

Chemical analyses in parts per million and equivalents per million

| Well number[1] | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date of collection | Feb. 12, 1959 | | Feb. 12, 1959 | | Mar. 27, 1959 | | Mar. 26, 1959 | | Mar. 27, 1959 | |
| | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm |
| Silica ($SiO_2$) | 8.6 | -- | 14 | -- | 24 | -- | 16 | -- | 19 | -- |
| Iron (Fe) in solution when collected | .05 | -- | .12 | -- | .17 | -- | .38 | -- | .03 | -- |
| Iron (Fe) in solution when analyzed | .00 | 0.00 | .01 | 0.00 | .01 | 0.00 | .15 | 0.00 | .01 | 0.00 |
| Manganese (Mn) in solution when collected | .01 | -- | .01 | -- | .05 | -- | .06 | -- | .17 | -- |
| Manganese (Mn) in solution when analyzed | .00 | .00 | .00 | .00 | .03 | .00 | .01 | .00 | .16 | .01 |
| Calcium (Ca) | 4.8 | .24 | 5.6 | .28 | 56 | 2.79 | 43 | 2.15 | 96 | 4.79 |
| Magnesium (Mg) | 2.9 | .24 | 2.4 | .20 | 12 | .99 | 10 | .82 | 11 | .90 |
| Sodium (Na) | 3.7 | .16 | 3.0 | .13 | 7.4 | .32 | 10 | .44 | 12 | .52 |
| Potassium (K) | 1.3 | .03 | 5.0 | .13 | 1.1 | .03 | 4.9 | .13 | 1.0 | .03 |
| Carbonate ($CO_3$) | 0 | .00 | 0 | .00 | 0 | .00 | 0 | .00 | 0 | .00 |
| Bicarbonate ($HCO_3$) | 7 | .11 | 20 | .33 | 166 | 2.72 | 110 | 1.80 | 240 | 3.93 |
| Sulfate ($SO_4$) | 14 | .29 | 5.1 | .11 | 44 | .92 | 42 | .87 | 72 | 1.50 |
| Chloride (Cl) | 3.5 | .10 | 5.5 | .16 | 6.0 | .17 | 8.6 | .24 | 17 | .48 |
| Fluoride (F) | .0 | .00 | .0 | .00 | .0 | .00 | .2 | .01 | .9 | .00 |
| Nitrate ($NO_3$) | 8.1 | .13 | 8.6 | .14 | 8.9 | .14 | 28 | .45 | 7.6 | .12 |
| Dissolved solids (residue on evaporation at 180°C | 58 | -- | 59 | -- | 241 | -- | 253 | -- | 361 | -- |
| Hardness as ($CaCO_3$) | 24 | -- | 24 | -- | 189 | -- | 149 | -- | 285 | -- |
| Noncarbonate | 19 | -- | 8 | -- | 53 | -- | 59 | -- | 88 | -- |
| Specific conductance (micromhos at 25°C) | 83 | -- | 79 | -- | 379 | -- | 355 | -- | 583 | -- |
| pH | 6.1 | -- | 6.5 | -- | 7.8 | -- | 6.9 | -- | 7.6 | -- |
| Color | 4 | -- | 5 | -- | 3 | -- | 50 | -- | 2 | -- |

[1] Location of wells, see figure 1.

Table 2.--Chemical analyses of ground water, Swatara Creek Basin, Pa., 1959--Con.

Chemical analyses in parts per million and equivalents per million

| Well number[1] | 6 | | 7 | | 8 | | 9 | | 10 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date of collection | Feb. 13, 1959 | | Feb. 13, 1959 | | Mar. 26, 1959 | | Mar. 26, 1959 | | Mar. 27, 1959 | |
| | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm |
| Silica ($SiO_2$) | 5.9 | -- | 19 | -- | 10 | -- | 21 | -- | 18 | -- |
| Iron (Fe) in solution when collected | .37 | -- | .06 | -- | .43 | -- | .34 | -- | .20 | -- |
| Iron (Fe) in solution when analyzed | .02 | 0.00 | .01 | 0.00 | .04 | 0.00 | .02 | 0.00 | .03 | 0.00 |
| Manganese (Mn) in solution when collected | .03 | -- | .01 | -- | .33 | -- | .09 | -- | .00 | -- |
| Manganese (Mn) in solution when analyzed | .01 | .00 | .00 | .00 | .28 | .01 | .06 | .00 | .00 | .00 |
| Calcium (Ca) | 78 | 3.89 | 88 | 4.39 | 34 | 1.70 | 40 | 2.00 | 53 | 2.64 |
| Magnesium (Mg) | 32 | 2.63 | 29 | 2.38 | 6.3 | .52 | 14 | 1.15 | 12 | .99 |
| Sodium (Na) | 17 | .74 | 27 | 1.17 | 3.2 | .14 | 5.0 | .22 | 4.2 | .18 |
| Potassium (K) | 1.8 | .05 | 3.4 | .09 | .7 | .02 | 1.0 | .03 | 2.1 | .05 |
| Carbonate ($CO_3$) | 0 | .00 | 0 | .00 | 0 | .00 | 0 | .00 | 0 | .00 |
| Bicarbonate ($HCO_3$) | 302 | 4.95 | 342 | 5.61 | 128 | 2.10 | 151 | 2.47 | 170 | 2.79 |
| Sulfate ($SO_4$) | 58 | 1.21 | 55 | 1.15 | 4.3 | .09 | 39 | .81 | 28 | .58 |
| Chloride (Cl) | 14 | .39 | 20 | .56 | 2.3 | .06 | 1.2 | .03 | 4.6 | .13 |
| Fluoride (F) | .0 | .00 | 1 | .01 | .1 | .01 | .2 | .01 | .0 | .00 |
| Nitrate ($NO_3$) | 38 | .61 | 36 | .58 | 1.9 | .03 | .5 | .01 | 25 | .40 |
| Dissolved solids (residue on evaporation at 180°C | 395 | -- | 444 | -- | 125 | -- | 194 | -- | 241 | -- |
| Hardness as ($CaCO_3$) | 326 | -- | 339 | -- | 111 | -- | 158 | -- | 182 | -- |
| Noncarbonate | 79 | -- | 58 | -- | 6 | -- | 34 | -- | 42 | -- |
| Specific conductance (micromhos at 25°C) | 649 | -- | 741 | -- | 216 | -- | 310 | -- | 357 | -- |
| pH | 7.6 | -- | 7.5 | -- | 7.5 | -- | 7.6 | -- | 7.4 | -- |
| Color | 3 | -- | 2 | -- | 8 | -- | 5 | -- | 2 | -- |

1/ Location of wells, see figure 1.

## Runoff

About half the precipitation in the Swatara Creek basin leaves the basin as runoff. During the period 1920-59 the annual runoff at the Geological Survey gaging station at Harper Tavern averaged 570 cfs (cubic feet per second), or 23.2 inches. During this period, streamflow at Harper Tavern ranged from a low of 8 cfs in September 1932 to a maximum discharge of 25,300 cfs in August 1933 (U. S. Geological Survey, 1962). Ten percent of the time flow equalled or exceeded 1,250 cfs; 50 percent of the time, 326 cfs; and 90 percent of the time, 60 cfs (fig. 4).

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Figure 4.--(Caption on next page) belongs near here.

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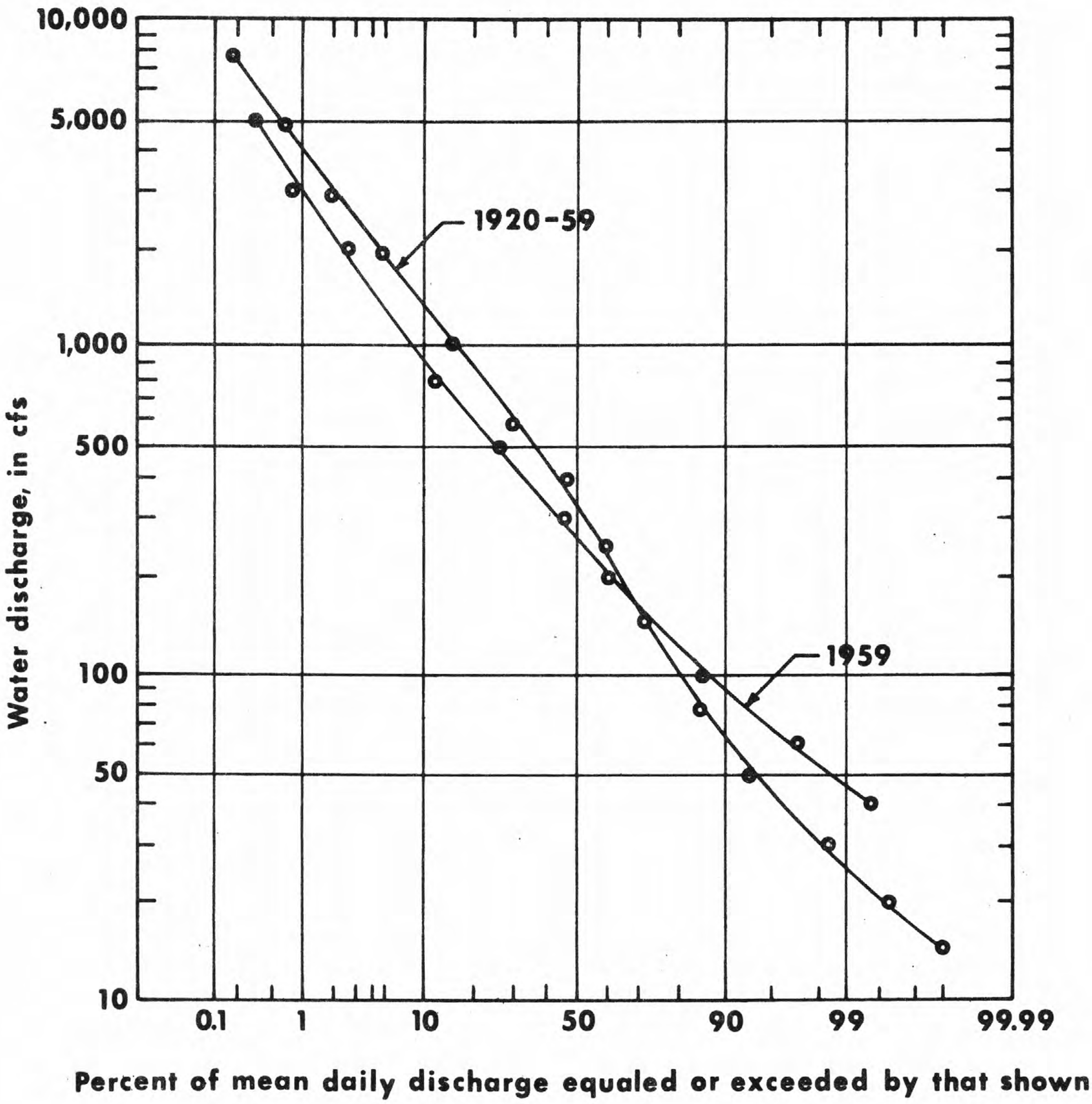


Figure 4.--Comparison of flow-duration curve for 1959 water year with long-term curve ending September 30, 1959, Swatara Creek at Harper Tavern, Pa.

## Public Water Supplies

Six public water supply companies are known to use Swatara Creek or its tributaries as a source of supply. The highest responsibility of public water suppliers is to distribute potable water. Most suppliers are able to do this by complying with the drinking water standards of the U. S. Public Health Service (1962). In Pennsylvania most public water supplies are chlorinated to destroy harmful bacteria and to control growth of algae. Many supplies receive further treatment for sediment removal and for controlling corrosiveness. However, public water supplies using Swatara Creek or its tributaries require only moderate treatment before distribution. The urban communities within the drainage area are served by water-supply companies drawing mostly from surface streams within the basin, although several communities use spring or well water.

The largest public water supply system in the Swatara basin is at Lebanon and serves a population exceeding 50,000. Before distribution, the water is chlorinated and treated to control corrosiveness. When analyzed in 1959 this treated water contained 72 ppm of dissolved solids and had a calcium carbonate hardness of 21 ppm. This water is satisfactory for most industrial purposes. Information about public water supplies distributed by seven of the larger water-supply systems in the Swatara basin is presented in table 3.

Table 3.--Summary of public water supplies and analyses of samples collected in 1959, Swatara Creek basin, Pa.

| County location and population served (thousands) | Ownership | Source | Treatment | Treatment plant capacity (mgd) | Raw-water storage (mg) | Finished-water storage (mg) | Chemical analyses of treated water in parts per million: Silica ($SiO_2$) | Iron (Fe) | Manganese (Mn) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Fluoride (F) | Nitrate ($NO_3$) | Dissolved solids (residue on evaporation at 180°C) | Hardness as $CaCO_3$ | | Specific conductance (in micromhos at 25°C) | pH | Color |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | | | | Calcium magnesium | Non-carbonate | | | |
| Tremont, Schuylkill Co. 0.5 | Private Tremont Gas & Water Co. Harrisburg, Pa. | Hoddenback and Poplar Runs and 6 springs | Chlorination | | | 2.7 | 6.1 | .13 | .15 | 11 | 6.9 | 4.0 | 0.5 | 8.0 | 52 | 3.4 | 0.0 | 0.2 | 113 | 56 | 50 | 140 | 6.5 | 3 |
| Pine Grove, Schuylkill Co. 4 | Municipal Pine Grove Bureau of Water Pine Grove, Pa. | Adams Run and Black Creek | Chlorination | | 20 | | 5.2 | .14 | .03 | 1.6 | .7 | 2.0 | .4 | 1.0 | 10 | .4 | .0 | .6 | 55 | 7 | 6 | 23 | 5.2 | 28 |
| Jonestown, Lebanon Co. | See Lebanon | | | | | | 5.1 | .11 | .09 | 6.9 | 1.1 | 2.8 | .5 | 12[1] | 14 | 1.6 | .0 | .2 | 67 | 22 | 9 | 60 | 8.9 | 7 |
| Lebanon, Lebanon Co. 50 | Municipal Lebanon Municipal Water Works, Lebanon, Pa. | Swatara, Fishing, and Hammer Creeks and Gold Mine Run | Filtration, chlorination, calogon, lime and alum sulfate | 6 | 370 | 1.1 | 4.9 | .13 | .10 | 6.9 | .9 | 2.8 | 1.0 | 13 | 15 | 1.4 | .0 | .2 | 72 | 21 | 10 | 58 | 8.1 | 12 |
| Hershey and Union Deposit, Lebanon Co. 2 | Private Hershey Estates Hershey, Pa. | Manada and Swatara Creeks | Filtration, chlorination, soda ash, and alum | 3 | 15 | 2.5 | 7.0 | .03 | .02 | 11 | 2.6 | 22 | 1.2 | 41 | 39 | 4.6 | .0 | 4.7 | 134 | 38 | 5 | 182 | 7.1 | 4 |
| Hummelstown and suburban Harrisburg Dauphin Co. 9 | Municipal Hummelstown Water Supply Co., Harrisburg, Pa. | Swatara Creek | Filtration, chlorination, sedimentation, alum and soda ash | 2 | | | 6.6 | .01 | .12 | 16 | 4.3 | 12 | 1.8 | 33 | 40 | 5.0 | .0 | 7.4 | 130 | 58 | 31 | 178 | 6.7 | 6 |
| Middletown, Dauphin Co. 15 | Municipal Middletown Water Co. | Iron Mine Run, Swatara Creek, and 1 well | Filtration, chlorination, sedimentation, lime and alum | 1 | | 25 | 19 | .09 | .02 | 28 | 27 | 11 | 1.5 | 86 | 105 | 9.8 | .0 | 6.5 | 294 | 181 | 111 | 400 | 7.2 | 3 |

1/ Includes 3 ppm $CO_3$

Most streams in the basin today (1962) are acceptable sources of public supply and are usable also for recreation. However, a few headwater streams may have limited usefulness because they are acidic (pH less than 4.5). Acidic streams usually contain large concentrations of dissolved solids, of which a high percentage are sulfates. Also, approximately 50 industries discharge their treated and untreated wastes into streams of the basin. There are seven municipal sewage plants that treat their effluents before discharge, and approximately 30 small communities that discharge untreated sewage into basin streams.

## Economic Significance of the Area and Land Use

The Swatara Creek basin is in an area of increasing industrial activity and urban development. Although the basin drains only parts of Schuylkill, Berks, and Dauphin Counties, the main stream is the major waterway in Lebanon County, a county with an estimated population of 90,000, increasing at a rate of 1 percent annually. In 1954 approximately 210 industries in Lebanon County manufactured products valued at $155,100,000; 1,762 farms on 141,674 acres produced field and fruit crops valued at $7,000,000; and stockmen marketed livestock and livestock products valued at $5,800,000. In the lower reaches, the stream flows through a part of Dauphin County before it flows into the Susquehanna River at Middletown. In 1954, 326 manufacturing and mining establishments in Dauphin County produced goods valued at $390,100,000 (Pennsylvania Department of Internal Affairs, 1956). Harrisburg, Capital of Pennsylvania, is located in Dauphin County.

Three regions in the basin are of major influence on the chemical quality of Swatara Creek (fig. 5). The use of land for mining of coal

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Figure 5.--(Caption on next page) belongs near here.)

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and limestone affects the quality of Swatara Creek in two of these regions. In the headwaters there are abundant coal deposits. Downstream Ordovician limestone is mined. In mining either coal or limestone, the associated ground water is pumped to the surface and carried by tributaries to Swatara Creek. This water affects the quality of the stream and limits its re-use in some segments.

In the headwaters, acidic effluents from the mines are discharged into tributaries. Fine coal particles from "breakers", where coal is "sized" and washed, also are discharged into many of these streams. In the lower half of the basin, water pumped from the ground during mining operations for limestone also flows to nearby streams. This pumped water and other ground water and the surface water flowing through the limestone belt dissolve alkaline materials and transport the solutes to Swatara Creek.

In the Swatara basin, generally, most of the economy is centered around agriculture, although in the upper basin the wealth is in the form of coal deposits and water. The region drained by Swatara Creek and its tributaries in the upper basin is part of the Southern Field, the most productive anthracite region in the Western hemisphere.

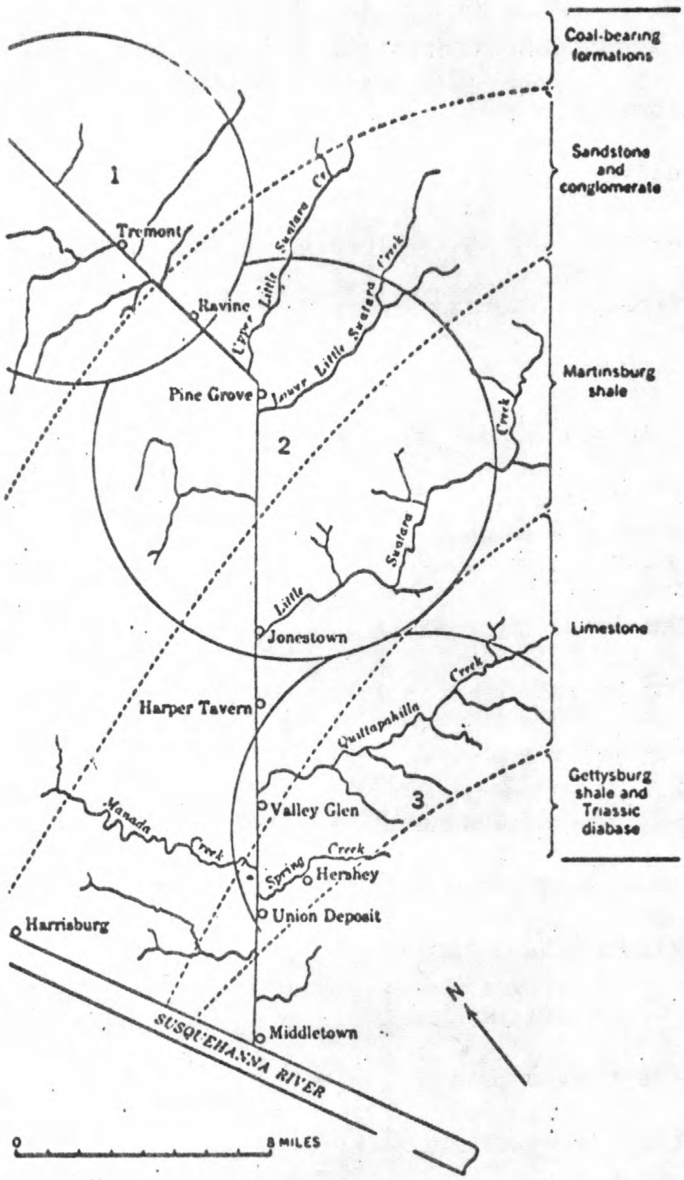


Figure 5.-- Schematic diagram of Swatara Creek basin, Pa., showing major regions affecting water quality

Coal was first discovered in eastern Pennsylvania in the outcrops about 1760. In the Southern Field, coal veins run deep (Ash and Kynor, 1953). As mine workings went deeper, coal costs rose correspondingly, and the mines became less economical to operate. After World War II most mines were abandoned. During mining operations, water levels underground in the mines were controlled by pumping, but unworked mines stored large volumes of water accumulated from surface runoff, streambed seepage, underground streams and springs. Strip mining contributed heavily to the infiltration of water to underground pools in this area.

Probably the degrading effects of mine effluents on surface streams started when underground mining of coal in the United States began in the early 19th century. The conditions that produce acid water in mines may have existed underground long before anthracite mines were dug. On this assumption, acid water could seep to the surface through springs and cause discolorations to sand and gravel in streambeds. Possibly these discolorations occurring in acid streams suggested to the Indian such names as Yellow Creek or Red Creek.

First to feel the effects of acid mine water were the coal operators who faced continually mounting costs for replacement of pumps and equipment destroyed by corrosion. As coal-mining activity increased, more water was pumped from the mines. Some of the water was stored nearby for washing coal in breakers, wetting down dusts, and combating mine fires. Most of the pumped water and water used by breakers reached nearby streams, where fine coal carried from the breakers was deposited. With continued operations the effects of acidic pollutants and fine coal particles released from mines extended farther downstream (White and Lindholm, 1950).

As late as 1948, the entire length of Swatara Creek ran black with coal wastes (Siebert, 1951). Even in 1960 at least one operator dredged the stream for salvable fine coal. However, today (1962) there are few operating mines, even fewer operating breakers. Also the several active collieries in the drainage basin control the discharge of coal "silts". Control of effluents from active or unworked mines and washings from breakers has improved the quality of the headwater tributaries and the upper Swatara. The fine coal deposits, that were normally washed into the streams in the Swatara Creek basin, are less noticeable today as the bed of the stream assumes a light color of sand and gravel.

## WATER QUALITY AND FACTORS OF INFLUENCE

The chemical and physical quality of water at different locations along Swatara Creek is caused by the solution of materials from the earth and the atmosphere, and of those materials introduced into the stream by man. More specifically, chemical quality variations in stream segments are caused by contributions of ground water and surface runoff and also by the way man uses land and water within an area of influence. Figure 6 illustrates chemical quality changes of the stream at different locations during a low-flow period in October 1959. During

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Figure 6.--(Caption on next page) belongs near here.

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this period, water flowing in Swatara Creek 10 miles from Tremont, although acidic because of mine effulents, had approximately the same dissolved-solids content as it had at the mouth. However, the chemical character of Swatara Creek differs between these locations because of the quality of water contributed to it by tributaries and ground-water seepage.

During a study of the basin on July 14, 16, and 17, 1958, 20 samples of the stream and its principal tributaries were obtained at selected locations for analyses. Chemical analyses showed how the quality of the main stream changed along its length because of the quality of inflowing tributaries. (fig. 7).

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Figure 7.--(Caption on next page) belongs near here.

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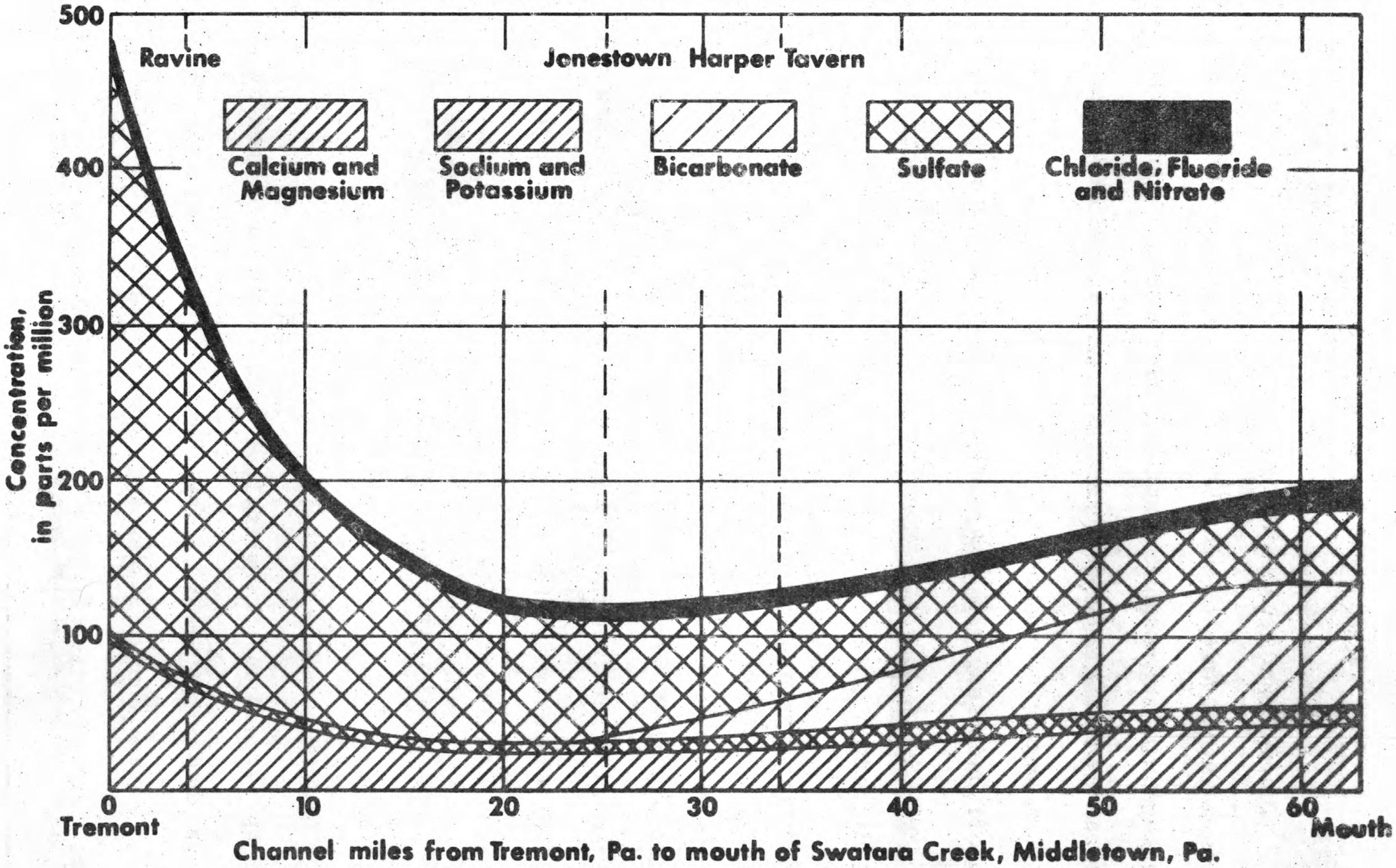


Figure 6.--Chemical composition of Swatara Creek at low base flow, October 1959

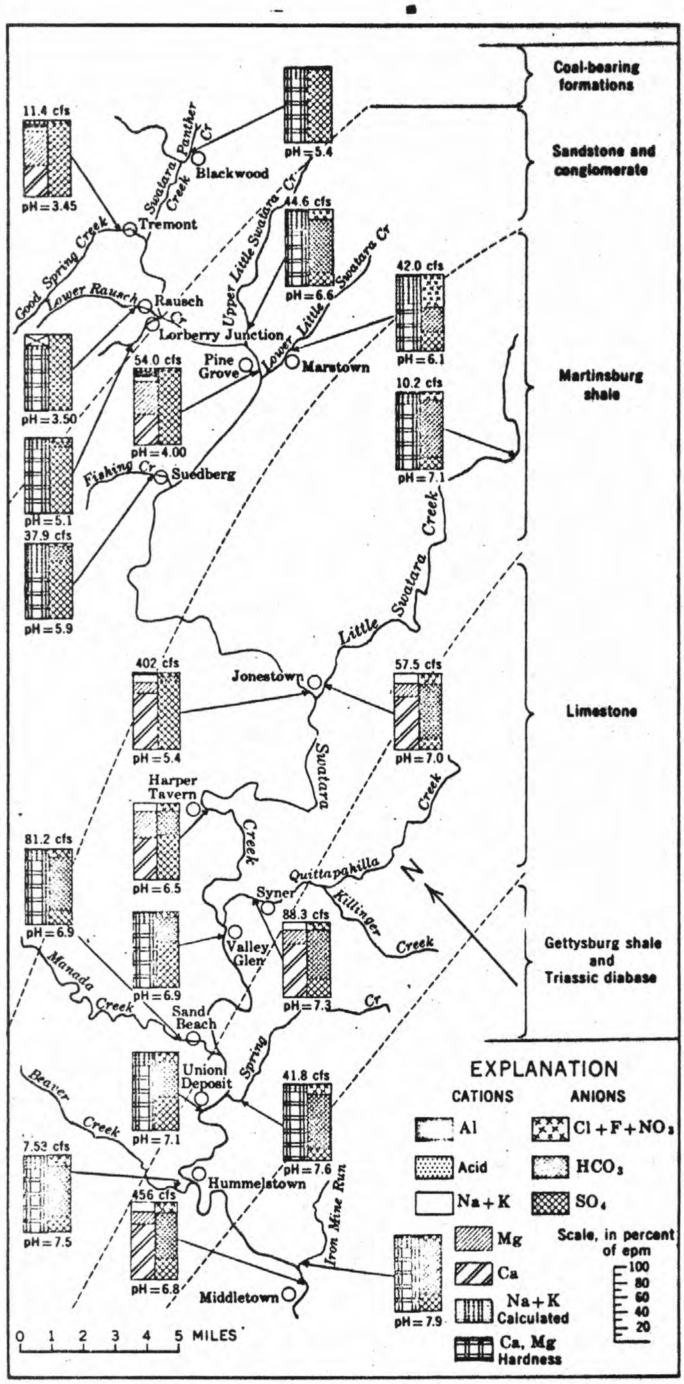


Figure 7.--Chemical quality study, Swatara Creek drainage basin, Pa., July 14, 16, and 17, 1958.

Several tributaries to Swatara Creek, downstream from Jonestown, have alkaline properties and are lower in dissolved solids than the main stem. These streams help to neutralize and to dilute acidic water in Swatara Creek. After the pH of an acidic stream is raised to a pH of about 4.5 or more, bicarbonate can exist in the water. Thus, the ratio of bicarbonate to sulfate concentration increases as the water moves downstream from the acid region to the neutral and alkaline regions (fig. 8).

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Figure 8.--(Caption on next page) belongs near here.

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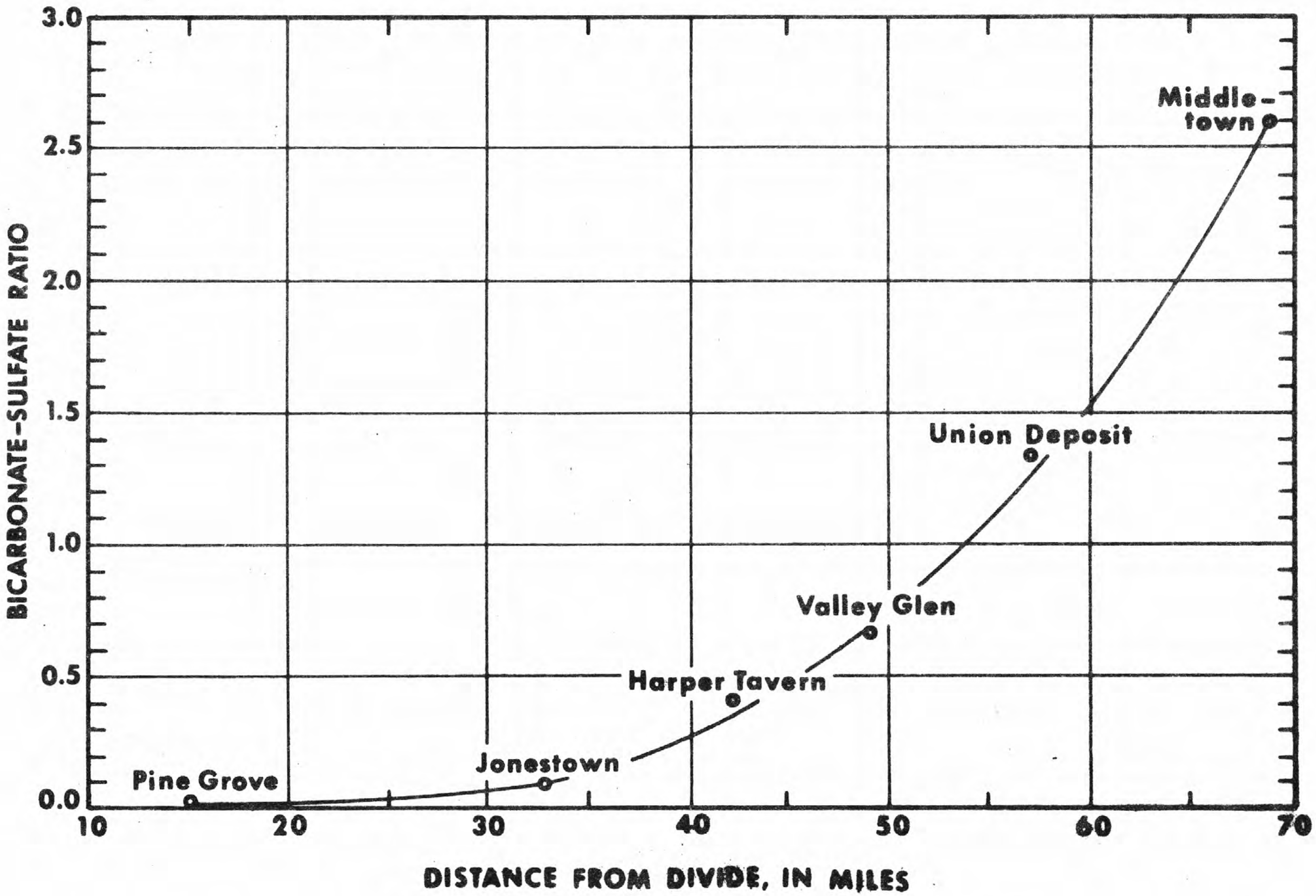


Figure 8 Bicarbonate-sulfate ratio of Swatara Creek in downstream sequence at low flow, July 1958

## Coal Mines--Source of Acidity to Swatara Creek

Coal is insoluble and is difficult to represent by chemical formula because it is not a single chemical compound. However, coal is mostly carbon, hydrogen, oxygen, and nitrogen. Nitrogen enters the composition of coal probably from the remains of organic matter. Sulfur and iron are usually present as impurities in coals and in most sedimentary rocks associated with the adjoining coals. These impurities may exist as iron disulfide ($FeS_2$), known also as "iron pyrite", "fools gold", or "sulfur balls". The oxidation of iron pyrite in air can be represented by the equation:

$$2FeS_2 + 2H_2O + 7O_2 \longrightarrow 2FeSO_4 + 2H_2SO_4$$

As the acidity in a stream is neutralized and further oxidation of the iron occurs, iron is precipitatied as hydrous ferric oxide. This precipitate is often called "yellow boy". During field investigations, "yellow boy" was observed at mine overflows, in the streambed, and on the banks of streams.

The decrease in mining activities has caused many deep mines to fill with water. These impoundments contain about 37.5 billion gallons of water in 37 known pools throughout the Southern Anthracite field (Ash and Kynor, 1953). Many other small pools in the basin are impounded in abandoned independent mines. Their size and location are unknown because many entrances to independent mine workings have been destroyed by cave-ins or concealed by physical changes to the landscape. Large reserves of anthracite are covered by these pools that must be drained or pumped away before mining operations can resume.

The rate of flow of mine drainage from any pool to surface streams does not vary greatly throughout the year. However, when it does vary, the rate of flow from each mine depends upon the static head of these underground impoundments. The static head may change in response to natural causes, such as rainfall and thaws of ice and snow that may reach the underground pool through breaks in the earth and porous formations, or down open shafts of mine workings. Water that may escape from other pools also can increase the static head and rate of flow from pools receiving such water. For example, underground mine pools are separated from each other by barrier pillars. Barrier pillars are underground partitions that mark property lines of mine ownership underground, and during periods of mining activity owners were responsible for their maintenance (Ash and Kynor, 1953). The care of barrier pillars, which prevent the release of accumulated water from mines into those adjacent, was of primary significance in safeguarding miner's lives. Any breakthrough of water through a punctured pillar that may result from increased pressures, or occur following subsidence, (Briggs, 1929), would raise the static head of the pool receiving the escaped water. Also, water escaping from higher levels creates a force for mixing and movement in receiving pools. This mobility and air could help water dissolve iron sulfide associated with coal and could cause the water to become more acidic.

Deterioration of barrier pillars caused by increased pressures of stored water, or destruction of pillars by minor earth movements within the basin, constitute a hazard that could affect the chemical quality of surface streams. Accidents to barrier pillars in the Swatara Creek basin could cause the release of acidic water in excess of that now being released from mines as normal overflow. In mining areas adjacent to the Swatara Creek basin an accident to barrier pillars is less likely to occur because of the practice of pumping water from deep wells. The practice keeps water levels in pools from rising and overflowing into active mines and prevents excessive pressure on barrier pillars.

To confirm the several sources of acid mine drainage and to estimate the quantities of mine effluents reaching Swatara Creek, a chemical quality basin study was completed during a stable high-flow period, April 21-26, 1959 (table 4). In the headwaters, streams receiving acid mine drainage were sampled, and discharge measurements were taken within distances of 1.5 miles from the mine overflow. The sampled water consisted of a mixture of ground water and mine effluents. The stream discharge and the acid content of the samples were used to compute the pounds of sulfuric acid that were discharged daily into the stream. The discharge of acid into the streams confirmed the source of the acidic water and indicated also the quantity that can be expected to come from a mine under similar circumstances (table 5).

Table 4 .--Chemical composition of Swatara Creek and tributaries during a period of high flow, 1959
(Chemical analyses in parts per million and equivalents per million)

| Source and Location No. | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | | 8 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date of collection | Apr.24,1959 | | Apr.24,1959 | | Apr.24,1959 | | Apr.24,1959 | | Apr.21,1959 | | Apr.22,1959 | | Apr.22,1959 | | Apr.22,1959 | |
| | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm |
| Silica ($SiO_2$) | — | — | — | — | 9.0 | — | — | — | — | — | 10 | — | 7.0 | — | 7.5 | — |
| Iron (Fe) in soln. when collected. | — | — | — | — | .14 | — | — | — | — | — | 3.7 | — | .19 | — | .16 | — |
| Iron (Fe) in soln. when analyzed | 0.36 | 0.01 | 0.06 | 0.00 | .03 | 0.00 | 0.14 | 0.00 | 0.03 | 0.00 | .14 | 0.00 | .07 | 0.00 | .16 | 0.01 |
| Manganese (Mn) in soln. when collected | — | — | — | — | 1.4 | — | — | — | — | — | 2.0 | — | .13 | — | .17 | — |
| Manganese (Mn) in soln. when analyzed | — | — | — | — | 1.4 | .05 | — | — | — | — | 2.0 | .07 | .01 | .00 | .01 | .00 |
| Calcium (Ca) | — | — | — | — | 29 | 1.45 | — | — | — | — | 46 | 2.30 | 4.0 | .20 | 13 | .65 |
| Magnesium (Mg) | — | — | — | — | 4.1 | .34 | — | — | — | — | 2.2 | .18 | 1.7 | .14 | 3.4 | .28 |
| Sodium (Na) | — | — | — | — | 1.8 | .08 | — | — | — | — | 1.8 | .08 | 2.1 | .09 | 2.3 | .10 |
| Potassium (K) | — | — | — | — | .7 | .02 | — | — | — | — | .8 | .02 | .5 | .01 | 1.0 | .03 |
| Carbonate ($CO_3$) | 0 | .00 | 0 | .00 | 0 | .00 | 0 | .00 | 0 | .00 | 0 | .00 | 0 | .00 | 0 | .00 |
| Bicarbonate ($HCO_3$) | 0 | .00 | 0 | .00 | 4 | .07 | 0 | .00 | 2 | .03 | 0 | .00 | 12 | .20 | 36 | .59 |
| Sulfate ($SO_4$) | 404 | 8.41 | 148 | 3.08 | 90 | 1.87 | 284 | 5.91 | 80 | 1.67 | 134 | 2.79 | 2.4 | .05 | 13 | .27 |
| Chloride (Cl) | 3.0 | .08 | 2.0 | .06 | .5 | .01 | 2.0 | .06 | 1.0 | .03 | 2.0 | .06 | 1.8 | .05 | 2.9 | .08 |
| Fluoride (F) | — | — | — | — | .1 | .01 | — | — | — | — | .0 | .00 | .0 | .00 | .0 | .00 |
| Nitrate ($NO_3$) | .1 | .00 | .1 | .00 | .2 | .00 | .3 | .00 | .1 | .00 | .3 | .00 | 7.3 | .12 | 6.5 | .10 |
| Dissolved solids (residue on evaporation at 180°) | 497 | — | 225 | — | 148 | — | 451 | — | 111 | — | 204 | — | 33 | — | 69 | — |
| Hardness as ($CaCO_3$) | 235 | — | 128 | — | 90 | — | 255 | — | 66 | — | 124 | — | 17 | — | 46 | — |
| Noncarbonate | 235 | — | 128 | — | 86 | — | 255 | — | 65 | — | 124 | — | 7 | — | 17 | — |
| Dissolved oxygen | 7.9 | — | 8.4 | — | 10.1 | — | 8.1 | — | 4.4 | — | 9.8 | — | 10.8 | — | 11.1 | — |
| Specific conductance (micromhos at 25°C) | 801 | — | 392 | — | 228 | — | 671 | — | 181 | — | 325 | — | 43 | — | 95 | — |
| pH | 3.60 | — | 4.00 | — | 5.0 | — | 3.80 | — | 4.7 | — | 4.10 | — | 7.1 | — | 7.9 | — |
| Color | 5 | — | 2 | — | 2 | — | 2 | — | 3 | — | 3 | — | 2 | — | 3 | — |
| Total acidity as $H_2SO_4$ | 78 | — | 24 | — | | — | 43 | — | 5 | — | 83 | — | — | — | — | — |
| Mean discharge (cfs) | 15.3 | — | 10.2 | — | 16.9 | — | 7.61 | — | 14.3 | — | 114 | — | 23.5 | — | 22.7 | — |

| Source and Location No. | 9 | | 10 | | 11 | | 12 | | 13 | | 14 | | 15 | | 16 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date of collection | Apr.22,1959 | | Apr.22,1959 | | Apr.22,1959 | | Apr.22,1959 | | Apr.23,1959 | | Apr.23,1959 | | Apr.23,1959 | | Apr.23,1959 | |
| | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm |
| Silica ($SiO_2$) | 7.1 | — | 9.0 | — | 8.4 | — | 7.9 | — | 8.6 | — | 12 | — | 5.4 | — | 5.2 | — |
| Iron (Fe) in soln. when collected. | .18 | — | .32 | — | .24 | — | .15 | — | .29 | — | .21 | — | .13 | — | .15 | — |
| Iron (Fe) in soln. when analyzed | .03 | 0.00 | .01 | 0.00 | .07 | 0.00 | .04 | 0.00 | .07 | 0.00 | .04 | 0.00 | .06 | 0.00 | .14 | 0.01 |
| Manganese (Mn) in soln. when collected | .12 | — | .67 | — | .48 | — | .34 | — | .22 | — | .17 | — | .07 | — | .24 | — |
| Manganese (Mn) in soln. when analyzed | .01 | .00 | .67 | .02 | .31 | .01 | .03 | .00 | .02 | .00 | .00 | .00 | .02 | .00 | .02 | .00 |
| Calcium (Ca) | 17 | .85 | 9.6 | .48 | 12 | .60 | 72 | 3.59 | 8.4 | .42 | 59 | 2.94 | 25 | 1.25 | 24 | 1.20 |
| Magnesium (Mg) | 4.4 | .36 | 6.6 | .54 | 5.4 | .44 | 15 | 1.23 | 2.7 | .22 | 6.9 | .57 | 6.6 | .54 | 5.8 | .48 |
| Sodium (Na) | 3.5 | .15 | 1.8 | .08 | 2.3 | .10 | 16 | .70 | 2.5 | .11 | 4.9 | .21 | 5.8 | .25 | 4.0 | .17 |
| Potassium (K) | 1.4 | .04 | .9 | .02 | 1.0 | .03 | 4.4 | .11 | 1.0 | .03 | 2.1 | .05 | 1.5 | .04 | 1.6 | .04 |
| Carbonate ($CO_3$) | 0 | .00 | 0 | .00 | 0 | .00 | 0 | .00 | 0 | .00 | 0 | .00 | 2 | .07 | 0 | .00 |
| Bicarbonate ($HCO_3$) | 53 | .87 | 4 | .07 | 17 | .28 | 206 | 3.38 | 30 | .49 | 170 | 2.79 | 72 | 1.18 | 57 | .93 |
| Sulfate ($SO_4$) | 15 | .31 | 49 | 1.02 | 37 | .77 | 71 | 1.48 | 7.2 | .15 | 29 | .60 | 28 | .58 | 34 | .71 |
| Chloride (Cl) | 3.6 | .10 | 1.2 | .03 | 2.2 | .06 | 13 | .37 | 1.9 | .05 | 5.8 | .16 | 6.8 | .19 | 4.5 | .13 |
| Fluoride (F) | .0 | .00 | .0 | .00 | .0 | .00 | .0 | .00 | .0 | .00 | .0 | .00 | .1 | .01 | .0 | .00 |
| Nitrate ($NO_3$) | 9.6 | .15 | 1.7 | .03 | 3.5 | .06 | 18 | .29 | 3.9 | .06 | 18 | .29 | 9.6 | .15 | 14 | .22 |
| Dissolved solids (residue on evaporation at 180°) | 92 | — | 80 | — | 85 | — | 321 | — | 54 | — | 217 | — | 127 | — | 126 | — |
| Hardness as ($CaCO_3$) | 61 | — | 51 | — | 52 | — | 241 | — | 32 | — | 176 | — | 90 | — | 84 | — |
| Noncarbonate | 17 | — | 48 | — | 38 | — | 72 | — | 8 | — | 36 | — | 31 | — | 38 | — |
| Dissolved oxygen | 10.1 | — | 9.1 | — | 9.3 | — | 10.1 | — | 9.7 | — | 8.8 | — | 10.2 | — | 10.0 | — |
| Specific conductance (micromhos at 25°C) | 133 | — | 127 | — | 126 | — | 511 | — | 74 | — | 365 | — | 201 | — | 200 | — |
| pH | 8.1 | — | 5.4 | — | 7.5 | — | 7.9 | — | 7.8 | — | 8.0 | — | 8.5 | — | 7.4 | — |
| Color | 4 | — | 2 | — | 2 | — | 3 | — | 3 | — | 5 | — | 2 | — | 3 | — |
| Total acidity as $H_2SO_4$ | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Mean discharge (cfs) | 73.[illegible] | — | 206 | — | 120 | — | 85.0 | — | 28.4 | — | 29.9 | — | 17.5 | — | 302 | — |

1. Middle Creek at Tremont, Pa.
2. Good Spring Creek at Tremont, Pa.
3. Swatara Creek at Tremont, Pa.
4. Lower Rausch Cr. at Lorberry Junction, Pa.
5. Lorberry Creek at Lorberry Junction, Pa.
6. Swatara Creek at Ravine, Pa.
7. Lower Little Swatara Cr. at Marstown, Pa.
8. Little Swatara Creek nr. Mount Aetna, Pa.
9. Little Swatara Creek nr. Jonestown, Pa.
10. Swatara Creek at Jonestown, Pa.
11. Swatara Creek at Harper Tavern, Pa.
12. Quittapahilla Creek at Syner, Pa.
13. Manada Creek at Sandbeach, Pa.
14. Spring Creek nr. Union Deposit, Pa.
15. Beaver Creek at Hummelstown, Pa.
16. Swatara Creek nr. Middletown, Pa.

Table 5.--Discharge of sulfuric acid by streams in Swatara Creek basin during period of high flow, April 24, 1959

| Stream and sampling location | Discharge (cfs) | pH | Total acidity as $H_2SO_4$ (ppm) | Load delivered $H_2SO_4$ (lbs/day) |
|---|---|---|---|---|
| Middle Creek at Tremont, Pa. | 15.3 | 3.60 | 78 | 6,480 |
| Good Spring Creek at Tremont, Pa. | 10.2 | 4.00 | 24 | 1,300 |
| Lower Rausch Creek at Lorberry Junction, Pa. | 7.6 | 3.80 | 43 | 1,772 |
| Lorberry Creek at Lorberry Junction, Pa. | 14.3 | 4.7 | 5. | 456 |

Acidic effluents from underground pools within the drainage basin reach the Swatara above Ravine via Panther Creek, Middle Creek, Good Spring Creek, Lower Rausch Creek, and Lorberry Creek (fig 1). Compared with natural water, the concentrations of solutes are high in these effluents. The principal cations of water in the pools were calcium and magnesium, and the heavy metals--iron, manganese, and aluminum were more concentrated than they are normally in natural water. The principal anion was sulfate. Most effluents from the pools contained individual cations whose concentration decreased in the order of: calcium, magnesium, iron, manganese, aluminum, sodium, and potassium and anions whose concentrations decreased in the order of sulfate, chloride, fluoride and nitrate.

The chemical quality of water draining from each pool was found to be much the same, with one exception--the overflow from the New Lincoln Mine was low in dissolved solids (62 ppm) and had an alkalinity of 9.8 ppm of calcium carbonate (table 6). This alkalinity is possible because coal occurs in geologic formations that contain shale and other sedimentary rocks such as dolomite (calcium magnesium carbonate) and limestone (calcium carbonate). Dolomite and limestone are capable of neutralizing acid water, but they may also increase the hardness of water. Also, lack of acidity from the New Lincoln Mine could have been due to the little or no iron sulfide or oxygen available in the mine at areas of water exposure, or the represented water may have infiltrated from a recent rainfall so that it was exposed only briefly to the mine's environment.

Table 6.--Chemical analyses of water from anthracite coal mines in Swatara Creek basin, Pa., collected June 25, 1959

| | Good Spring Mine | | Middle Creek Mine | | Colket Mine | | New Lincoln Mine | | Rausch Creek East Franklin Mine | | Lincoln Mine | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm | ppm | epm |
| Silica ($SiO_2$) | 13 | — | 16 | — | 15 | — | 8.6 | — | 17 | — | 15 | — |
| Aluminum (Al) | .5 | 0.06 | 5.6 | 0.62 | 1.9 | 0.21 | — | — | 10 | 1.11 | 1.1 | 0.12 |
| Iron (Fe) in solution when collected | 9.0 | — | 9.2 | — | 10 | — | 5.0 | — | 9.6 | — | 2.3 | — |
| Iron (Fe) in solution when analyzed | .04 | .00 | 1.7 | .06 | 1.0 | .04 | .00 | 0.00 | 1.3 | .05 | .02 | .00 |
| Manganese (Mn) in solution when collected | 2.9 | — | 4.9 | — | 2.5 | — | .72 | — | 5.8 | — | — | — |
| Manganese (Mn) in solution when analyzed | 2.7 | .10 | 3.0 | .11 | 1.2 | .04 | .73 | .03 | 5.8 | .21 | 4.3 | .16 |
| Calcium (Ca) | 41 | 2.05 | 61 | 3.04 | 39 | 1.95 | 4.9 | .24 | 80 | 3.99 | 21 | 1.05 |
| Magnesium (Mg) | 24 | 1.97 | 48 | 3.95 | 31 | 2.55 | 5.6 | .46 | 56 | 4.61 | 23 | 1.89 |
| Sodium (Na) | 2.0 | .09 | 2.0 | .09 | 1.4 | .06 | 1.4 | .06 | 1.4 | .06 | 1.4 | .06 |
| Potassium (K) | 1.8 | .05 | 1.5 | .04 | 1.2 | .03 | 1.0 | .03 | 1.5 | .04 | 1.8 | .05 |
| Carbonate ($CO_3$) | 0 | .00 | 0 | .00 | 0 | .00 | 0 | .00 | 0 | .00 | 0 | .00 |
| Bicarbonate ($HCO_3$) | 0 | .00 | 0 | .00 | 0 | .00 | 12 1/ | .20 | 0 | .00 | 0 | .00 |
| Sulfate ($SO_4$) | 214 | 4.46 | 427 | 8.89 | 280 | 5.83 | 27 | .56 | 516 | 10.74 | 158 | 3.29 |
| Chloride (Cl) | 1.2 | .03 | 3.2 | .06 | .6 | .02 | 1.4 | .04 | 1.6 | .05 | .6 | .02 |
| Fluoride (F) | .3 | .02 | .3 | .02 | .3 | .02 | .2 | .01 | .4 | .02 | .3 | .02 |
| Nitrate ($NO_3$) | .3 | .00 | .4 | .01 | .2 | .00 | .3 | .00 | .3 | .00 | .1 | .00 |
| Dissolved solids (Residue on evaporation at 180°C) | 332 | — | 671 | — | 446 | — | 62 | — | 821 | — | 252 | — |
| Hardness as ($CaCO_3$) | 201 | — | 350 | — | 225 | — | 35 | — | 430 | — | 147 | — |
| Noncarbonate | 201 | — | 350 | — | 225 | — | 35 | — | 430 | — | 147 | — |
| Specific conductance (Micromhos at 25°C) | 533 | — | 1,080 | — | 864 | — | 92 | — | 1,200 | — | 400 | — |
| pH | 3.60 | — | 2.95 | — | 2.95 | — | 6.1 | — | 3.00 | — | 3.75 | — |
| Color | 1 | — | 1 | — | 2 | — | 2 | — | 1 | — | 2 | — |
| Total acidity as $H_2SO_4$ | 59 | — | 108 | — | 69 | — | — | — | 132 | — | 15 | — |

1/ 10 ppm expressed as calcium carbonate alkalinity

## Swatara Creek at Ravine and Pine Grove

At Ravine, Swatara Creek is acidic and has a high concentration of dissolved solids (table 7). Sulfate is a prominent constituent of the stream at this location, a result of oxidation of metallic sulfides such as $FeS_2$ associated with coal deposits.

Noncarbonate hardness of the stream is approximately 200 ppm during periods of low flow. Hardness of natural water is caused principally by calcium and magnesium ions, but in acidic segments of Swatara Creek it is caused also by aluminum, iron, and hydrogen ions. That portion of the hardness equivalent to the bicarbonate and carbonate is referred to as carbonate hardness. Hardness in excess of carbonate hardness is called noncarbonate hardness.

Hardness (as $CaCO_3$) of water from two wells in the Ravine area averaged 24 ppm, which is considerably less than the calcium carbonate hardness of Swatara Creek at Ravine (table 7). Hardness of surface water at Ravine exceeds hardness of ground water because additional constituents that cause hardness are carried into the stream by the acidic effluents of coal mines (table 6).

Between Ravine and Swatara Gap at Inwood, a calcium bicarbonate type of water, low in dissolved solids, from the Upper Little and Lower Little Swatara Creeks mixes with the Swatara to begin diluting the concentration of solutes and neutralizing the acidity of Swatara Creek. Although these streams originate in Schuylkill County, they are unaffected by mining wastes, and low in dissolved solids (less than 50 ppm), are calcium bicarbonate water, and have a pH range of 6.0 to 7.0.

Table 7.--Miscellaneous chemical analyses of streams in Swatara Creek Basin, Pa. 1958-59

Chemical analyses, in parts per million

9-2681

| Date of collection | Mean discharge (cfs) | Temperature (°F) | 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 (F) | 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 $H^{+1}$ | Specific conductance (micromhos at 25°C) | pH | Color | D.O. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PANTHER CREEK AT BLACKWOOD** | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 24, 1958 | | 61 | | | | | | | 8.0 | | 1 | 127 | 0.5 | | 0.2 | | 116 | 115 | 0.3 | 278 | 4.7 | 3 | |
| July 16,.... | | 74 | | | | | | | 6.2 | | 3 | 133 | .5 | | .0 | | 128 | 126 | -- | 293 | 5.4 | 3 | |
| **MIDDLE CREEK AT TREMONT** | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 24, 1958 | -- | 52 | -- | -- | -- | -- | -- | -- | -- | -- | 0 | 305 | 16 | -- | 0.4 | -- | 262 | 262 | 1.4 | 731 | 3.40 | 3 | -- |
| Apr. 24, 1959 | 15.3 | 55 | -- | -- | 0.36 | -- | -- | -- | -- | -- | 0 | 404 | 3.0 | -- | .1 | 497 | 285 | 285 | 1.6 | 777 | 3.60 | 5 | 7.9 |
| Aug. 26,.... | 2.17 | 74 | 14 | 17 | 1.4 | 1.0 | 88 | 60 | 5.5 | 2.0 | 0 | 597 | 1.4 | 0.1 | .4 | 944 | 466 | 466 | 2.9 | 1,310 | 3.10 | 2 | -- |
| Oct. 8, .... | 5.76 | 66 | 12 | 10 | .62 | 5.4 | 61 | 33 | 3.1 | 1.0 | 0 | 374 | 3.1 | .2 | .4 | 560 | 288 | 288 | 2.2 | 870 | 3.20 | 1 | -- |
| **GOOD SPRING CREEK NR. TREMONT** | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 24, 1958 | 31.5 | 58 | 10 | 4.5 | 0.09 | 3.5 | 34 | 23 | 2.5 | 1.5 | 0 | 222 | 2.0 | 0.4 | 0.7 | 342 | 228 | 228 | 1.1 | 536 | 3.50 | 3 | -- |
| July 16,.... | 11.4 | 77 | 12 | 2.5 | .21 | .00 | 45 | 31 | 3.6 | 2.0 | 0 | 273 | 6.0 | -- | .0 | -- | 273 | 273 | 1.2 | 662 | 3.45 | 5 | -- |
| Apr. 24, 1959 | 10.2 | 56 | -- | -- | .06 | -- | -- | -- | -- | -- | 0 | 148 | 2.0 | -- | .1 | 225 | 128 | 128 | .5 | 392 | 4.00 | 2 | 8.4 |
| Aug. 26,.... | 1.74 | 75 | 18 | 4.8 | 2.3 | 3.5 | 39 | 30 | 3.5 | 2.0 | 0 | 276 | 3.8 | .2 | .5 | 448 | 221 | 221 | 1.2 | 690 | 3.20 | 3 | -- |
| Oct. 8,..... | 4.57 | 65 | 13 | 5.2 | .22 | 2.9 | 34 | 28 | 5.0 | 2.0 | 0 | 268 | 3.0 | .2 | .2 | 360 | 200 | 200 | 1.4 | 651 | 3.35 | 5 | -- |
| **SWATARA CREEK AT TREMONT** | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 24, 1959 | 16.9 | 52 | 9.0 | -- | 0.03 | 1.4 | 29 | 4.1 | 1.8 | 0.7 | 4 | 90 | 0.5 | 0.1 | 0.2 | 148 | 90 | 86 | -- | 228 | 5.0 | 2 | 10.1 |
| Oct. 8,..... | 4.93 | 67 | 9.8 | 4.8 | .03 | 3.3 | 26 | 23 | 3.2 | 1.0 | 0 | 201 | 2.0 | .1 | .2 | 273 | 160 | 160 | 0.8 | 438 | 4.00 | 2 | -- |
| **BLACK CREEK NR. TREMONT** | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 24, 1959 | | 53 | | | 0.07 | | | | 5.3 | | 19[1/] | 5.1 | 1.0 | | 0.2 | 48 | 11 | 0 | | 47 | 8.4 | 3 | |

1/ Includes carbonate

Table 7.--Miscellaneous chemical analyses of streams in Swatara Creek Basin, Pa. 1958-59--Continued

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Chemical analyses, in parts per million

| Date of collection | Mean discharge (cfs) | Temperature (°F) | 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 (F) | Nitrate ($NO_3$) | Dissolved solids (residue on evaporation at 180°C) | Hardness as $CaCO_3$ Calcium magnesium | Hardness as $CaCO_3$ Non-carbonate | Total acidity as $H^{+1}$ | Specific conductance (micromhos at 25°C) | pH | Color | D.O. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LOWER RAUSCH CREEK AT RAUSCH | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 24, 1958 | -- | 58 | | | -- | | | | -- | | 0 | 277 | 3.5 | | 0.3 | -- | 237 | 237 | 1.2 | 664 | 3.40 | 2 | -- |
| July 16,.... | -- | 67 | | | -- | | | | -- | | 0 | 337 | 1.1 | | .1 | -- | 280 | 280 | 1.2 | 758 | 3.50 | 3 | -- |
| Apr. 21, 1959 | 2.07 | 58 | | | 0.04 | | | | 8.7 | | 2 | 247 | 4.0 | | .3 | 367 | 245 | 244 | .4 | 526 | 4.7 | 2 | 5.4 |
| RAUSCH CREEK AT LORBERRY JUNCTION | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 24, 1959 | 7.61 | 62 | -- | -- | 0.14 | -- | -- | -- | -- | -- | 0 | 284 | 2.0 | -- | 0.3 | 451 | 255 | 255 | 0.9 | 671 | 3.80 | 2 | 8.1 |
| Aug. 26,.... | 1.65 | 74 | 18 | 4.2 | .19 | 3.3 | 65 | 43 | 2.2 | 1.7 | 0 | 378 | 2.4 | 0.3 | .5 | 565 | 339 | 339 | 1.2 | 846 | 3.45 | 5 | -- |
| Oct. 8,..... | 3.25 | 64 | 12 | 5.7 | .16 | 3.7 | 61 | 31 | 3.1 | 1.0 | 0 | 320 | 1.8 | .2 | .3 | 491 | 280 | 280 | 1.2 | 760 | 3.50 | 1 | -- |
| LORBERRY CREEK AT LORBERRY JUNCTION | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 24, 1958 | -- | 58 | -- | -- | -- | -- | -- | -- | -- | | 0 | 77 | 0.3 | -- | 0.0 | -- | 63 | 63 | 0.2 | 195 | 4.05 | 2 | -- |
| July 16,.... | -- | 70 | -- | -- | -- | -- | -- | -- | 3.2 | | 2 | 38 | .6 | -- | .4 | -- | 38 | 37 | -- | 109 | 5.1 | 27 | -- |
| Apr. 21, 1959 | 14.3 | 53 | -- | -- | 0.03 | -- | -- | -- | 9.4 | | 2 | 80 | 1.0 | -- | .1 | 111 | 66 | 65 | .1 | 181 | 4.7 | 3 | 4.4 |
| Aug. 26,.... | 1.58 | 75 | 11 | -- | .01 | 0.48 | 20 | 13 | 3.3 | 1.3 | 4 | 105 | 1.0 | 0.1 | .2 | 164 | 104 | 100 | -- | 241 | 6.1 | 5 | -- |
| Oct. 7,..... | 4.36 | 64 | 10 | 1.0 | .01 | 2.0 | 14 | 13 | 3.2 | 1.2 | 0 | 98 | 4.0 | .1 | .4 | 147 | 89 | 89 | .2 | 240 | 4.15 | 2 | -- |
| SWATARA CREEK AT RAVINE | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 22, 1959 | 114 | 50 | 10 | -- | 0.14 | 2.0 | 46 | 2.2 | 1.8 | 0.8 | 0 | 134 | 2.0 | 0.0 | 0.3 | 204 | 124 | 124 | 1.7 | 338 | 4.10 | 3 | 9.8 |
| Aug. 26,.... | 13.8 | 76 | 12 | 4.3 | .10 | 3.6 | 41 | 23 | 4.3 | 1.5 | 0 | 237 | 3.1 | .1 | .8 | 369 | 197 | 197 | .7 | 557 | 3.60 | 2 | -- |
| Oct. 8,..... | 28.1 | 63 | 12 | 4.7 | .10 | 3.0 | 36 | 27 | 3.2 | 1.5 | 0 | 252 | 2.0 | .1 | .3 | 344 | 201 | 201 | 1.0 | 585 | 3.45 | 3 | -- |
| UPPER LITTLE SWATARA CREEK NR. PINE GROVE | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 24, 1958 | 31.4 | 66 | | | | | | | 3.0 | | 12 | 6.9 | 1.9 | | 3.8 | | 16 | 6 | | 47 | 6.9 | 3 | |
| July 16,.... | 44.6 | 82 | | | | | | | 3.4 | | 24 | 5.5 | 2.1 | | .9 | | 21 | 2 | | 61 | 6.6 | 5 | |

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Table 7.--Miscellaneous chemical analyses of streams in Swatara Creek Basin, Pa. 1958-59--Continued

Chemical analyses, in parts per million

| Date of collection | Mean discharge (cfs) | Temperature (°F) | 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 (F) | Nitrate ($NO_3$) | Dissolved solids (residue on evaporation at 180°C) | Hardness as $CaCO_3$: Calcium magnesium | Hardness as $CaCO_3$: Non-carbonate | Total acidity as $H^{+1}$ | Specific conductance (micromhos at 25°C) | pH | Color | D.O. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SWATARA CREEK AT PINE GROVE** | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 24, 1958 | 175 | 60 | 7.4 | 2.0 | 0.02 | 1.4 | 15 | 11 | 1.9 | 1.1 | 0 | 99 | 1.5 | | 0.2 | -- | 98 | 98 | 0.4 | 232 | 4.30 | 3 | |
| July 16,.... | 54.0 | 75 | 10 | 1.9 | .03 | .00 | 23 | 16 | 2.5 | 1.4 | 0 | 134 | 4.0 | | .2 | 220 | 139 | 139 | .4 | 315 | 4.00 | 8 | |
| **LOWER LITTLE SWATARA CREEK AT MARSTOWN** | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 24, 1958 | 77.7 | 58 | -- | | -- | -- | -- | -- | 3.2 | | 8 | 6.7 | 1.7 | -- | 2.7 | -- | 11 | 5 | | 39 | 6.1 | 3 | -- |
| July 16,.... | 42.0 | 74 | -- | | -- | -- | -- | -- | 5.5 | | 12 | 7.7 | 2.5 | -- | 13 | -- | 20 | 10 | | 63 | 6.1 | 80 | -- |
| Apr. 22, 1959 | 38.5 | 49 | 7.1 | | 0.07 | 0.01 | 4.0 | 1.7 | 2.1 | 0.5 | 12 | 2.4 | 1.8 | 0.0 | 7.3 | 33 | 17 | 7 | | 43 | 7.1 | 2 | 10.8 |
| Aug. 26,.... | 3.04 | 80 | 6.8 | | .02 | .00 | 4.1 | 2.4 | 2.2 | 1.5 | 22 | 5.1 | 2.6 | .0 | .7 | 48 | 20 | 2 | | 53 | 6.7 | 3 | -- |
| Oct. 8,..... | 13.7 | 67 | 4.9 | | .03 | .00 | 4.9 | 2.7 | 4.0 | 1.5 | 18 | 9.5 | 3.2 | .1 | 4.4 | 43 | 23 | 8 | | 78 | 6.5 | 3 | -- |
| **FISHING CREEK NR. SUEDBERG** | | | | | | | | | | | | | | | | | | | | | | | |
| July 16, 1958 | 37.9 | 77 | | | | | | | 3.0 | | 4 | 12 | 0.5 | | 0.3 | | 10 | 7 | | 39 | 5.9 | 4 | |
| **LITTLE SWATARA CREEK NR. MT. AETNA** | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 24, 1958 | 38.8 | 59 | -- | | -- | -- | -- | -- | 4.4 | | 29 | 14 | 2.4 | -- | 2.5 | -- | 35 | 11 | | 89 | 6.7 | 7 | -- |
| July 16,.... | 10.2 | 76 | -- | | -- | -- | -- | -- | 5.1 | | 71 | 11 | 3.8 | -- | 3.9 | -- | 67 | 9 | | 159 | 7.1 | 17 | -- |
| Apr. 22, 1959 | 22.7 | 50 | 7.5 | | 0.16 | 0.01 | 13 | 3.4 | 2.3 | 1.0 | 36 | 13 | 2.9 | -- | 6.5 | 69 | 46 | 17 | | 95 | 7.9 | 3 | 11.1 |
| Aug. 27,.... | 20.3 | 73 | 6.2 | | .35 | .09 | 20 | 3.6 | 3.3 | 5.0 | 60 | 15 | 4.8 | 0.1 | 6.8 | 130 | 65 | 16 | | 155 | 6.9 | 110 | -- |
| Oct. 8,..... | 4.3 | 74 | 4.9 | | .02 | .00 | 23 | 4.4 | 5.0 | 2.8 | 82 | 15 | 4.2 | .2 | 2.5 | 101 | 76 | 9 | | 183 | 7.4 | 3 | -- |
| **LITTLE SWATARA CREEK NR. JONESTOWN** | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 24, 1958 | 139 | 59 | 6.4 | | 0.02 | 0.03 | 17 | 2.7 | 3.0 | 1.5 | 46 | 16 | 2.8 | 0.4 | 5.0 | 98 | 54 | 16 | | 129 | 6.7 | 7 | -- |
| July 16,.... | 57.5 | 80 | 10 | | .00 | .00 | 26 | 3.8 | 4.0 | 2.6 | 80 | 13 | 5.0 | -- | 7.5 | 120 | 81 | 15 | | 186 | 7.0 | 5 | -- |
| Apr. 22, 1959 | 73.2 | 58 | 7.1 | | .08 | .01 | 17 | 4.4 | 3.5 | 1.4 | 53 | 15 | 3.6 | .0 | 9.6 | 92 | 61 | 17 | | 133 | 8.1 | 4 | 10.1 |
| Aug. 27,.... | 215 | 77 | 6.8 | | .27 | .04 | 16 | 2.1 | 3.3 | 5.0 | 39 | 15 | 4.0 | .1 | 8.3 | 111 | 49 | 17 | | 134 | 6.7 | 110 | -- |
| Oct. 8,..... | 24.0 | 73 | 6.7 | | .02 | .02 | 29 | 4.0 | 6.7 | 3.2 | 89 | 18 | 3.0 | .1 | 7.0 | 112 | 89 | 16 | | 237 | 7.3 | 2 | -- |

Table 7.--Miscellaneous chemical analyses of streams in Swatara Creek Basin, Pa. 1958-59--Continued

9-2681

Chemical analyses, in parts per million

| Date of collection | Mean discharge (cfs) | Temperature (°F) | 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 (F) | 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 $H^{+1}$ | Specific conductance (micromhos at 25°C) | pH | Color | D.O. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SWATARA CREEK AT JONESTOWN** | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 24, 1958 | 423 | 59 | 5.6 | 0.6 | 0.02 | 0.49 | 7.3 | 4.9 | 1.9 | .8 | 2 | 41 | 1.0 | -- | 0.9 | -- | 43 | 41 | | 102 | 4.9 | 2 | -- |
| July 16,.... | 402 | 78 | 7.9 | .4 | .00 | .00 | 22 | 2.8 | 2.5 | 1.5 | 4 | 67 | 3.0 | -- | 1.1 | -- | 69 | 65 | | 169 | 5.4 | 3 | -- |
| Apr. 22, 1959 | 286 | 62 | 9.0 | -- | .01 | .67 | 9.6 | 6.6 | 1.8 | .9 | 4 | 49 | 1.2 | 0.0 | 1.7 | 80 | 51 | 48 | | 127 | 5.4 | 2 | 9.1 |
| Aug. 27,.... | 76.4 | 77 | 6.9 | -- | .06 | .02 | 16 | 6.7 | 3.3 | 2.5 | 6 | 59 | 2.9 | .1 | 4.0 | 135 | 68 | 63 | | 175 | 5.8 | 17 | -- |
| Oct. 7,..... | 82.0 | 74 | 8.0 | -- | .00 | 1.0 | 15 | 9.1 | 5.0 | 1.8 | 3 | 79 | 3.4 | .1 | 2.9 | 122 | 75 | 73 | | 190 | 5.5 | 3 | -- |
| **QUITTAPAHILLA CREEK AT LEBANON** | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 25, 1958 | | 57 | | | | | | | 10 | | 209 | 54 | 18 | | 18 | | 245 | 74 | | 510 | 7.8 | 4 | |
| **KILLINGER CREEK NR. ANNVILLE** | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 25, 1958 | | 58 | | | | | | | 3.9 | | 222 | 37 | 7.4 | | 21 | | 240 | 58 | | 470 | 7.5 | 4 | |
| **QUITTAPAHILLA CREEK AT SYNER** | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 25, 1958 | 123 | 57 | 11 | | 0.01 | 0.06 | 69 | 17 | 8.3 | 4.5 | 198 | 60 | 9.0 | 0.2 | 20 | 313 | 242 | 80 | | 482 | 7.5 | 4 | -- |
| July 17,.... | 88.3 | 64 | 10 | | .02 | .00 | 74 | 12 | 10 | 4.8 | 208 | 59 | 11 | -- | 18 | -- | 234 | 64 | | 502 | 7.3 | 5 | -- |
| Apr. 22, 1959 | 85.0 | 59 | 7.9 | | .04 | .03 | 72 | 15 | 16 | 4.4 | 206 | 71 | 13 | .0 | 18 | 321 | 241 | 72 | | 511 | 7.9 | 3 | 10.1 |
| Aug. 26,.... | 47.2 | 70 | 9.6 | | .02 | .00 | 78 | 15 | 18 | 6.0 | 218 | 78 | 15 | .1 | 24 | 361 | 256 | 78 | | 560 | 7.7 | 5 | -- |
| Oct. 7,..... | 45.9 | 68 | 10.0 | | .01 | .01 | 78 | 14 | 28 | 8.0 | 218 | 97 | 14 | .2 | 25 | 370 | 252 | 74 | | 590 | 7.4 | 6 | -- |
| **SWATARA CREEK AT VALLEY GLEN** | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 25, 1958 | | 59 | | | | | | | 6.7 | | 60 | 38 | 3.8 | | 6.4 | | 86 | 37 | | 201 | 7.0 | 3 | |
| July 17,.... | | 74 | | | | | | | 4.4 | | 34 | 51 | 3.2 | | 3.7 | | 79 | 51 | | 193 | 6.9 | 5 | |

Table 7.--Miscellaneous chemical analyses of streams in Swatara Creek Basin, Pa. 1958-59--Continued

9-2681

Chemical analyses, in parts per million

| Date of collection | Mean discharge (cfs) | Temperature (°F) | 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 (F) | Nitrate ($NO_3$) | Dissolved solids (residue on evaporation at 180°C) | Hardness as $CaCO_3$: Calcium magnesium | Hardness as $CaCO_3$: Non-carbonate | Total acidity as $H^{+1}$ | Specific conductance (micromhos at 25°C) | pH | Color | D.O. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MANADA CREEK AT SAND BEACH** | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 25, 1958 | 33.6 | 60 | -- | | -- | -- | -- | -- | 3.0 | | 25 | 9.1 | 1.8 | -- | 1.1 | -- | 27 | 7 | | 68 | 6.8 | 3 | -- |
| July 17, .... | 81.2 | 74 | -- | | -- | -- | -- | -- | 3.0 | | 35 | 7.1 | 2.0 | -- | 2.1 | -- | 34 | 6 | | 85 | 6.9 | 40 | -- |
| Apr. 23, 1959 | 28.4 | 51 | 8.6 | | 0.07 | 0.02 | 8.4 | 2.7 | 2.5 | 1.0 | 30 | 7.1 | 1.9 | 0.0 | 3.9 | 54 | 32 | 8 | | 74 | 7.8 | 3 | 9.7 |
| Aug. 27, .... | 21.7 | 77 | 7.5 | | .06 | .00 | 16 | 3.5 | 3.3 | 2.5 | 56 | 13 | 4.0 | .2 | 2.9 | 90 | 55 | 9 | | 136 | 7.4 | 20 | -- |
| Oct. 7, ..... | 2.43 | | 3.4 | | .00 | .00 | 14 | 3.8 | 3.8 | 2.0 | 56 | 19 | 4.0 | .1 | 1.4 | 81 | 51 | 5 | | 152 | 6.8 | 3 | -- |
| **SPRING CREEK NR. UNION DEPOSIT** | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 25, 1958 | 39.5 | 69 | -- | | -- | -- | -- | -- | 5.8 | | 191 | 27 | 7.0 | | 22 | -- | 200 | 44 | | 406 | 7.5 | 3 | -- |
| July 17, .... | 41.8 | 78 | -- | | -- | -- | -- | -- | 7.1 | | 169 | 31 | 9.1 | -- | 14 | -- | 180 | 42 | | 382 | 7.6 | 5 | -- |
| Apr. 23, 1959 | 29.9 | 65 | 12 | | 0.04 | 0.00 | 59 | 6.9 | 4.9 | 2.1 | 170 | 29 | 5.8 | 0.0 | 18 | 217 | 176 | 36 | | 365 | 8.0 | 5 | 8.8 |
| Aug. 20, .... | 37.5 | 84 | 9.6 | | .02 | .00 | 56 | 7.7 | 7.4 | 4.5 | 166 | 32 | 7.9 | .2 | 16 | 232 | 171 | 35 | | 378 | 7.4 | 7 | -- |
| Oct. 6, ..... | 32.0 | 81 | 8.6 | | .00 | .00 | 59 | 9.1 | 6.8 | 2.5 | 167 | 39 | 7.4 | .1 | 13 | 231 | 185 | 48 | | 388 | 7.5 | 3 | -- |
| **SWATARA CREEK NR. UNION DEPOSIT** | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 25, 1958 | | 62 | | | | | | | 5.3 | | 52 | 36 | 3.5 | | 6.1 | | 79 | 37 | | 185 | 7.3 | 3 | |
| July 17, .... | | 77 | | | | | | | 5.8 | | 59 | 45 | 4.2 | | 5.9 | | 94 | 46 | | 222 | 7.1 | 7 | |
| **BEAVER CREEK AT HUMMELSTOWN** | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 25, 1958 | 22.8 | 64 | -- | | -- | -- | -- | -- | 7.4 | | 73 | 30 | 7.3 | -- | 3.4 | -- | 88 | 28 | | 203 | 7.0 | 4 | -- |
| July 17, .... | 7.53 | 71 | -- | | -- | -- | -- | -- | 9.0 | | 105 | 25 | 9.0 | -- | 3.8 | -- | 108 | 22 | | 258 | 7.5 | 15 | -- |
| Apr. 23, 1959 | 17.5 | 54 | 5.4 | | 0.06 | 0.02 | 25 | 6.6 | 5.8 | 1.5 | 72 | 28 | 6.8 | 0.1 | 9.6 | 127 | 90 | 31 | | 201 | 8.5 | 2 | 10.2 |
| Aug. 27, .... | 51.2 | 76 | 9.8 | | .09 | .01 | 25 | 5.1 | 5.5 | 3.0 | 70 | 24 | 7.3 | .1 | 6.1 | 138 | 84 | 26 | | 206 | 6.8 | 23 | -- |
| Oct. 7, ..... | 3.59 | -- | 5.9 | | .01 | .01 | 43 | 8.3 | 10 | 3.0 | 133 | 33 | 12 | .1 | 2.9 | 182 | 142 | 33 | | 328 | 7.7 | 8 | -- |

Table 7.--Miscellaneous chemical analyses of streams in Swatara Creek Basin, Pa. 1958-59--Continued

9-2681

Chemical analyses, in parts per million

| Date of collection | Mean discharge (cfs) | Temperature (°F) | 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 (F) | Nitrate ($NO_3$) | Dissolved solids (residue on evaporation at 180°C) | Hardness as $CaCO_3$: Calcium magnesium | Hardness as $CaCO_3$: Non-carbonate | Total acidity as $H^{+1}$ | Specific conductance (micromhos at 25°C) | pH | Color | D.O. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IRON MINE RUN NR. MIDDLETOWN | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 25, 1958 | | 64 | | | | | | | 4.8 | | 46 | 24 | 3.8 | | 1.8 | | 59 | 22 | | 142 | 7.1 | 15 | |
| July 17,.... | | 74 | | | | | | | 5.3 | | 71 | 18 | 4.1 | | 2.2 | | 73 | 15 | | 173 | 7.9 | 18 | |
| SWATARA CREEK AT MIDDLETOWN | | | | | | | | | | | | | | | | | | | | | | | |
| Apr. 25, 1958 | 1,160 | 64 | 7.1 | | 0.05 | 0.00 | 24 | 5.2 | 3.2 | 1.7 | 59 | 34 | 3.5 | 0.2 | 6.4 | 135 | 82 | 33 | | 191 | 6.9 | 7 | -- |
| July 17,.... | 456 | 76 | 7.1 | | .02 | .00 | 36 | 5.2 | 5.5 | 3.0 | 94 | 36 | 7.0 | | 9.0 | 170 | 112 | 35 | | 265 | 6.8 | 8 | -- |
| Apr. 23, 1959 | 502 | 58 | 5.2 | | .14 | .04 | 24 | 5.8 | 4.0 | 1.6 | 57 | 34 | 4.5 | .0 | 14 | 126 | 84 | 38 | | 200 | 7.4 | 3 | 10.0 |
| Aug. 22,.... | -- | 84 | -- | | -- | -- | -- | -- | -- | -- | 120 | 44 | -- | -- | -- | -- | 142 | -- | | 327 | 7.3 | -- | -- |
| Aug. 27,.... | 427 | 80 | 7.1 | | .03 | .00 | 24 | 7.2 | 7.4 | 3.8 | 96 | 32 | 7.3 | .2 | 8.8 | 172 | 115 | 36 | | 271 | 7.2 | 10 | -- |
| Aug. 29,.... | -- | 76 | -- | | -- | -- | -- | -- | -- | -- | 90 | 44 | -- | -- | -- | -- | 116 | -- | | 270 | 7.2 | -- | -- |
| Sept. 5,.... | -- | 66 | -- | | -- | -- | -- | -- | -- | -- | 43 | 33 | -- | -- | -- | -- | 69 | -- | | 172 | 6.9 | -- | -- |
| Sept. 12,... | -- | 57 | -- | | -- | -- | -- | -- | -- | -- | 73 | 41 | -- | -- | -- | -- | 102 | -- | | 242 | 7.3 | -- | -- |
| Sept. 19,... | -- | 48 | -- | | -- | -- | -- | -- | -- | -- | 114 | 54 | -- | -- | -- | -- | 148 | -- | | 336 | 7.6 | -- | -- |
| Sept. 26,... | -- | 65 | -- | | -- | -- | -- | -- | -- | -- | 116 | 59 | -- | -- | -- | -- | 154 | -- | | 349 | 7.6 | -- | -- |
| Oct. 3,..... | -- | 64 | -- | | -- | -- | -- | -- | -- | -- | 42 | 40 | -- | -- | -- | -- | 73 | -- | | 180 | 7.0 | -- | -- |
| Oct. 7,..... | 220 | 74 | 7.2 | | .00 | .00 | 33 | 8.4 | 8.8 | 3.0 | 80 | 50 | 7.6 | .1 | 6.9 | 167 | 117 | 52 | | 270 | 7.2 | 2 | -- |
| Oct. 10,.... | -- | 57 | -- | | -- | -- | -- | -- | -- | -- | 103 | 46 | -- | -- | -- | -- | 116 | -- | | 263 | 7.2 | -- | -- |
| Oct. 17,.... | -- | 53 | -- | | -- | -- | -- | -- | -- | -- | 89 | 58 | -- | -- | -- | -- | 132 | -- | | 303 | 7.2 | -- | -- |
| Oct. 24,.... | -- | 64 | -- | | -- | -- | -- | -- | -- | -- | 50 | 53 | -- | -- | -- | -- | 90 | -- | | 227 | 6.9 | -- | -- |
| Nov. 1,..... | -- | -- | -- | | -- | -- | -- | -- | -- | -- | 54 | 42 | -- | -- | -- | -- | 90 | -- | | 213 | 6.8 | -- | -- |
| Nov. 14,.... | -- | 57 | -- | | -- | -- | -- | -- | -- | -- | 61 | 48 | -- | -- | -- | -- | 100 | -- | | 235 | 7.1 | -- | -- |
| Nov. 21,.... | -- | 42 | -- | | -- | -- | -- | -- | -- | -- | 57 | 43 | -- | -- | -- | -- | 92 | -- | | 214 | 7.1 | -- | -- |
| Nov. 28,.... | -- | 44 | -- | | -- | -- | -- | -- | -- | -- | 60 | 35 | -- | -- | -- | -- | 86 | -- | | 209 | 6.8 | -- | -- |

The area drained by the Upper Little and Lower Little Swatara Creeks is underlain primarily by sandstones and conglomerates. Most sandstones and conglomerates generally contain quartz grains cemented together during contact with water containing solutes having bonding properties. The cementing materials of sandstone exposed to weathering by water may contain silica, calcium carbonate, calcium sulfate, ferrous oxides, or hydroxides of iron, which may return to solution under different conditions (Clarke, 1924). Presumably in shales, sandstones, and conglomerates, only small quantities of such soluble materials are available for solution. Samples of both surface water and ground water in sandstones and conglomerates had low dissolved solids contents.

Although downstream from Ravine, at Pine Grove, Swatara Creek contains less dissolved solids, the stream is still acidic and sulfate continues to be the principal anion. In segments of the stream between Pine Grove and Jonestown, Swatara Creek is partly neutralized, as indicated by its higher pH values in this area (table 7). Farther downstream, the water becomes softer because of the quality of water contributed by some tributaries draining a region underlain by sandstones and conglomerates (table 2, wells 1 and 2). These tributaries have low dissolved-solid contents and nearly neutral pH. Because of calcium and magnesium carbonate rocks in Martinsburg shale, and the limestone formations that underlie parts of Lebanon County, the hardness of ground water in these parts is greater than in other parts of the basin. Therefore, the main stream acquires some of these characteristics. This carbonate type of water seeping from the ground into surface streams is observed for the first time in segments of the Creek below Jonestown, where the ratio of calcium carbonate hardness to noncarbonate hardness begins to increase downstream to the mouth of Swatara Creek (fig. 9 ).

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Figure 9.--(Caption on next page) belongs near here.

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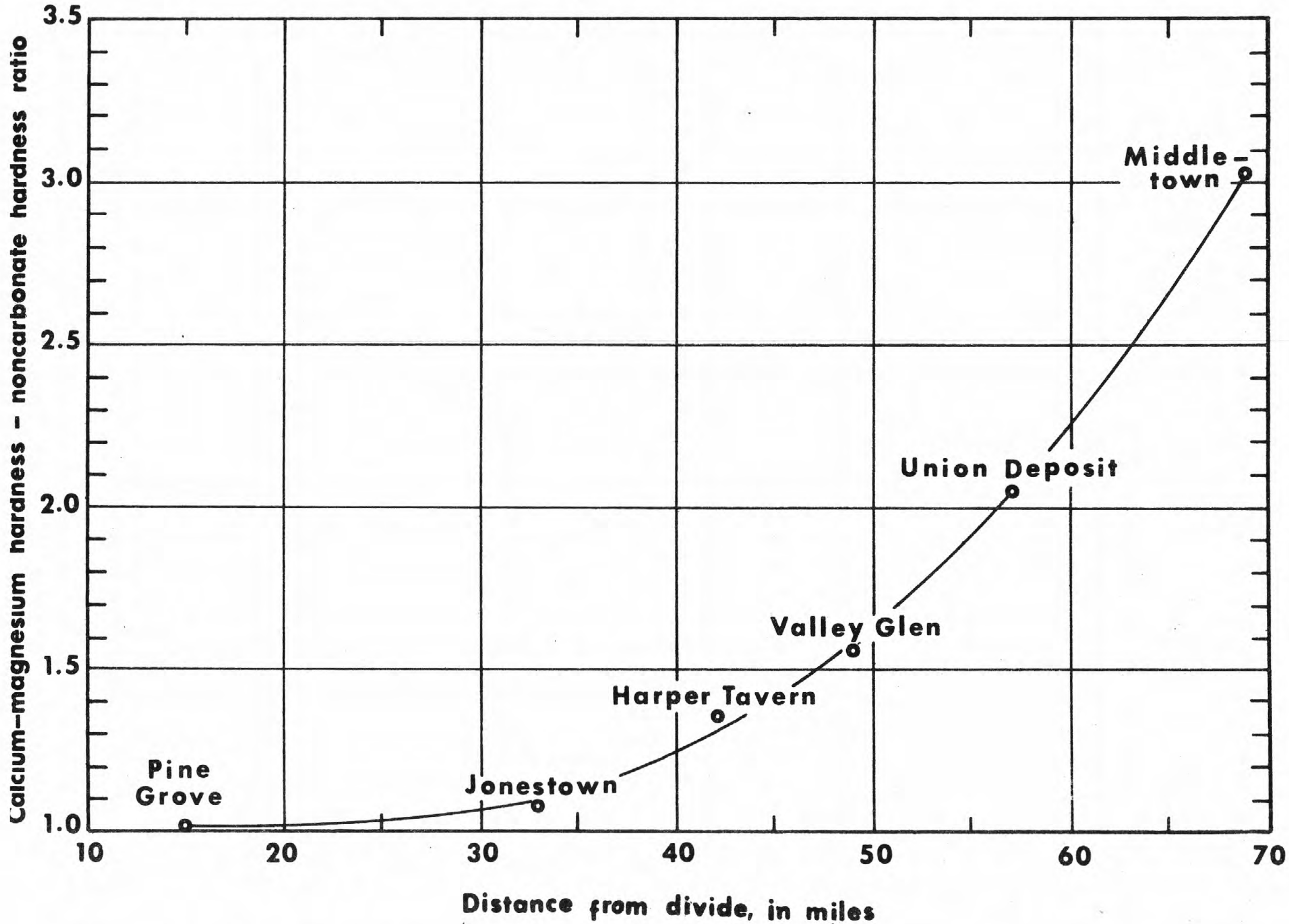


Figure 9 Ratio of calcium carbonate hardness to noncarbonate hardness, Swatara Creek, downstream sequence at low flow, July 1958

Suspended sediment in Swatara Creek is composed of both natural sediments and material from industry in the basin. Observations made at Ravine indicated higher suspended-sediment concentrations than in other streams in the basin (table 8), and a notable difference in the appearance of the water was observed, particularly during periods of high runoff. For the most part, industrial wastes transported by streams in the basin are fine coal particles from the Southern Anthracite Field, part of which is drained by upstream tributaries. Whereas other streams in the basin assume the color of the soils of the area, Swatara Creek at Ravine appears very dark in color, indicating that much of the suspended material is derived from wastes associated with the coal mining industry.

## Swatara Creek at Jonestown

Swatara Creek at Jonestown contains a mixture of acid mine drainage and acid-free water, low in dissolved solids, from tributaries that enter the Creek above Jonestown. The area drained by Swatara Creek above Jonestown is approximately 240 square miles. Above the confluence of the Little Swatara at Jonestown, the water of the main stem is a calcium sulfate type. The maximum dissolved-solids content of miscellaneous samples taken from Swatara Creek at Jonestown during 1958-59 at different stages of flow was 135 ppm (table 7). The stream was acidic (pH range 4.9 to 5.8).

TABLE 8 .--Suspended-sediment discharge of streams in Swatara Creek basin, Pa., 1959

| Date (1959) | Time | Water temperature (°F) | Suspended-sediment concentration (ppm) | Water discharge (cfs) | Water discharge (cfsm) | Suspended-sediment discharge tons/day | Suspended-sediment discharge tons/day/sq mi |
|---|---|---|---|---|---|---|---|
| **Swatara Creek at Ravine (drainage area 114 sq mi)** | | | | | | | |
| Sept. 2 | 9:50 P.M. | 80 | 927 | -- | -- | -- | -- |
| Oct. 1 | 7:30 A.M. | 67 | 2,120 | 634 | 5.56 | 3,630 | 31.8 |
| **Lower Little Swatara Creek at Pine Grove (drainage area 34.3 sq mi)** | | | | | | | |
| Sept. 2 | 10:30 P.M. | 72 | 1,010 | 1,100 | 32.1 | 3,000 | 87.5 |
| Oct. 1 | 8:30 A.M. | 71 | 239 | 180 | 5.35 | 116 | 3.38 |
| **Swatara Creek at Jonestown (drainage area 190 sq mi)** | | | | | | | |
| Aug. 27 | 11:50 A.M. | 77 | 225 | 76.4 | .40 | 46.5 | .24 |
| Oct. 1 | 12:30 P.M. | 70 | 299 | 952 | 5.01 | 769 | 4.05 |
| **Little Swatara Creek near Mount Aetna (drainage area 27.5 sq mi)** | | | | | | | |
| Aug. 27 | 9:10 A.M. | -- | 337 | 20.3 | .74 | 18.5 | .67 |
| Oct. 1 | 9:25 A.M. | 71 | 51 | 20.0 | .73 | 2.8 | .10 |
| **Little Swatara Creek near Jonestown (drainage area 83.7 sq mi)** | | | | | | | |
| Aug. 27 | 10:35 A.M. | 77 | 846 | 215 | 2.57 | 492 | 5.88 |
| Oct. 1 | 10:35 A.M. | 70 | 369 | 313 | 3.74 | 312 | 3.73 |
| **Quittapahilla Creek near Syner (drainage area 75.6 sq mi)** | | | | | | | |
| Aug. 23 | 12:00 noon | 69 | 14 | -- | -- | -- | -- |
| Dec. 12 | 8:00 P.M. | 49 | 72 | 153 | 2.02 | 29.8 | .39 |
| **Manada Creek near Sand Beach (drainage area 32 sq mi)** | | | | | | | |
| Aug. 23 | 1:00 P.M. | 69 | 72 | 10.7 | .33 | 2.08 | .065 |
| Aug. 27 | 2:15 P.M. | 77 | 67 | 21.7 | .68 | 3.93 | .12 |
| Oct. 9 | 12:05 A.M. | 70 | 188 | 41.4 | 1.29 | 21.0 | .66 |
| **Spring Creek at Union Deposit (drainage area 24.6 sq mi)** | | | | | | | |
| Aug. 23 | 10:50 A.M. | 75 | 97 | 31.3 | 1.27 | 8.2 | .33 |
| Aug. 27 | 3:00 P.M. | -- | 139 | 37.5 | 1.52 | 14.1 | .57 |
| Oct. 9 | 12:15 A.M. | -- | 206 | 28.2 | 1.15 | 15.7 | .64 |
| Dec. 12 | 9:05 P.M. | 56 | 249 | 77.5 | 3.15 | 52.2 | 2.12 |
| **Beaver Creek at Hummelstown (drainage area 27.1 sq mi)** | | | | | | | |
| Aug. 27 | 3:50 P.M. | -- | 102 | 51.2 | 1.89 | 14.1 | .52 |
| Oct. 8 | 11:15 P.M. | -- | 767 | 32.4 | 1.20 | 67.2 | 2.48 |
| **Swatara Creek at Middletown (drainage area 565 sq mi)** | | | | | | | |
| Aug. 23 | 4:10 P.M. | 77 | 39 | 178 | .32 | 18.8 | .033 |
| Aug. 27 | 5:00 P.M. | -- | 133 | 427 | .76 | 153 | .27 |

The quantity and quality of water in Swatara Creek at Jonestown meet the requirements of a public water supply system after minor treatment and pH adjustment. The stream is used for supply by the City of Lebanon, and by other smaller communities including Jonestown. A pumping station in Jonestown, part of the Lebanon water supply system, drew approximately 747,000,000 gallons from Swatara Creek in a 6-month period during 1959. This water and water from other sources is impounded in reservoirs for public distribution.

The available data show a marked trend of decreasing sediment load in Swatara Creek at Jonestown. At one time the streams draining the coal fields in the upper part of the basin were used for disposal of large quantities of waste material from several phases of coal mining and processing. Spoil banks in strip mining, mine drainage, and coal washing were the source of large quantities of material that was alternately transported and deposited by streams in the basin. Strict enforcement of regulations pertaining to stream pollution and a general decline in coal mining in the basin since late 1946 have changed the character of suspended material, as well as the nature of the stream bed of Swatara Creek (Siebert, 1951).

Additional verification of this decreasing trend in sediment loads of Swatara Creek is given by data on turbidity collected at Jonestown by the Lebanon Consolidated Water Co. (fig. 10). During 1946-60 there

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Figure 10.--(Caption on next page) belongs near here.

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was a reduction in average turbidity from about 3,000 to 6 turbidity unit

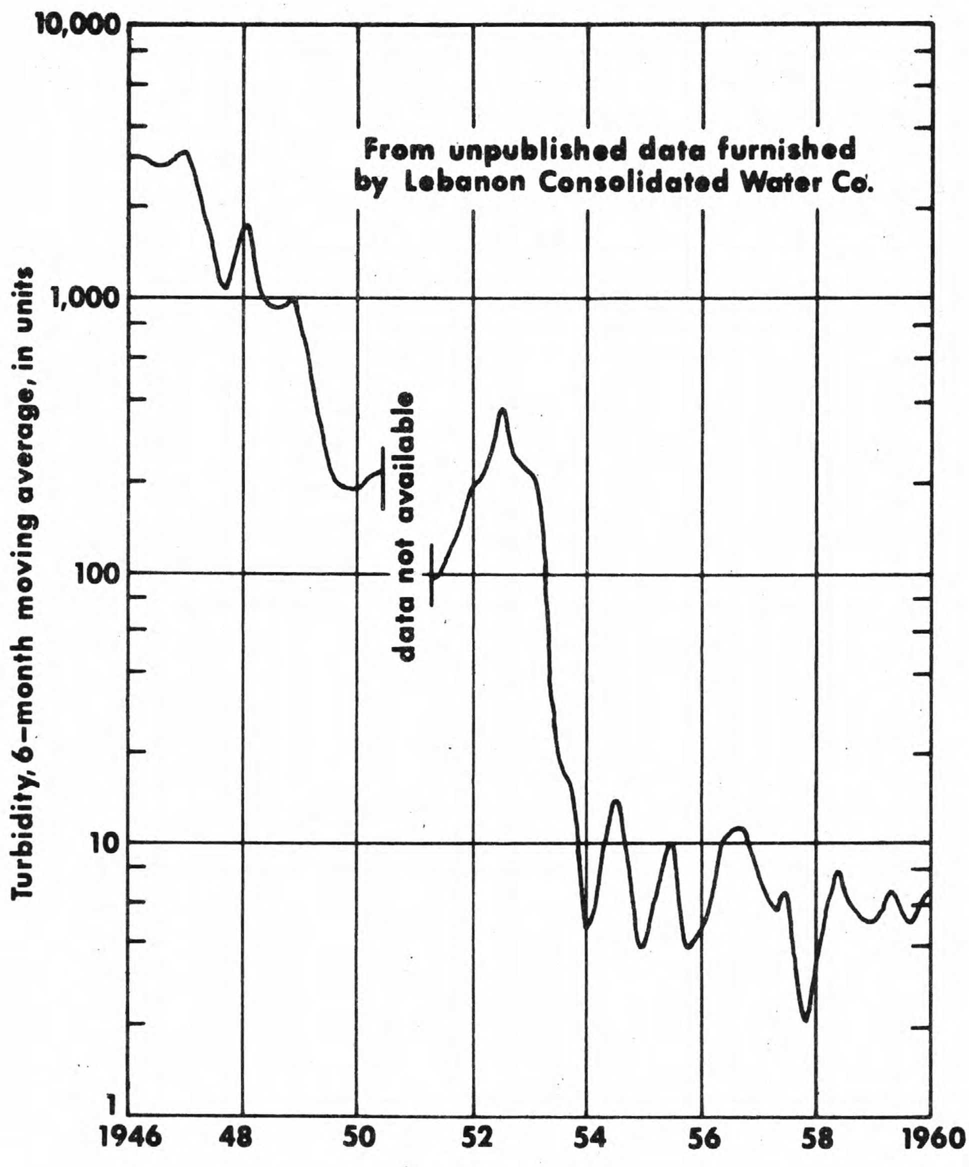


Figure 10 Turbidity, Swatara Creek at Jonestown, Pa.
1958

## Little Swatara Creek

Merging with the main stream at Jonestown, the Little Swatara Creek, largest of Swatara tributaries, drains an area of 96 square miles of northwestern Berks and eastern Lebanon Counties. The stream flows through the fertile Lebanon Valley where the principal industry is agriculture. Mean annual precipitation near Lebanon was approximately 44 inches for the period 1931-59.

The water of Little Swatara Creek is a calcium bicarbonate type having a pH range of 6.7 to 8.1. Bicarbonate, calcium, and sulfate ions make up more than 70 percent of the dissolved solids. During a low-flow period, October 8, 1959, the ratio of bicarbonate to sulfate (in parts per million) was approximately 5 to 1. During a high-flow period, August 27, 1959, it was approximately 2.5 to 1. Hardness at low flow was 89 ppm; at high flow 49 ppm. Dissolved solids during periods of study did not exceed 130 ppm, and specific conductance did not exceed 237 micromhos, (table 7).

Barring unusual hydrologic events causing variations in the quality of a stream along its course, the almost inexhaustible supply of ground water and its stable chemical composition determine a stream's basic chemical character. Because ground water is the basic source of Little Swatara Creek, the quality of the Creek during low flow was representative of the ground-water quality in the area. Although runoff after storms will dilute the concentration of solutes, and pollutants reaching Little Swatara Creek may increase the concentration of solutes and alter the stream's chemical character temporarily, the basic characteristics of Little Swatara Creek are rarely obscured.

The chemical quality of ground water depends mostly upon its lithological environment. The quality of water underlying the Little Swatara Creek basin is the product of a Martinsburg Shale environment. Martinsburg Shale is composed principally of feldspar, quartz, clay minerals, mica, and chlorite, part of which may dissolve in water. Feldspars, the most common minerals in the earth's crust, are composed of aluminum, silicates, and, in varying amounts, calcium, sodium, or potassium. Decomposition of feldspars yields clay minerals. The mica minerals in shale are hydrous potassium (or sodium), aluminum silicates that contain variable amounts of magnesium, iron, or lithium (Clarke, 1924).

Figure 11 illustrates the difference in water quality between

Figure 11.--(Caption on next page) belongs near here.

Little Swatara Creek at Mount Aetna and the average dissolved-solids content of ground water from four wells located in the area underlain by Martinsburg Shale. Even though the sample of stream water collected in August 1959 contains a greater quantity of dissolved minerals than that collected in April 1959, the dissolved-solids content does not approach that of water samples from the wells. However, close inspection of figure 13 reveals that the general character of the stream water is similar to the ground water depicted. Although the dissolved-solids content of Little Swatara Creek is less than that of the ground water, the proportions of the constituents are approximately the same.

Water from wells 3 and 5 (table 2) near Little Swatara Creek indicate that the average dissolved-solids content was nearly three times as great as Little Swatara Creek near Jonestown during a period of low flow, October 8, 1959 (table 7). Calcium and magnesium were the prevalent cations, and carbonate and sulfate were the predominant corresponding anions in solution.

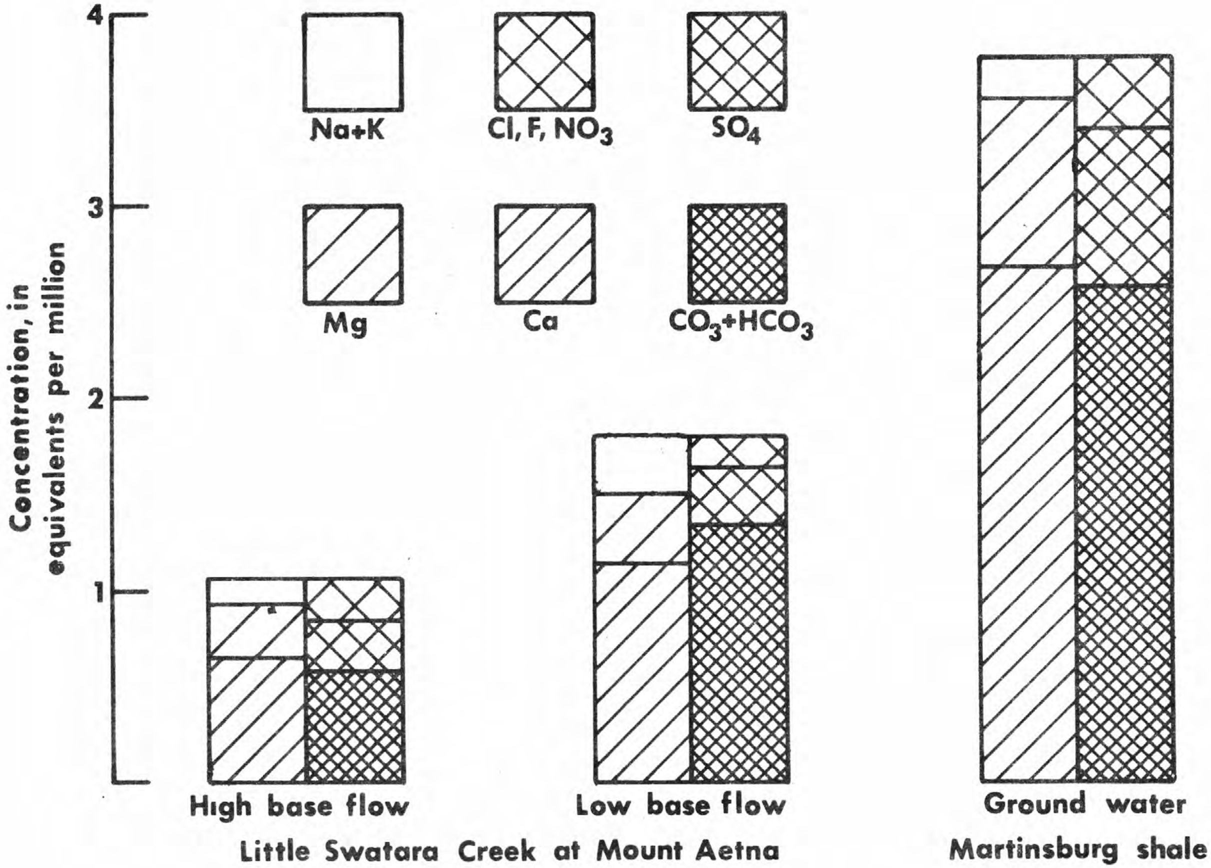


Figure 11 Chemical quality comparison of Little Swatara Creek at Mount Aetna, Pa. with average analyses of ground water in Martinsburg shale.

## Swatara Creek at Harper Tavern

The Swatara Creek sampling station at Harper Tavern is near East Hanover, a few miles south of Indiantown Gap Military Reservation. The Geological Survey has maintained a water-stage recorder there since October 1919. Because of this daily sampling station established at Harper Tavern, the description of the stream at this location is supported by continuous data (table 9).

At Harper Tavern the drainage area is 333 square miles. The average discharge for 38 years (1919-57) was 570 cfs. For more than half this period the discharge equalled or exceeded 320 cfs. Streamflow in the 1959 water year was not representative of long-term conditions. High flows occurred less frequently, and low flows occurred less frequently also during the 1959 water year.

Water of Swatara Creek at Harper Tavern is generally a calcium sulfate type; the pH of the water ranged 6.0 to 9.4. Based on chemical analyses made at different times during a 16-year period (1944-59), the maximum dissolved-solids content was 177 ppm; the hardness, 113 ppm; and the specific conductance, 329 micromhos (table 10). From October 1958 to September 1959 the specific conductance equalled or exceeded 220 micromhos only 10 percent of the time (fig. 12). During the 1959 water year neither

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Figure 12.--(Caption on next page) belongs near here.

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streamflow nor specific conductance was representative of the long-range averages for these factors. The high conductances were less than representative highs, and low conductances were likely higher than representative lows.

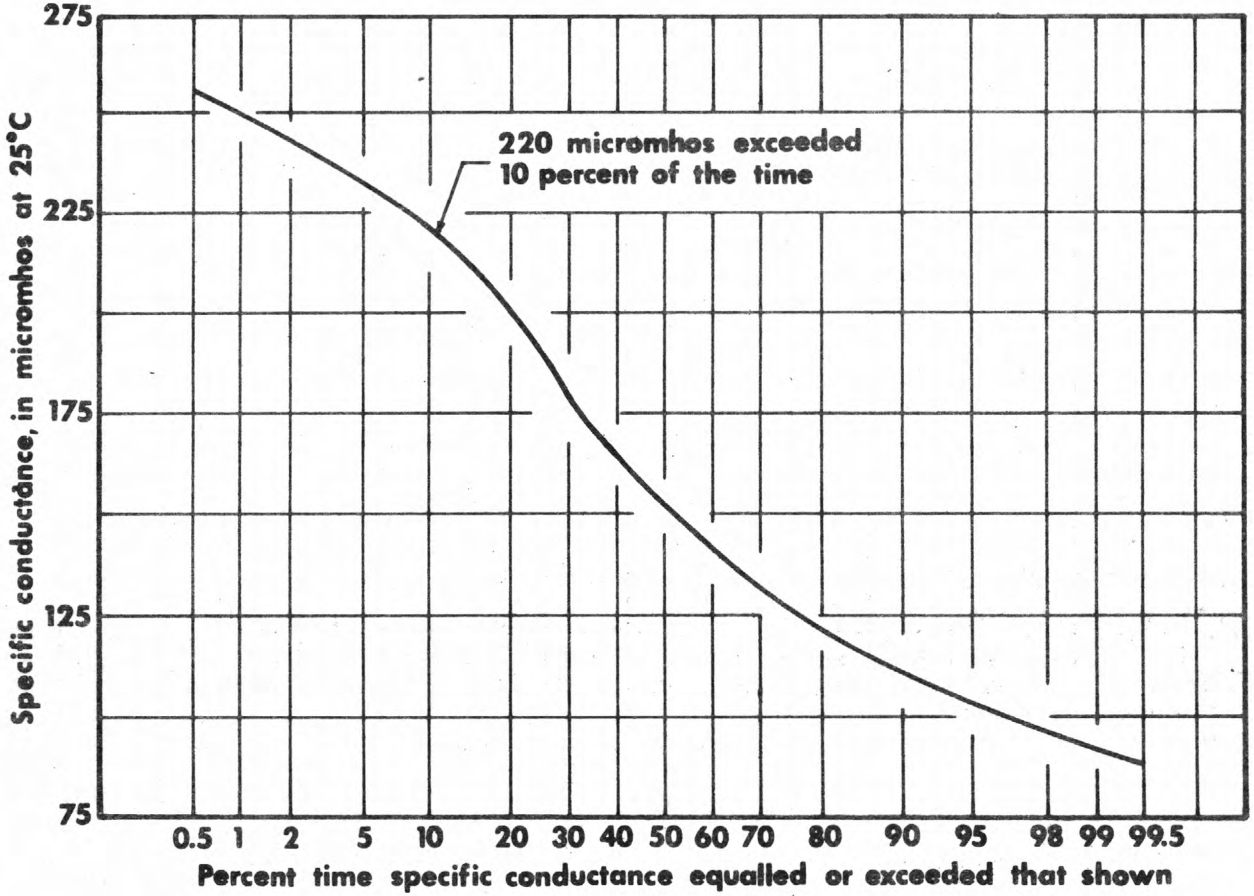


Figure 12 Cumulative frequency curve of specific conductance, Swatara Creek at Harpers Tavern, Pa., October 1958 - September 1959

Table 9 .--Swatara Creek at Harper Tavern, Pa. 1959 Water Year

LOCATION.--Highway bridge at Harper Tavern, Lebanon County, 6 miles N.W. of Annville and 8.5 miles downstream from Little Swatara Creek.
DRAINAGE AREA.--333 square miles.
RECORDS AVAILABLE.--Chemical analyses, August 1944 to September 1959.
EXTREMES, 1958-59.--Dissolved solids: Maximum, 165 ppm July 12-Aug. 5; minimum, 70 ppm, Mar. 7,9-14, 16-21, 23-28, 31 and Apr. 1-4, 6-11.
Hardness: Maximum, 95 ppm July 12-Aug. 5; minimum, 40 ppm Jan. 22, 24-28 and Apr. 1-4, 6-11.
Specific conductance: Maximum, 260 micromhos July 30; minimum, 79 micromhos Sept. 3.
Water temperatures: Maximum, 91°F Aug. 16; minimum, freezing point on many days during winter months.
EXTREMES, 1944-59.--Dissolved solids: Maximum, 177 ppm Oct. 22, 1949; minimum, 45 ppm Apr. 25, 1949.
Hardness: Maximum, 113 ppm Oct. 22, 1949; minimum, 34 ppm Apr. 25, 1949.
Specific conductance: Maximum, 329 micromhos Sept. 29, 1949; minimum, 79 micromhos Sept. 3, 1959 and Apr. 25, 1949.
REMARKS.--Records of specific conductance of daily samples available in district office at Philadelphia, Pa.

Chemical analyses, in parts per million

| Date of collection | Mean discharge (cfs) | 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 (F) | Nitrate ($NO_3$) | Dissolved solids (residue on evaporation at 180°C) | Hardness as $CaCO_3$: Calcium, magnesium | Hardness as $CaCO_3$: Non-carbonate | Specific conductance (micromhos at 25°C) | pH | Color |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct. 1-4,6-11, 1958.... | 339 | — | | — | — | — | — | 3.2 | | 34 | 29 | 3.8 | — | 8.1 | — | 63 | 35 | 169 | 7.3 | 2 |
| Oct. 12-23, ........... | 180 | 7.5 | | 0.01 | 0.00 | 21 | 7.8 | 4.4 | 2.0 | 37 | 56 | 3.6 | 0.0 | 6.1 | — | 85 | 54 | 211 | 6.8 | 3 |
| Oct. 24-Nov. 2, ....... | 352 | — | | — | — | — | — | 6 0 | | 30 | 40 | 4.0 | — | 5.4 | — | 63 | 39 | 159 | 6.8 | 5 |
| Nov. 3-9, ............. | 1,134 | — | | — | — | — | — | — | | 23 | 16 | — | — | — | — | — | — | 127 | 6.7 | 5 |
| Nov. 10-26, 28, ....... | 269 | — | | — | — | — | — | 2.3 | | 27 | 38 | 3.6 | — | 5.8 | — | 66 | 44 | 160 | 6.6 | 3 |
| Nov. 29-Dec. 10, ...... | 935 | — | | — | — | — | — | 3.4 | | 18 | 26 | 3.6 | — | 6.9 | 85 | 45 | 30 | 119 | 7.1 | 3 |
| Dec. 11-22, ........... | 387 | — | | — | — | — | — | 4.1 | | 20 | 38 | 3.5 | — | 6.5 | 108 | 57 | 41 | 148 | 7.1 | 3 |
| Dec. 23-Jan. 1, 1959... | 225 | — | | — | — | — | — | 3.9 | | 21 | 47 | 3.3 | — | 6.1 | 125 | 67 | 50 | 167 | 7.1 | 2 |
| Jan. 7-10, 12-21, ..... | 276 | — | | — | — | — | — | 4.6 | | 20 | 44 | 3.8 | — | 5.1 | 118 | 62 | 46 | 159 | 7.0 | 3 |
| Jan. 22, 24-28, ....... | 1,378 | — | | — | — | — | — | 4.4 | | 12 | 30 | 3.3 | — | 4.8 | 80 | 40 | 30 | 112 | 6.9 | 15 |
| Jan. 29-31, Feb. 2-4, . | 575 | — | | — | — | — | — | 4.1 | | 15 | 38 | 3.3 | — | 4.6 | 105 | 51 | 39 | 134 | 7.2 | 5 |
| Feb. 5-8, 12-14,16, 18-21,23-26, ........... | 420 | 7.3 | 0.1 | .03 | .14 | 11 | 3.9 | 2.8 | 2.0 | 15 | 31 | 3.0 | .1 | 4.7 | 82 | 44 | 31 | 119 | 6.9 | 5 |
| Feb. 28-Mar. 5, ....... | 264 | — | | — | — | — | — | 3.7 | | 18 | 37 | 6.2 | — | 3.6 | 96 | 57 | 42 | 145 | 6.9 | 2 |
| Mar. 6, ............... | 2,140 | — | | — | — | — | — | — | | 17 | 32 | — | — | — | — | — | — | 253 | 6.0 | — |
| Mar. 7, 9-14, 16-21, 23-28, 31, ........... | 692 | — | | — | — | — | — | 3.4 | | 17 | 29 | 3.3 | — | 5.2 | 70 | 45 | 31 | 119 | 6.6 | 2 |
| Apr. 1-4, 6-11, ....... | 1,364 | 7.5 | | .00 | .00 | 9.8 | 3.8 | 1.5 | 1.2 | 12 | 27 | 3.4 | .2 | 5.0 | 70 | 40 | 30 | 108 | 6.5 | 3 |
| Apr. 13-15, 17-18, 20-25, 27-29, ......... | 559 | — | | — | — | — | — | 4.1 | | 20 | 37 | 2.4 | — | 3.4 | 84 | 52 | 36 | 134 | 6.9 | 1 |
| May 8-9, 11-16, 18-21, | 300 | — | | — | — | — | — | 3.2 | | 18 | 38 | 2.1 | — | 1.8 | 101 | 52 | 37 | 130 | 6.9 | 1 |
| May 22-June 2, ........ | 185 | 6.9 | | .00 | .04 | 16 | 6.2 | 3.5 | 1.5 | 24 | 47 | 2.6 | .1 | 1.1 | 100 | 66 | 46 | 158 | 6.7 | 3 |
| June 3-5, ............. | 1,225 | — | | — | — | — | — | — | | 15 | 24 | — | — | — | — | — | — | 108 | 6.6 | — |
| June 6, 8, 10-15, ..... | 312 | — | | — | — | — | — | 6.4 | | 17 | 48 | 3.4 | — | 3.5 | 98 | 58 | 44 | 154 | 6.9 | 3 |
| June 16-28, ........... | 158 | — | | — | — | — | — | 6.4 | | 21 | 60 | 3.5 | — | 3.3 | 116 | 73 | 56 | 186 | 7.4 | 1 |
| June 29-July 11, ...... | 97.2 | — | | — | — | — | — | 5.8 | | 25 | 69 | 4.2 | — | 2.6 | 147 | 88 | 68 | 217 | 6.8 | 4 |
| July 12-Aug. 5, ....... | 75.6 | 8.6 | | .00 | .00 | 23 | 9.0 | 5.5 | 2.5 | 28 | 74 | 4.8 | .3 | 3.8 | 165 | 95 | 72 | 234 | 7.0 | 3 |
| Aug. 6-14, 16-26, ..... | 129 | 8.0 | | .01 | .01 | 23 | 7.1 | 5.6 | 3.5 | 37 | 57 | 5.0 | .1 | 4.7 | 133 | 87 | 56 | 220 | 7.0 | 5 |
| Aug. 27-Sept. 1, ...... | 130 | — | | — | — | — | — | 6.7 | | 40 | 47 | 5.0 | — | 5.5 | 127 | 79 | 46 | 201 | 7.4 | 10 |
| Sept. 2-6, ............ | 2,111 | — | | — | — | — | — | 4.8 | | 14 | 32 | 3.6 | — | 7.1 | 86 | 45 | 34 | 123 | 6.8 | 10 |
| Sept. 7-14, ........... | 184 | — | | — | — | — | — | 4.4 | | 24 | 46 | 4.4 | — | 6.3 | 128 | 69 | 50 | 169 | 7.2 | 6 |
| Sept. 15-30, .......... | 90.4 | — | | — | — | — | — | 4.8 | | 31 | 61 | 4.6 | — | 3.8 | 160 | 88 | 63 | 212 | 6.5 | 5 |

Table 10.--Miscellaneous chemical analyses in parts per million of Swatara creek at Harper Tavern, Pa.

| Date of collection | Mean discharge (cfs) | Temperature (°F) | Silica ($SiO_2$) | Iron (Fe) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Fluoride (F) | Nitrate ($NO_3$) | Dissolved solids (residue on evaporation at 180°C) | Hardness as $CaCO_3$ | | Specific conductance (micromhos at 25°C) | pH | Color |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | Calcium, magnesium | Noncarbonate | | | |
| Aug. 23, 1944 | 39.8 | 69 | 6.4 | 0.02 | 27 | 10 | 10 | | 36 | 83 | 8.5 | 0.1 | 3.2 | 176 | 108 | 79 | 286 | 7.7 | 6 |
| Mar. 21, 1945 | 930 | 53 | 6.3 | .06 | 11 | 3.7 | 4.9 | | 23 | 24 | 3.0 | .0 | 4.0 | 70 | 43 | 24 | 111 | 7.5 | 8 |
| Feb. 24, 1949 | 1,530 | 44 | 2.0 | .08 | 9.5 | 2.8 | 3.5 | | 1/16 | 19 | 5.0 | .0 | 3.6 | 51 | 35 | — | 87 | 9.4 | 5 |
| Mar. 25 | 371 | 52 | — | .05 | — | — | — | | 18 | 39 | 3.0 | .0 | 3.0 | 69 | 46 | 31 | 113 | 6.9 | 5 |
| Apr. 25 | 1,290 | 50 | — | .15 | — | — | — | | 12 | 28 | 3.0 | .0 | 3.4 | 45 | 34 | 24 | 79 | 6.8 | 5 |
| May 20 | 264 | 67 | 8.6 | .09 | 13 | 5.2 | 1.9 | | 22 | 32 | 3.0 | .2 | 2.6 | 89 | 54 | 36 | 122 | 6.8 | 5 |
| June 15 | 92 | 75 | — | .03 | — | — | — | | 21 | 61 | 3.0 | .0 | 1.8 | 132 | 70 | 53 | 180 | 7.1 | 1 |
| July 21 | 164 | 80 | — | .11 | — | — | — | | 54 | 38 | 4.0 | .0 | 7.8 | 125 | 66 | 22 | 164 | 7.4 | 7 |
| Aug. 26 | 45 | 68 | 5.2 | .19 | 27 | 10 | 5.2 | | 38 | 75 | 5.0 | .2 | 3.5 | 154 | 108 | 77 | 241 | 7.2 | 5 |
| Sept. 29 | 71 | 80 | 7.0 | .02 | 26 | 11 | 4.9 | | 20 | 95 | 3.0 | .0 | 1.6 | 171 | 110 | 94 | 320 | 6.5 | 10 |
| Oct. 22 | 40 | 48 | — | .02 | 27 | 11 | 8.6 | | 36 | 92 | 3.0 | .0 | 2.3 | 177 | 113 | 83 | 271 | 7.2 | 2 |
| Dec. 2 | 78 | 34 | — | .02 | 23 | 7.7 | 7.1 | | 36 | 64 | 4.0 | .0 | 3.4 | 145 | 89 | 60 | 208 | 7.5 | 1 |
| Dec. 22 | 147 | 41 | — | .02 | 15 | 6.2 | 4.0 | | 20 | 44 | 3.0 | .0 | 6.4 | 112 | 63 | 47 | 153 | 6.8 | 4 |
| Jan. 27, 1950 | 399 | 46 | — | .11 | 14 | 4.8 | 4.4 | | 18 | 39 | 3.5 | .0 | 4.9 | 90 | 55 | 40 | 141 | 6.7 | 5 |
| Feb. 24 | 645 | 38 | — | .04 | 11 | 4.6 | 1.7 | 0.9 | 11 | 35 | 2.1 | .0 | 4.6 | 75 | 46 | 37 | 123 | 6.2 | 3 |
| Mar. 17 | 444 | 40 | — | .10 | 11 | 4.9 | 3.4 | | 17 | 33 | 2.0 | .0 | 4.9 | 81 | 48 | 34 | 121 | 7.2 | 4 |
| Apr. 19 | 294 | 51 | — | .04 | 12 | 5.4 | 5.2 | | 24 | 37 | 2.0 | .0 | 3.2 | 93 | 52 | 32 | 128 | 7.3 | 5 |
| May 24 | 1,580 | 61 | — | .39 | 9.8 | 3.0 | 4.1 | | 22 | 22 | 2.5 | .0 | 1.6 | 68 | 37 | 19 | 90 | 7.2 | 20 |
| June 21 | 359 | 67 | — | .03 | 13 | 4.8 | 6.5 | | 32 | 32 | 3.0 | .0 | 3.3 | 87 | 52 | 26 | 130 | 6.9 | 2 |
| July 19 | 255 | 79 | — | .09 | 12 | 5.4 | 6.3 | | 30 | 33 | 3.5 | .0 | 2.5 | 92 | 52 | 28 | 130 | 6.8 | 2 |
| Aug. 16 | 68 | 77 | — | .01 | 22 | 8.3 | 6.5 | | 30 | 71 | 2.0 | .0 | 2.4 | 139 | 89 | 64 | 211 | 7.5 | 2 |
| Sept. 20 | 122 | 66 | — | .08 | 19 | 6.5 | 5.6 | | 37 | 46 | 3.0 | .0 | 4.7 | 113 | 74 | 44 | 174 | 7.3 | 5 |
| Oct. 12, 1957 | — | 50 | — | — | — | — | 13 | | 44 | 85 | 4.0 | — | 3.0 | — | 104 | 68 | 266 | 6.5 | 6 |
| Apr. 25, 1958 | 681 | 57 | 5.0 | .02 | 11 | 4.1 | 2.7 | 1.0 | 16 | 35 | 3.0 | — | 2.9 | 105 | 45 | 32 | 118 | 6.1 | 3 |
| July 14 | 142 | 73 | 7.3 | .03 | 17 | 6.3 | 3.0 | 1.7 | 30 | 34 | 4.0 | — | 3.6 | — | 69 | 44 | 163 | 6.5 | 5 |
| July 17 | 268 | 78 | 6.4 | .02 | 12 | 4.9 | 3.0 | 1.8 | 16 | 29 | 4.0 | — | 3.6 | — | 50 | 37 | 131 | 6.5 | 5 |
| Apr. 22, 1959 2/ | 420 | 60 | 8.4 | .07 | 12 | 5.4 | 2.3 | 1.0 | 17 | 37 | 2.2 | .0 | 3.5 | 85 | 52 | 38 | 126 | 7.5 | 2 |
| Aug. 26 | — | 82 | — | .03 | 25 | 7.3 | 6.7 | 3.5 | 48 | 53 | 5.5 | .1 | 5.7 | 151 | 93 | 53 | 236 | 6.9 | 6 |

1/ Includes the equivalent of 6 ppm carbonate

2/ Dissolved oxygen content was 9.3 ppm

Water temperatures during 1959 were less than 54°F 50 percent of the time and exceeded 75°F only 22 percent of the time (fig. 13).

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Figure 13.--(Caption on next page) belongs near here.

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During the 1959 water year Swatara Creek carried approximately 37,000 tons of dissolved solids past Harper Tavern. Of the total, 37 percent was sulfate and 17 percent bicarbonate as calcium bicarbonate (table 11). Figure 14 shows the variation of sulfate and bicarbonate discharge in tons, as related to changes in water discharge.

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Figure 14.--(Caption on next page) belongs near here.

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Two selected streams in Pennsylvania that drain areas approximately the size drained by Swatara Creek are Conestoga Creek at Lancaster and Lackawanna River at Old Forge. During the 1948 water year Conestoga Creek, under flow conditions similar to those of Swatara Creek during the 1959 water year, discharged approximately 89,000 tons of dissolved solids, and Lackawanna River at Old Forge discharged approximately 365,000 tons (White, 1951).

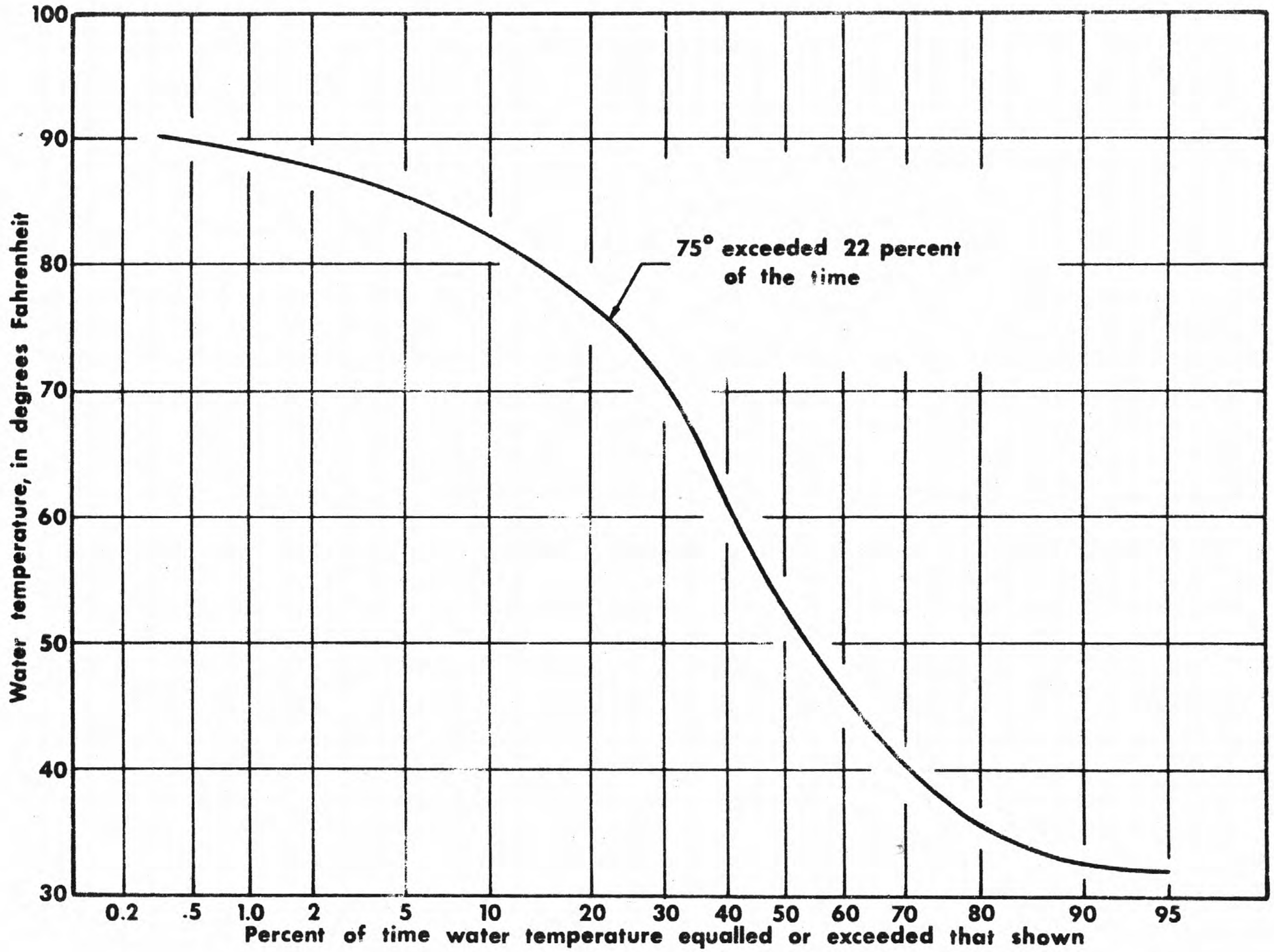


Figure 13 Cumulative frequency curve of water temperature, Swatara Creek at Harper Tavern, Pa., October 1958 - September 1959.

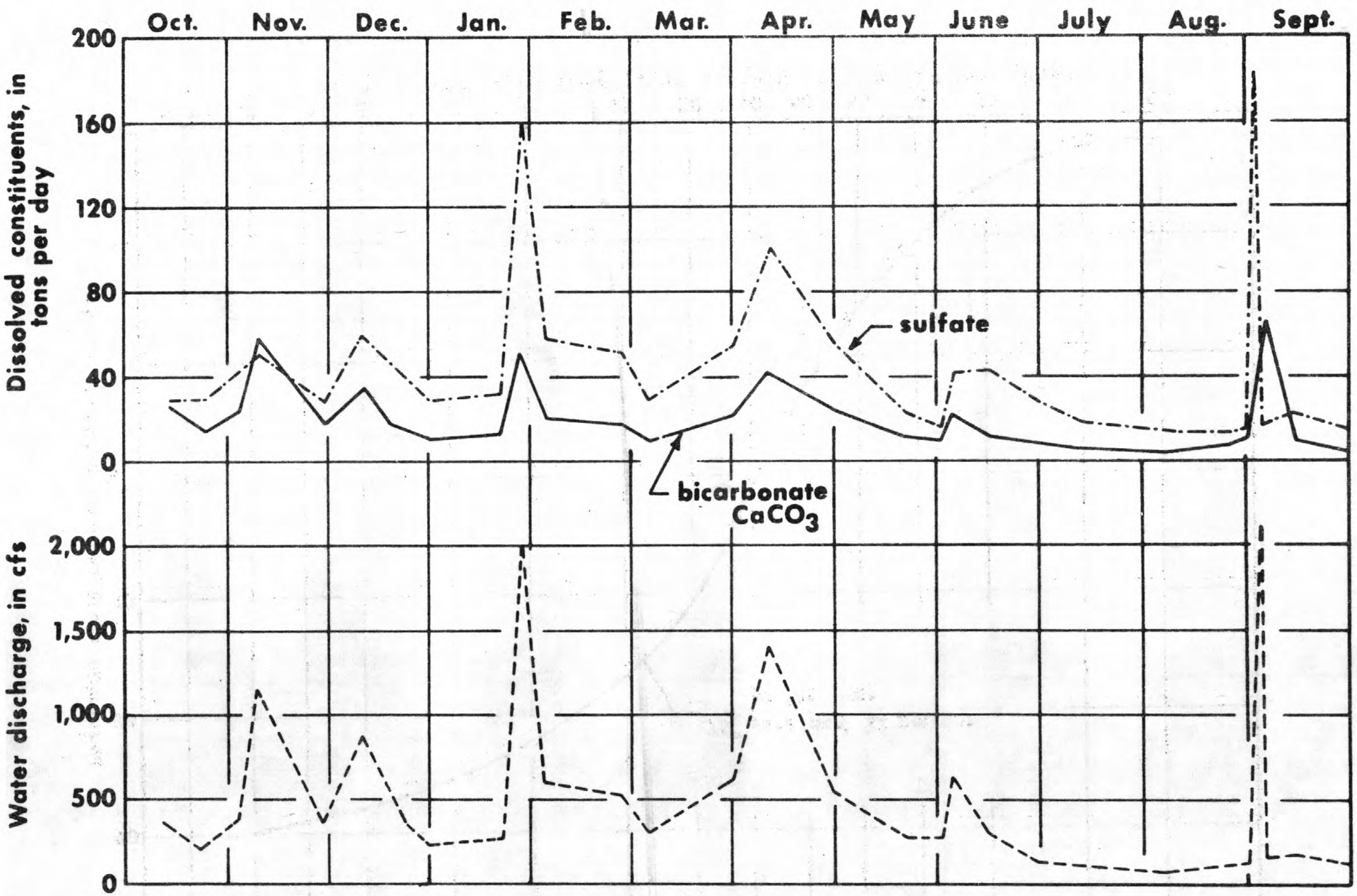


Figure 14 Water discharge, sulfate and bicarbonate discharge, Swatara Creek at Harper Tavern, Pa., October 1958 - September 1959.

Table 11.--Load studies of Swatara Creek at Harper Tavern, Pa.,

October 1, 1958 to September 30, 1959

| Composite period of daily samples | Number of days | Load in tons | | | | | | Average water discharge per period (cfs) |
|---|---|---|---|---|---|---|---|---|
| | | Dissolved solids | | Sulfate | | Bicarbonate as $CaCO_3$ | | |
| | | Per day | Per period | Per day | Per period | Per day | Per period | |
| Oct. 1-4,6-11, 1958 | 11 | 112 | 1,232 | 26.6 | 293 | 25.6 | 282 | 340 |
| Oct. 12-23 | 12 | 61.7 | 740 | 27.2 | 326 | 14.7 | 176 | 180 |
| Oct. 24-Nov. 2 | 10 | 107 | 1,070 | 38.0 | 380 | 23.4 | 234 | 352 |
| Nov. 3-9 | 7 | 85.3 | 597 | 48.9 | 342 | 57.8 | 405 | 1,130 |
| Nov. 10-28 | 19 | 110 | 2,090 | 27.6 | 504 | 16.1 | 306 | 269 |
| Nov. 29-Dec.10 | 12 | 196 | 2,352 | 59.8 | 718 | 33.9 | 407 | 851 |
| Dec. 11-22 | 12 | 112 | 1,344 | 39.5 | 474 | 17.1 | 205 | 387 |
| Dec. 23-Jan. 1, 1959 | 10 | 76.0 | 760 | 28.6 | 286 | 10.5 | 105 | 225 |
| Jan. 2-21 | 20 | 87.9 | 1,758 | 32.8 | 656 | 12.2 | 244 | 276 |
| Jan. 22-28 | 7 | 425 | 2,975 | 159 | 1,113 | 52.2 | 365 | 1,960 |
| Jan. 29-31 | 3 | - | - | - | - | - | - | - |
| Feb. 1-4 | 4 | 162 | 648 | 58.9 | 236 | 19.1 | 76 | 575 |
| Feb. 5-26 | 22 | 134 | 2,948 | 51.8 | 1,140 | 17.3 | 380 | 520 |
| Feb. 27-Mar. 5 | 7 | 68.4 | 479 | 26.4 | 185 | 10.5 | 74 | 264 |
| Mar. 6-31 | 25 | 130 | 3,250 | 53.6 | 1,340 | 21.2 | 530 | 685 |
| Apr. 1-11 | 12 | 262 | 2,882 | 101 | 1,212 | 40.9 | 491 | 1,390 |
| Apr. 12-30 | 19 | 123 | 2,337 | 54.4 | 1,034 | 24.1 | 460 | 544 |
| May 1-7 | 7 | - | - | - | - | - | - | - |
| May 8-21 | 14 | 80.4 | 1,126 | 30.2 | 436 | 11.8 | 165 | 295 |
| May 22-Jun. 2 | 12 | 50.0 | 600 | 23.5 | 282 | 9.8 | 118 | 185 |
| Jun. 3-5 | 3 | - | - | 40.8 | 122 | 20.9 | 63 | 630 |
| Jun. 6-15 | 10 | 84.7 | 847 | 41.5 | 415 | 12.0 | 120 | 320 |
| Jun. 16-28 | 13 | 52.3 | 680 | 27.0 | 351 | 7.8 | 101 | 167 |
| Jun. 29-Jul. 11 | 13 | 38.5 | 500 | 18.1 | 235 | 5.4 | 70 | 97 |
| Jul. 12-Aug. 5 | 25 | 33.0 | 825 | 14.8 | 370 | 4.6 | 115 | 74 |
| Aug. 6-26 | 21 | 33.4 | 701 | 14.3 | 300 | 7.6 | 160 | 93 |
| Aug. 27-Sept. 1 | 6 | 44.6 | 268 | 16.5 | 99 | 11.5 | 69 | 130 |
| Sept. 2-6 | 5 | 490 | 2,450 | 18.2 | 91 | 65.4 | 327 | 2,11 |
| Sept. 7-14 | 8 | 63.6 | 509 | 22.9 | 183 | 9.8 | 78 | 184 |
| Sept. 15-30 | 16 | 38.9 | 622 | 14.8 | 237 | 6.2 | 99 | 90 |
| Totals | | | 36,590 | | 11,775 | | 5,766 | |

Concentrations of suspended sediment in streams are related to rainfall, streamflow, soil erodibility, land use, and other hydrologic and cultural factors. Heavy rainfall in Swatara Creek basin usually results in high sediment concentrations. The effect of a summer rainstorm and the resulting runoff on sediment concentrations of Swatara Creek at Harper Tavern is shown in figure 15. Before the

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Figure 15.--(Caption on next page) belongs near here.

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rainfall of September 2, 1959, the sediment concentration of Swatara Creek was about 40 ppm. During the high runoff period the concentration increased to more than 1,600 ppm and decreased to about 20 ppm by September 4. This general pattern likely occurs during each significant runoff event.

During the period May 8 to September 30, 1959, the mean daily sediment concentration of Swatara Creek ranged from 2 to 568 ppm (table 1 The duration of sediment concentration for the period of sediment record is given in figure 16.

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Figure 16.--(Caption on next page) belongs near here.

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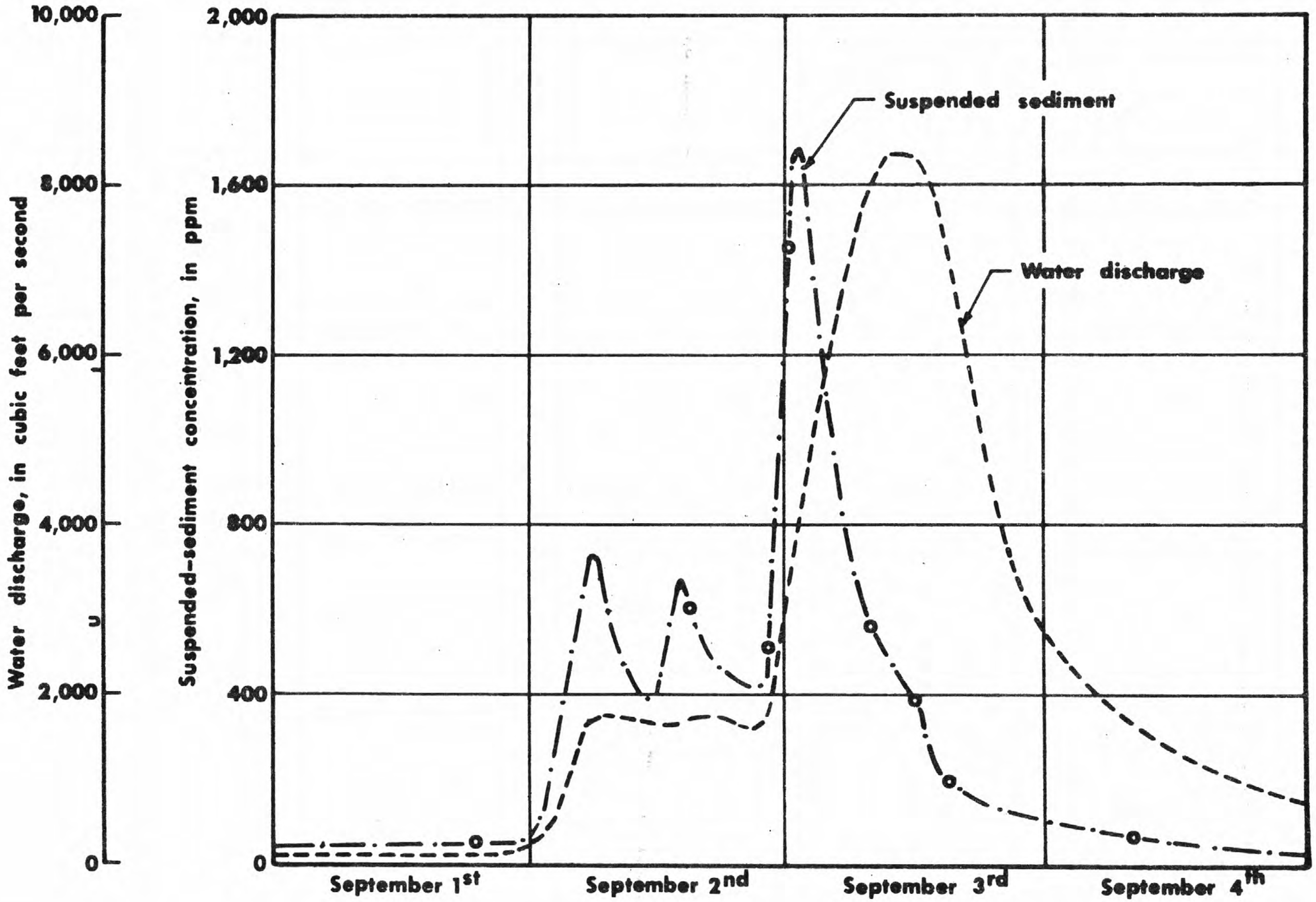


Figure 15 Water discharge and suspended-sediment concentration, Swatara Creek at Harper Tavern, Pa., September 1-4, 1959

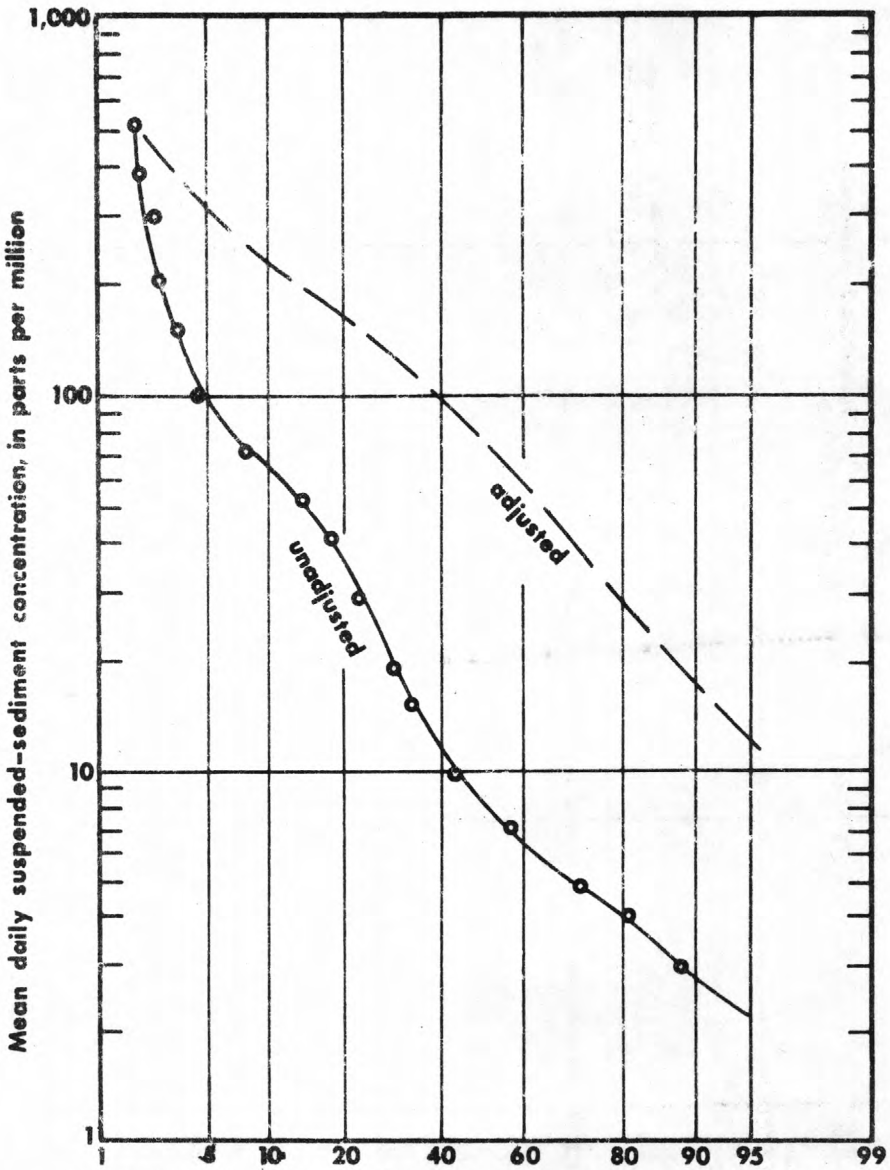


Figure 16 Duration curve of suspended-sediment concentration, Swatara Creek at Harper Tavern, Pa. May 8 - Sept. 30, 1959

le.12.--Water discharge, concentration and discharge of suspended sediment, Swatara Creek at Harper Tavern, Pa., May 8 - September 30, 1959

| Day | May | | | June | | | July | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean discharge (cfs) | Suspended sediment | | Mean discharge (cfs) | Suspended sediment | | Mean discharge (cfs) | Suspended sediment | |
| | | Mean concentration (ppm) | Tons per day | | Mean concentration (ppm) | Tons per day | | Mean concentration (ppm) | Tons per day |
| 1...... | | | | 117 | 5 | 2 | 104 | 7 | 2 |
| 2...... | | | | 559 | 104 | s/384 | 162 | 19 | 8 |
| 3...... | | | | 2,320 | 293 | s/2,170 | 137 | 9 | 3 |
| 4...... | | | | 804 | 38 | 83 | 104 | – | – |
| 5...... | | | | 550 | 32 | 48 | 89 | 6 | 1 |
| 6...... | -- | -- | -- | 535 | 49 | 71 | 83 | – | – |
| 7...... | -- | -- | -- | 421 | – | s/25 | 89 | – | – |
| 8...... | 304 | -- | -- | 333 | 16 | 14 | 89 | 8 | 2 |
| 9...... | 276 | 4 | 3 | 280 | – | s/8 | 74 | – | – |
| 10...... | 272 | – | s/3 | 252 | – | – | 80 | 55 | 12 |
| 11...... | 292 | -- | -- | 221 | 6 | 4 | 92 | 13 | 3 |
| 12...... | 292 | 3 | 2 | 221 | – | – | 92 | 10 | 2 |
| 13...... | 366 | 8 | 8 | 425 | 35 | 40 | 98 | 17 | 5 |
| 14...... | 515 | 18 | 25 | 333 | 24 | 22 | 104 | – | – |
| 15...... | 354 | 8 | 8 | 217 | – | – | 77 | – | – |
| 16...... | 304 | 5 | 4 | 176 | 6 | 3 | 71 | 7 | 1 |
| 17...... | 272 | – | s/2 | 172 | – | – | 71 | – | – |
| 18...... | 252 | -- | -- | 179 | – | – | 64 | – | – |
| 19...... | 232 | -- | -- | 172 | 4 | 2 | 80 | 26 | s/7 |
| 20...... | 225 | 2 | 1 | 176 | – | – | 130 | 10 | 4 |
| 21...... | 205 | -- | -- | 162 | – | – | 114 | 8 | 2 |
| 22...... | 198 | -- | -- | 137 | 3 | 1 | 86 | – | – |
| 23...... | 187 | -- | -- | 144 | – | – | 69 | – | – |
| 24...... | 176 | 2 | 1 | 144 | – | – | 64 | 6 | 1 |
| 25...... | 165 | -- | -- | 148 | – | s/36 | 61 | – | – |
| 26...... | 151 | -- | -- | 209 | 60 | 34 | 58 | – | – |
| 27...... | 144 | -- | -- | 154 | 30 | 12 | 56 | – | – |
| 28...... | 140 | -- | -- | 127 | 18 | 6 | 48 | – | – |
| 29...... | 134 | 2 | 1 | 114 | – | – | 46 | 13 | 2 |
| 30...... | 127 | -- | -- | 98 | 6 | 2 | 48 | – | – |
| 31...... | 124 | -- | -- | – | – | – | 86 | 50 | 12 |
| Total. | 5,707 | | 74 | 9,940 | | 2,990 | 2,626 | | 87 |

| Day | August | | | September | | |
|---|---|---|---|---|---|---|
| | Mean discharge (cfs) | Mean concentration (ppm) | Tons per day | Mean discharge (cfs) | Mean concentration (ppm) | Tons per day |
| 1...... | 69 | – | – | 111 | 42 | 13 |
| 2...... | 44 | – | – | 1,520 | 568 | s/2,650 |
| 3...... | 37 | 9 | 1 | 6,260 | 510 | s/8,780 |
| 4...... | 33 | – | – | 1,550 | 98 | s/419 |
| 5...... | 103 | 38 | s/16 | 741 | 60 | 120 |
| 6...... | 120 | 98 | s/33 | 486 | 38 | 50 |
| 7...... | 71 | 53 | 10 | 270 | – | – |
| 8...... | 69 | 24 | 4 | 210 | – | – |
| 9...... | 100 | 14 | 4 | 200 | – | – |
| 10...... | 235 | 48 | s/35 | 180 | 13 | 7 |
| 11...... | 158 | 50 | 21 | 170 | – | – |
| 12...... | 95 | 34 | 9 | 160 | – | – |
| 13...... | 74 | 20 | 4 | 148 | 4 | 1 |
| 14...... | 61 | 9 | 1 | 137 | | – |
| 15...... | 51 | – | s/1 | 124 | | 2 |
| 16...... | 48 | 3 | t | 114 | – | – |
| 17...... | 104 | 24 | s/10 | 117 | 8 | 3 |
| 18...... | 124 | 80 | 27 | 111 | 4 | 1 |
| 19...... | 90 | 42 | 10 | 95 | – | – |
| 20...... | 61 | – | s/4 | 92 | – | s/1 |
| 21...... | 48 | 14 | 2 | 89 | – | – |
| 22...... | 50 | 21 | s/3 | 89 | 4 | 1 |
| 23...... | 94 | 20 | s/6 | 92 | – | – |
| 24...... | 115 | 38 | s/14 | 89 | – | – |
| 25...... | 106 | 55 | 16 | 82 | 2 | t |
| 26...... | 71 | 42 | 8 | 80 | – | – |
| 27...... | 288 | 339 | s/320 | 64 | – | – |
| 28...... | 143 | 192 | s/79 | 69 | 2 | t |
| 29...... | 89 | 70 | 17 | 69 | – | – |
| 30...... | 74 | 60 | 12 | 71 | – | – |
| 31...... | 77 | 38 | 8 | | | |
| Total. | 2,902 | | 678 | 13,590 | | 12,093 |

s/ Estimated
g/ Computed by subdividing day

t/ Less than 0.5 ton

Because streamflow during the sediment sampling period did not represent the long-term regime, the concentration-duration curve was adjusted to give a more representative curve for a longer period. The relationship of suspended-sediment discharge to water discharge for the period May 8 to September 30, 1959 (fig. 17) and the long-term flow duration data were used to make the adjustment shown of figure 16.

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Figure 17.--(Caption on next page) belongs near here.

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The adjusted curve indicates that 10 percent of the time the suspended-sediment concentration equalled or exceeded about 230 ppm.

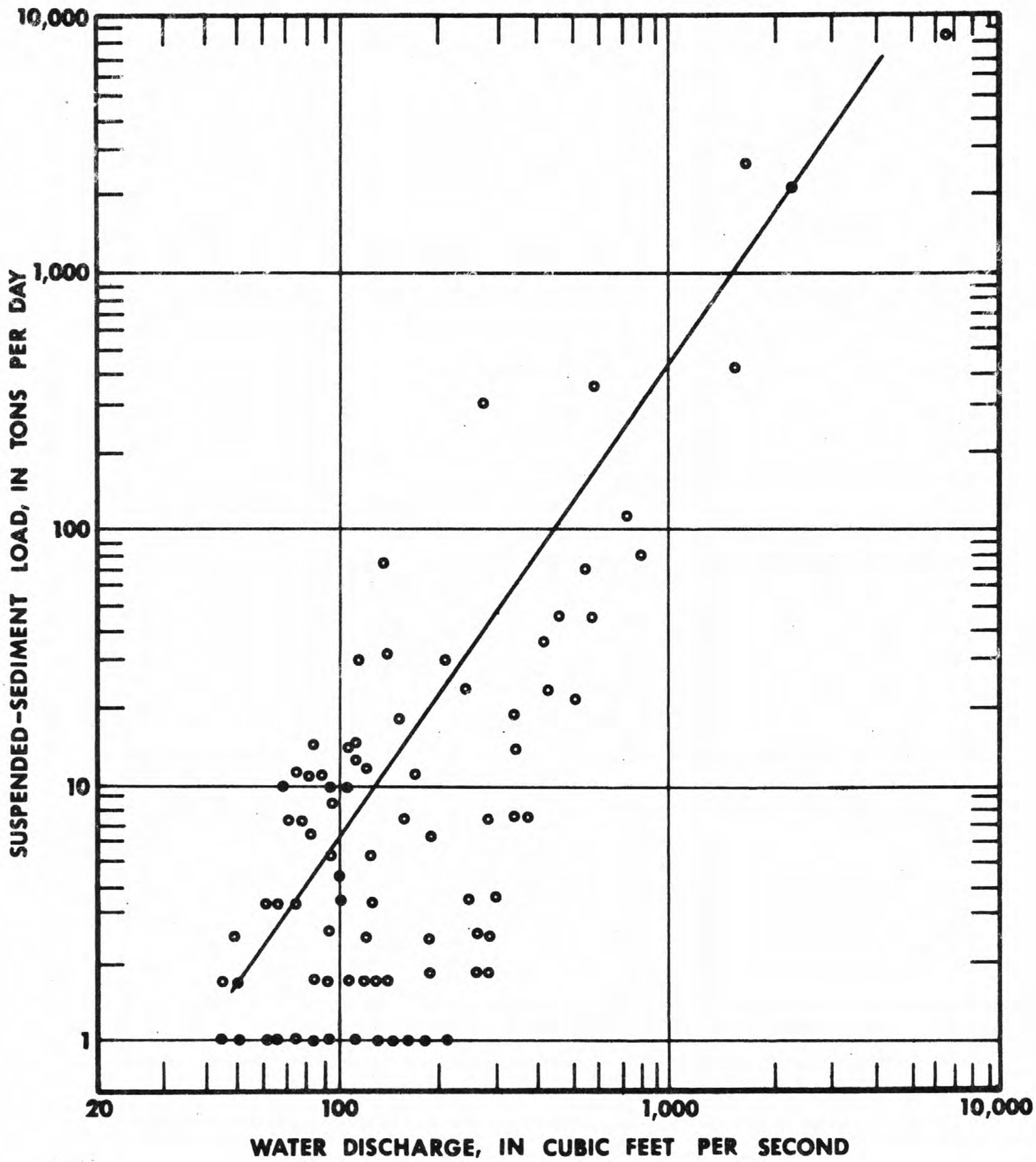


Figure 17 Relationship of suspended-sediment discharge to water discharge, Swatara Creek at Harper Tavern, Pa., May 8 September 30, 1959

Measured suspended-sediment discharges of Swatara Creek at Harper Tavern during the period of sediment record ranged from less than 0.5 ton per day to 8,780 tons per day (table 12). The average discharge was 109 tons per day. Because the streamflow during the measurement period was less than average, the relationship of suspended-sediment discharge to streamflow (fig. 17) for the period likely would not be the same as the long-term average. In general, during periods of low flow, sediment discharge for a given water discharge is greater than for the same discharge during periods of sustained high streamflow. Therefore, the relation curve of sediment discharge to water discharge probably yields a greater than average sediment discharge. However, if we assume that the relationship represents the average condition, an estimated average annual suspended-sediment discharge can be computed, using this relationship and the streamflow records for Harper Tavern. These computations are given in table 13. Briefly, the computations are made by dividing the long-term streamflow, as expressed by a flow duration curve (fig. 5), into several increments. The water discharge for the mid-point of each increment is used to obtain a suspended-sediment discharge from the sediment discharge - water discharge relationship. These loads are weighted according to the increment of time that each represents and then are totaled and multiplied by 365 to obtain an average annual discharge. The annual suspended-sediment discharge of Swatara Creek at Harper Tavern, computed by this method, is approximately 150,000 tons, or 450 tons per square mile.

Table 13.--Computation of average annual suspended-sediment discharge, Swatara Creek at Harper Tavern, Pa.

| Percent limits | Interval (percent) | Mid-ordinate (percent) | Water discharge (cfs) | Sediment discharge (tons/day) | Time weighted discharge (tons/day) |
|---|---|---|---|---|---|
| 0.00 - 0.25 | 0.25 | 0.125 | 8,800 | 27,500 | 68.8 |
| .25 - .75 | .50 | .5 | 5,320 | 11,000 | 55.0 |
| .75 - 1.50 | .75 | 1.125 | 3,800 | 6,000 | 45.0 |
| 1.5 - 2.5 | 1.0 | 2.0 | 2,900 | 3,620 | 36.2 |
| 2.5 - 4.5 | 2 | 3.5 | 2,200 | 2,020 | 40.4 |
| 4.5 - 8.5 | 4 | 6.5 | 1,600 | 1,200 | 48.0 |
| 8.5 -15 | 6.5 | 11.75 | 1,150 | 660 | 42.9 |
| 15 -25 | 10 | 20 | 820 | 350 | 39.0 |
| 25 -35 | 10 | 30 | 600 | 200 | 20.0 |
| 35 -45 | 10 | 40 | 445 | 118 | 11.8 |
| 45 -55 | 10 | 50 | 326 | 65 | 6.5 |
| 55 -75 | 20 | 65 | 184 | 23.5 | 4.7 |
| 75 -100 | 25 | 87.5 | 69 | 4.0 | 1.0 |
| Total | 100 | | | | 415.3 |

Average annual suspended sediment discharge =

415.3 X 365 = 152,000 tons

Particle-size analyses of suspended sediment in Swatara Creek at Harper Tavern show that about 36 percent of the sediment is clay (less than 0.004 mm), 50 percent is silt (0.004 to 0.062 mm), and 14 percent is sand (0.062 to 2.0 mm). The results of these analyses are given in table 14. The effect of dissolved minerals on the flocculation of fine material is shown by a comparison of the two analyses on the sampl collected on December 13, 1959. Particle-size analysis of the sample in distilled water indicates 25 percent of the sediment was clay and 50 percent was silt, whereas analysis in native (river) water shows onl 14 percent clay and 62 percent silt. These data indicate that flocculation occurred in the native water.

Semi-quantitative analyses of the amount of coal material in suspension in Swatara Creek at Harper Tavern were made on four samples collected during periods of high flow. A microscopic count of sand-size particles was used to determine the percent of coal in the suspende material (table 15). Although no attempt was made to determine the amou of coal in the finer (less than 0.062 mm) portion of these samples, visu examination indicated that the finer material also contained some coal particles.

Table 14.--Particle-size analysis of suspended sediment, Swatara Creek at Harper Tavern, Pa.

| Date | Time | Water discharge (cfs) | Water temperature (°F) | Concentration of sample (ppm) | Percent finer than indicated size, in millimeters | | | | | | | | Methods of Analysis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.004 | 0.008 | 0.016 | 0.031 | 0.062 | 0.125 | 0.250 | 0.500 | |
| June 3, 1959 | 9:00 a.m. | 2,900 | 63 | 273 | 42 | 62 | 79 | 88 | 93 | 94 | | | BSWC |
| Sept. 3 | 12:40 a.m. | 4,370 | 76 | 1,450 | 39 | 56 | 88 | 90 | 92 | 95 | 97 | 99 | BSWC |
| Sept. 3 | 7:32 a.m. | 7,630 | 73 | 583 | 53 | 64 | 73 | 85 | 89 | 92 | 95 | 98 | BSWC |
| Oct. 24 | 2:30 p.m. | 3,690 | 60 | 671 | 25 | 48 | 65 | 80 | 85 | 92 | 96 | 99 | BSWC |
| Nov. 28 | 9:45 a.m. | 3,970 | -- | 953 | 38 | 58 | 71 | 84 | 88 | 93 | 97 | 99 | BSWC |
| Dec. 13 | 5:50 a.m. | 6,150 | 45 | 308 | 25 | 44 | 56 | 70 | 75 | 88 | 94 | 98 | BSWC |
| Dec. 13 | 5:50 a.m. | 6,150 | 45 | 308 | 14 | 26 | 48 | 68 | 76 | 88 | 94 | 98 | BSN |
| Jan. 3, 1960 | 6:45 p.m. | 4,270 | 38 | 454 | 31 | 51 | 65 | 77 | 79 | 87 | 93 | 96 | BSWC |

Methods of analysis: B, bottom withdrawal tube; S, sieve; N, in native water; W, in distilled water; C, chemically dispersed.

Table 15.--Percentage of coal particles in suspended-sediment samples, Swatara Creek at Harper Tavern, Pa.

| Date | Water discharge | Percentage of coal retained on indicated sieve size | |
|---|---|---|---|
| | | 0.062 mm | 0.125 mm |
| Oct. 24, 1959 | 3,690 | 13 | 38 |
| Nov. 28, 1959 | 3,970 | 10 | 26 |
| Dec. 13, 1959 | 6,150 | 26 | 35 |
| Jan. 3, 1960 | 4,270 | 16 | -- |

In addition to observations of the sediment discharge at Harper Tavern, measurements were made at ten other locations in the basin (table 8). These measurements were made during periods of storm runoff when the greater portion of the sediment load is transported. Although the number of measurements is not sufficient to estimate the annual sediment discharge at each location, a comparison is made in figure 18 with the instantaneous sediment discharge - water discharge

Figure 18.--(Caption on next page) belongs near here.

relationship at Harper Tavern. Most of the points plot above the Harper Tavern curve. This may indicate that the average sediment discharge of Swatara Creek at Harper Tavern is less than the average for many tributaries in the basin.

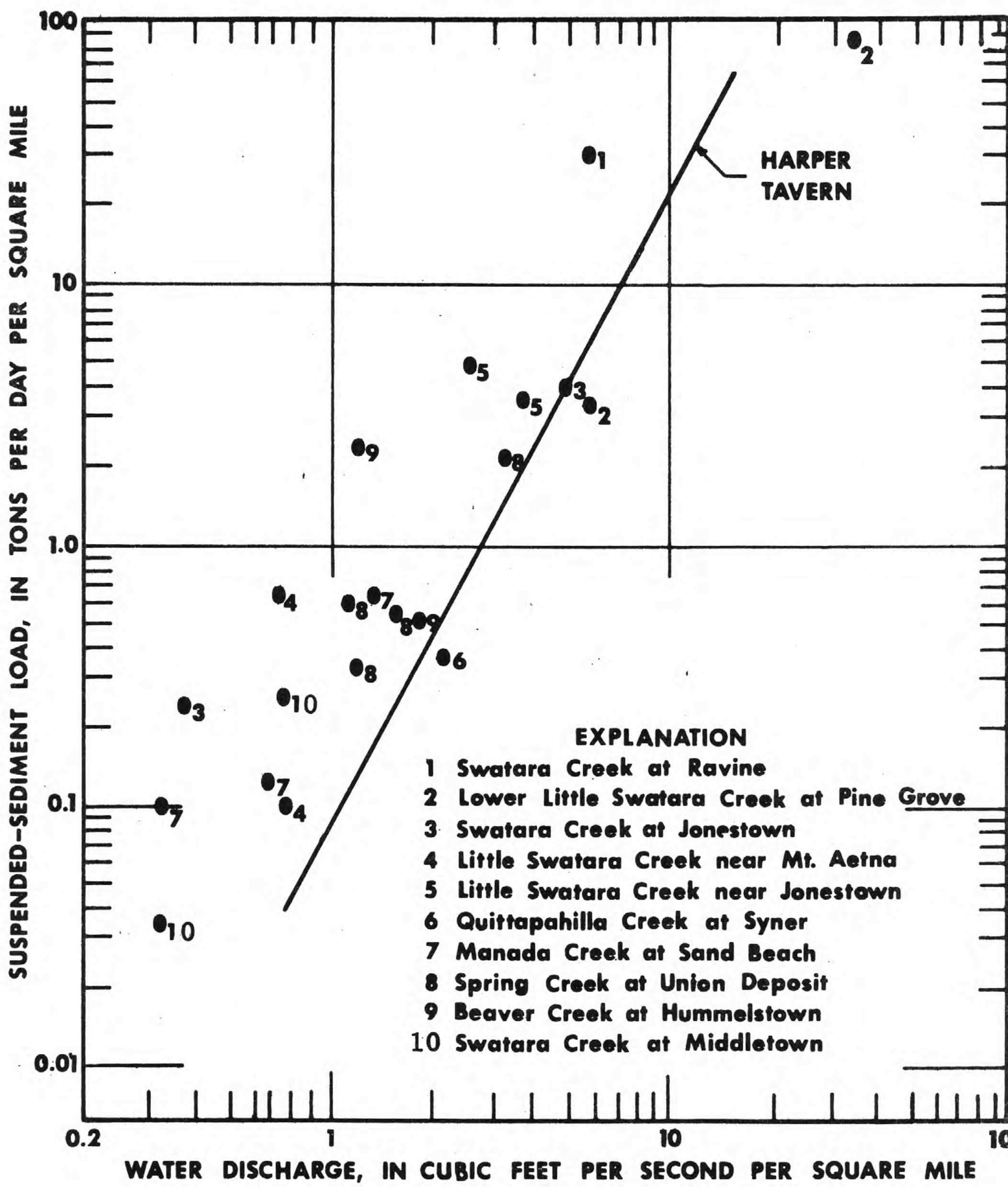


Figure 18 Relationship of suspended-sediment discharge to water discharge for streams in Swatara Creek basin, Pa.

## Quittapahilla Creek

Approximately 4.5 miles downstream from Harper Tavern, at Brindnagles, Quittapahilla Creek flows into Swatara Creek. The upper part of this sub-basin is underlain by limestone and dolomite; the lower part by Martinsburg Shale.

The name Quittapahilla is a corruption of the older Cuwepehelle, Quitpehelle, or Cuwitpehelle--Indian names that mean "a spring that flows among the pines".

During this country's early history, inland waterways were developed in order to transport raw materials and manufactured products to and from the interior and the Atlantic seaboard. Quittapahilla Creek was a link in the system of inland waterways of Pennsylvania. The stream is 17.5 miles long and drains an area of 78 square miles in central and southern Lebanon County. The stream flows westerly from its source, approximately one mile northeast of Lebanon, and follows a course through the city to Annville, where it flows northwesterly to Syner. Syner is 1.5 miles from the confluence of Quittapahil Creek with Swatara Creek at Brindnagles.

The creek flows through a cultivated valley and some woodlands. In the upper reaches it flows through a canal of a steel company in Lebanon. Here, water is diverted for cooling and later returned to the canal.

Between Lebanon and Annville in North Cornwall Township near Cleona, Quittapahilla Creek receives as much as 3,500,000 gallons of treated sewage effluent each day from the Lebanon Treatment Plant. Before discharge to the creek, approximately 65 percent of the suspended organic solids are removed.

For a large part of its length Quittapahilla Creek flows nearly parallel to deposits of high quality limestone (Leesport limestone). Several large quarrying operations are adjacent to the creek. Ground water that normally seeps into the quarries is continuously pumped to the surface to expedite limestone removal. Some of this water is used by mines for cooling purposes, sprinkling, and dust control. During the summer some of the water is diverted for pasture irrigation, and some is used to wash clays and other fine particles from stone and gravel. One company directs the flow of these washings, high in suspended material, to abandoned quarry pits. The sediment from the washing process accumulated in the pit while the water seeps through the ground. The practice minimizes pollution of nearby streams and returns portions of the pumped ground water to the water table. Excesses of pumped water flow directly into Killinger Creek, a tributary to the Quittapahilla.

Normally, ground water contains more dissolved gases than surface water because of higher pressures existing below the earth's surface. Perhaps the most significant dissolved gases in ground water of limestone areas are oxygen and carbon dioxide. Carbon dioxide increases water's solvent power for limestone, but much of this gas is lost from ground water when the water is pumped to the surface. Presumably, ground water that percolates through limestone and seeps into streams in the Swatara basin contains heavier concentrations of dissolved solids than that pumped and allowed to flow overland to the same streams. The pumped ground water reaches Swatara Creek via the Killinger and Quittapahilla Creeks.

Limestone is more readily dissolved by natural water than are most other rocks. This solubility is attributable to the composition of limestone and to carbon dioxide in the water. Carbon dioxide in water is absorbed from the atmosphere and from soils through which the water percolates. Water containing carbon dioxide becomes a stronger solvent than water without carbon dioxide by the formation of a weak acid ($H_2CO_3$). It reacts with limestone ($CaCO_3$) as follows:

$$CaCO_3 + H_2CO_3 \longrightarrow Ca^{+2} + 2HCO_3^{-1}$$

Limestone + carbonic acid ⟶ calcium ions + bicarbonate ions

Pumpage of ground water from limestone quarries in the basin apparently does not significantly affect the chemical character of receiving streams. Ground water pumped from some quarries and discharged into receiving streams could originate in aquifers that normally do not contribute water to Swatara Creek. If this is true, then the stream is receiving alkaline water that otherwise would not be discharged into it. However, if the pumped ground water would have reached Swatara Creek eventually by natural means, the fact that it is pumped first to the surface might change its quality somewhat. The change may occur when some of the gases in ground water are released when brought to the surface, or when ions in solution are exchanged for ions on the soils as the water flows over the land surface or through the soil. Quality differences in the ground water resulting from the pumpage are likely inconsequential, because the gases that do escape are normally in minor concentrations, and the length of time that this water is exposed to soils as it flows into Swatara Creek and its tributaries is short.

During the period, October 12-21, 1959, 48 ground-water samples were obtained from wells in Lebanon County (Meisler, H., written communication, 1960). Chemical analyses of these samples indicated that the water was mostly a calcium bicarbonate type. Average, maximum, minimum, and median values for dissolved solids and chemical constituents in these ground-water samples are shown in table 16.

Table 16.--Average, maximum, minimum, and median values, chemical analyses of water from 48 wells, Lebanon County, Pa., October 12-21, 1959

| | Dissolved solids | Silica $SiO_2$ | Iron (Fe) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Nitrate ($NO_3$) | Hardness as $CaCO_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average | 344 | 11 | 0.01 | 78 | 21 | 11 | 5.2 | 260 | 36 | 15 | 39 | 285 |
| Maximum | 768 | 25 | .05 | 135 | 55 | 84 | 42 | 462 | 70 | 82 | 182 1/ | 564 |
| Minimum | 126 | 4.2 | .00 | 18 | 4.5 | 1.7 | .8 | 50 | 5.9 | 1.8 | .2 | 64 |
| Median | 333 | 10 | .00 | 77 | 18 | 5.7 | 2.6 | 260 | 36 | 8.0 | 23 | 278 |

1/ In areas in which the nitrate content of water is known to be in excess of 45 ppm, the public should be warned of the potential dangers of using the water for infant feeding. (U.S.P.H.S. 1962)

In figure 19 a comparison is made between typical ground-water

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Figure 19.--(Caption on next page) belongs near here.

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quality in that part of the basin underlain by carbonaceous rock and the water quality of Quittapahilla Creek at Syner. In contrast with ground water in the Martinsburg Shale, there were only small differences between the dissolved-solids content of ground water and surface water in the Quittapahilla Creek basin. In general, the $Ca^{+2}$ and $HCO_3^{-1}$ content is higher in the ground water than in the more dilute surface water passing Syner during high base flow.

Quittapahilla Creek is predominantly a calcium bicarbonate water, relatively higher in dissolved solids than other tributaries in the basin, excepting acid streams. Table 7 shows the chemical quality of the creek for samples collected at Lebanon and Syner. These analyses indicate that Quittapahilla Creek contributes water having the greatest titratable alkalinity observed in this study. The bicarbonate-sulfate ratio was about 3 to 1; calcium carbonate hardness of water averaged about 245 ppm. Apparently there is little variation in the hardness from high to low base flow. For example, samples collected during high base flow on April 22, 1959, when water discharge was 85 cfs had a hardness of 241 ppm. On October 7, 1959 when streamflow was 45.9 cfs, the hardness was 252 ppm.

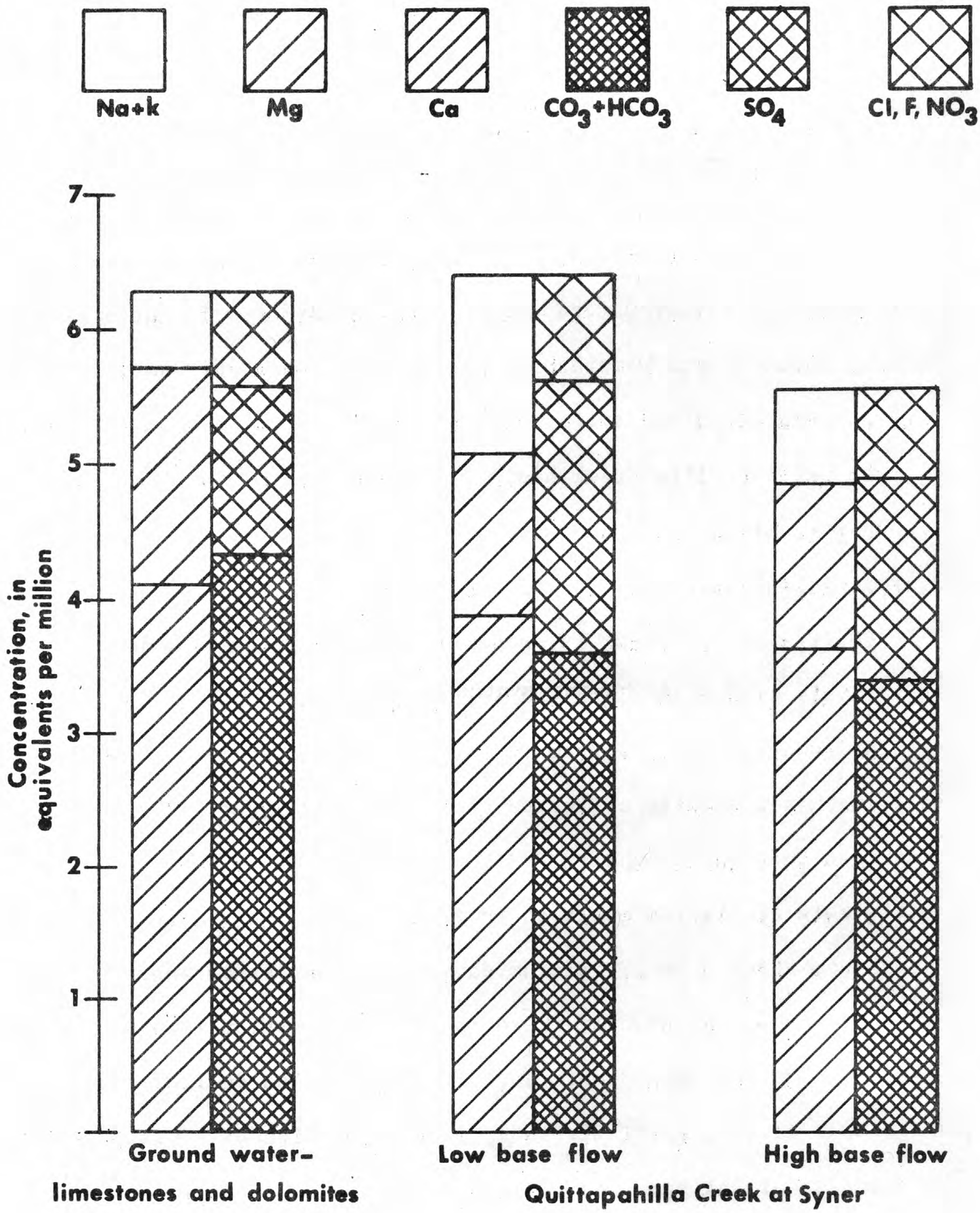


Figure 19 Comparison of surface and ground water quality in the Quittapahilla Creek basin, Pa., 1959

The specific conductance of Quittapahilla Creek usually exceeds 500 micromhos. Figure 20 shows a continuous record of specific

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Figure 20.--(Caption on next page) belongs near here.

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conductance of Quittapahilla Creek at Syner for a 25-hour period in August 1959. During a period of approximately 2 hours the conductance decreased from 570 micromhos to 505 micromhos. This decrease illustrates the dilution effect of a local rainstorm on the quality of surface water.

Snowy mounds of suds 3 feet in height are a common sight on Quittapahilla Creek at Annville, below a dam. On windy days the foam can be blown across country. The foaming of streams is becoming a rather common sight around urban areas. It is usually an indication that the stream is having synthetic detergents discharged into it.

Even the most modern sewage treatment plant does not completely remove detergents from its effluents (Sewage and Industrial Wastes, 1959), and these detergents inhibit the growth of bacteria required for sewage digestion. The Lebanon plant removes an estimated 30 percent, while the remainder is discharged into Quittapahilla Creek. In the Lebanon Sewage Treatment Plant foaming in the settling basins is reduced by recycling the suspended solids.

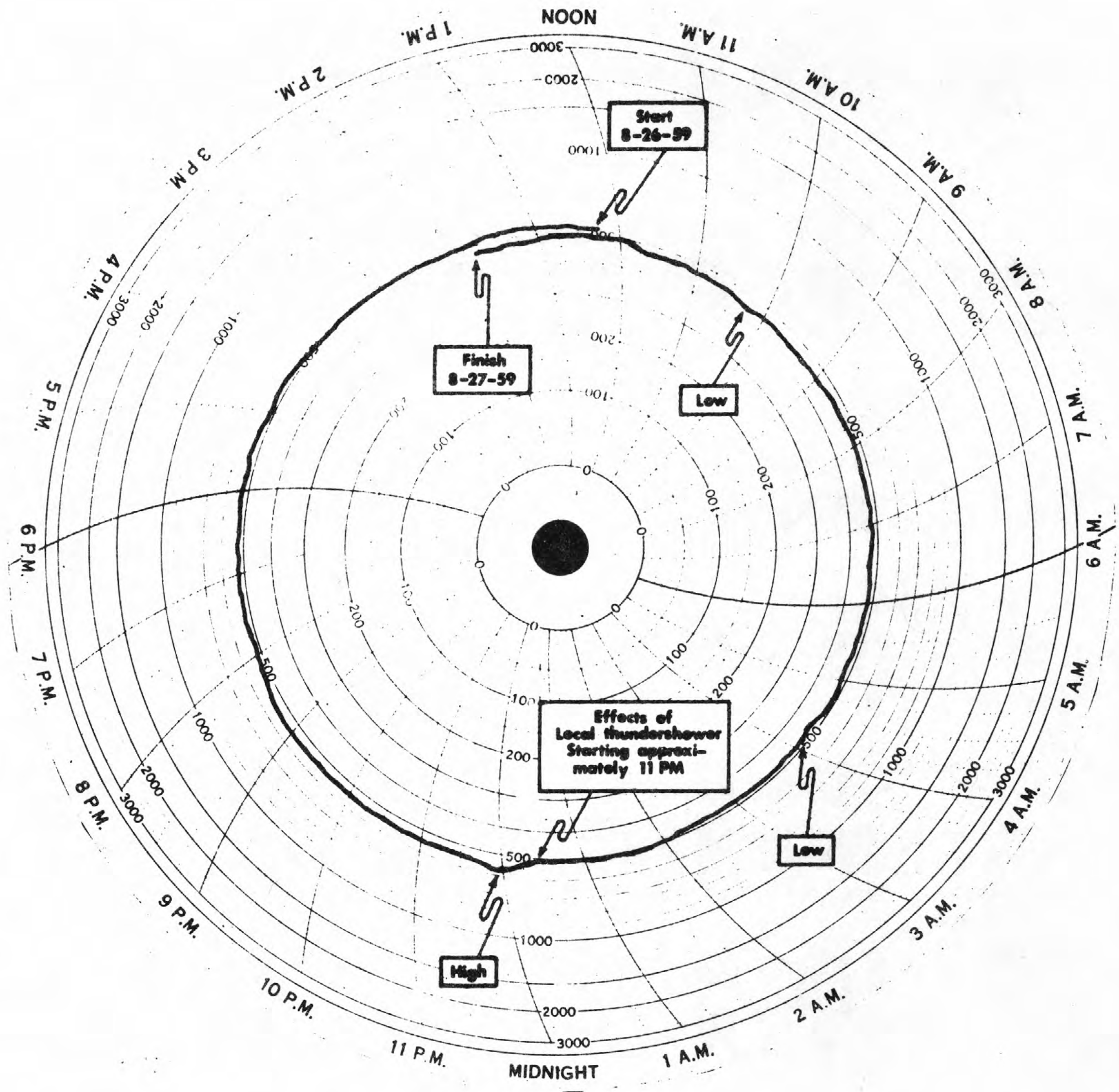


Figure 20 Continuous instrument record showing specific conductance variations, Quittapahilla Creek at Syner, Pa. August 26-27, 1959

Manada Creek

Manada Creek enters the Swatara in Dauphin County approximately 5 miles downstream from Quittapahilla Creek. The drainage area is 32 square miles and underlain primarily by Martinsburg Shale. The headwaters of Manada Creek drain sandstones and conglomerates of Silurian and Devonian age. Manada Creek at Sand Beach was found to be a calcium bicarbonate water, lower in dissolved solids content than Swatara Creek at confluence of the streams. Hardness of this water was less than 50 ppm on the average, and the pH ranged from 6.8 to 7.8 (table 7).

The analysis of water from well #9 (table 2) located in Manada Creek basin indicates a calcium bicarbonate type of water. This sample has a dissolved-solids content of 194 ppm and a hardness of 158 ppm. The bicarbonate sulfate ratio of the water is approximately 3 to 1 and the pH is 7.6. The chemical quality of surface water and ground water in this area is somewhat similar, except for the higher dissolved solids content of the ground water.

## Spring Creek

Spring Creek, a small tributary to Swatara Creek, flows through the lower part of the limestone region in the basin and drains an area of 23 square miles. It flows through Hershey and reaches Swatara Creek at Union Deposit. At times during periods of low flow the stream seems to disappear into the limestone crevices that underlie portions of the stream bed.

As many as 100 sink holes appeared in the valley of Spring Creek during 1949 when the ground water level in the area was lowered by limestone mining operations, which pumped ground water from deep mining levels (Foose, 1950). The water in the creek is a calcium bicarbonate type and the ratio of parts per million of bicarbonate to parts per million of sulfate is more than 5 to 1. Hardness of water averages approximately 180 ppm (table 7). Although both Spring Creek and Quittapahilla Creek drain parts of the same limestone region, the dissolved-solids content is generally less than that of Quittapahilla Creek.

## Beaver Creek and Iron Mine Run

Beaver Creek and Iron Mine Run, near the mouth of Swatara Creek, drain smaller areas than most of the streams studied. Beaver Creek drains an area of 27 square miles in Dauphin County. For more than half its length in the upper segments the stream drains an area underlain by Martinsburg Shale. The lower basin is underlain by limestone and dolomite. At Hummelstown the creek receives some waste discharges from industry and a sewage treatment plant. Beaver Creek is another stream that has a calcium bicarbonate type of water, but its dissolved-solids content and calcium and magnesium contents exceed those of Manada Creek. The average dissolved-solids content of Beaver Creek was approximately 155 ppm, from April 1958 to October 1959; calcium carbonate hardness was approximately 100 ppm; and the pH ranged from 6.8 to 8.5 (table 7).

Iron Mine Run near Middletown drains only 7 square miles of Dauphin County. The stream is underlain by Gettysburg Shale and Triassic diabase. Hardness of water for samples collected during high and low-flow periods of the stream were 59 and 73 ppm, respectively; pH was 7.1 and 7.9 (table 7). Iron Mine Run has a calcium bicarbonate type of water. On March 27, 1959, the dissolved-solids content of ground water in the drainage area was 241 ppm; hardness, 182 ppm; and pH, 7.4 (table 2, well #10).

## Swatara Creek at Middletown

At the mouth of Swatara Creek, in Middletown, the chemical quality of the stream before it flows into the Susquehanna River, is a product of precipitation and runoff, geology and ground water, and the use of land and water within the drainage basin. Here, the concentrations of most solutes are at their highest level during the summer months and periods of low flow.

Many combinations of factors determine the chemical quality of Swatara Creek at a given time. For example, there are as many as 48 creeks and runs in the basin, and when rainfall is distributed unequally throughout the basin, the tributaries carrying the storm runoff influence the quality of the main stream more than they ordinarily do. Discharge from areas where ground-water levels are higher than usual likewise affects the chemical quality of the main stream disproportionately. This factor can be more effective during periods of low streamflow than of high streamflow because the ratio of ground water to runoff is greater.

At Middletown, the water of Swatara Creek is a calcium bicarbonate type and the ratio of parts per million of calcium to parts per million of magnesium averages about 5 to 1 (table 7). For natural water, the ratio ranges generally from 1 to 1 to 5 to 1, depending largely on the natural availability and solubility of calcium and magnesium and the relative concentrations of each constituent. The ratio of calcium to magnesium concentration in Swatara Creek indicates the influence of ground water entering the creek from formations in which the soluble calcium-bearing minerals probably predominate. Calcium may be derived from solution of complex silicates, but in the Swatara Creek Basin most of it probably is dissolved from the sedimentary minerals, calcium carbonate and calcium sulfate.

Calcium and magnesium carbonates are common in the Swatara Creek Basin. At Middletown, Swatara Creek water is a calcium bicarbonate type and the hardness usually exceeds 100 ppm. In solution, bicarbonates may decompose with the loss of carbon dioxide. When water containing bicarbonate is heated sufficiently to drive off carbon dioxide, carbonate precipitates. An example of this chemical change can be seen in teakettles where the insoluble carbonate forms on the inner sides and bottoms of the kettles. Although not usually seen, such carbonate deposits occur in hot water pipes and boilers where, with the silicates and other minerals, they form scales of complex composition.

Hardness of water and the concentration of most constituents in Swatara Creek vary inversely with streamflow. At the same time specific conductance is roughly proportional to the quantities of ionic constituents present, (fig. 21).

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Figure 21.--(Caption on next page) belongs near here.

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Daily extremes and seasonal trends are shown in the continuous record of specific conductance of Swatara Creek at Middletown for the period July 30 through December 10, 1959 (fig. 22 and table 17). The maximum specific conductance during this period was 391 micromhos on August 16,

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Figure 22.--(Caption on next page) belongs near here.

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and the minimum was 109 micromhos on September 3 and 4., after days of intermittent rains that increased runoff. The greatest differential was 176 micromhos, which occurred on October 2. This spread also reflected the effects of increased runoff after a rainstorm that was general throughout the basin on October 2. The record also indicates a trend of decreasing specific conductance during the late autumn and winter months. The influence of steady rain and of heavy rainstorms occurring locally on electrical conductivity of Swatara Creek at Middletown is shown on electrical conductivity charts (fig. 23 and fig. 24).

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Figure 23,--(Caption on next page) belongs near here.

Figure 24,--(Caption on next page) belongs near here.

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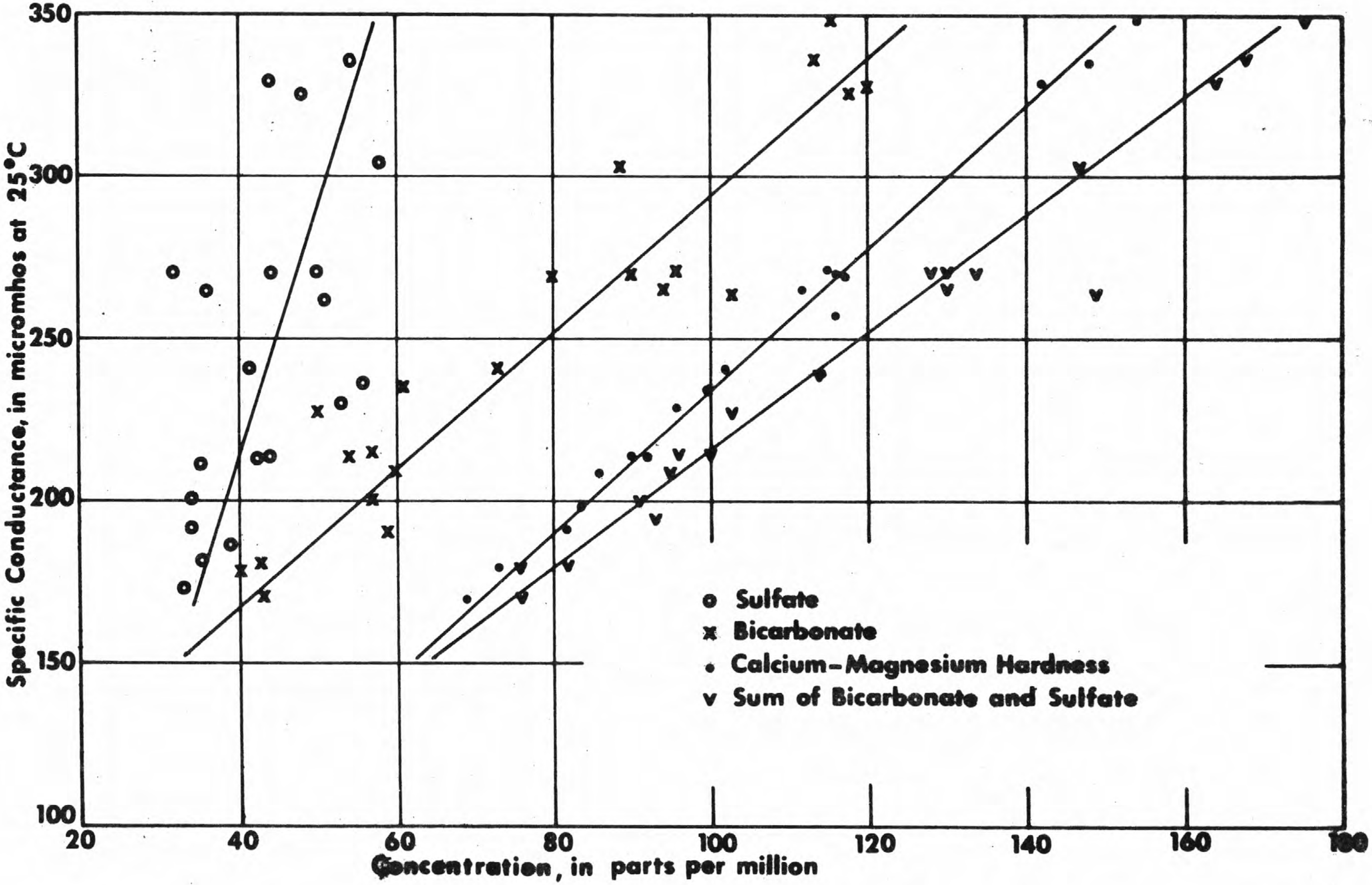


Figure 21 Relationship of calcium and magnesuim hardness and concentration of principal ions to specific conductance, in Swatara Creek at Middletown, Pa., April 1958 to November 1959.

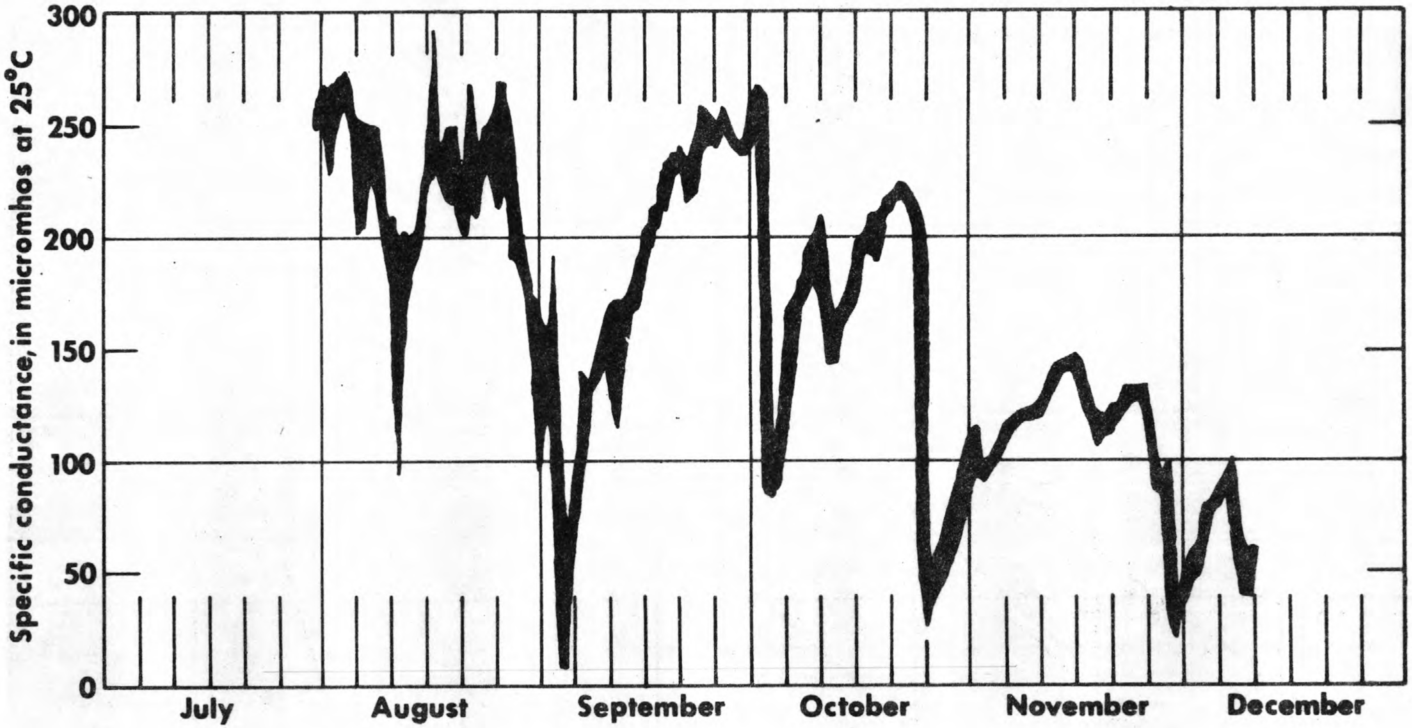


Figure 22  Daily maximum and minimum specific conductance of Swatara Creek at Middletown, Pa., July 30 to December 10, 1959.

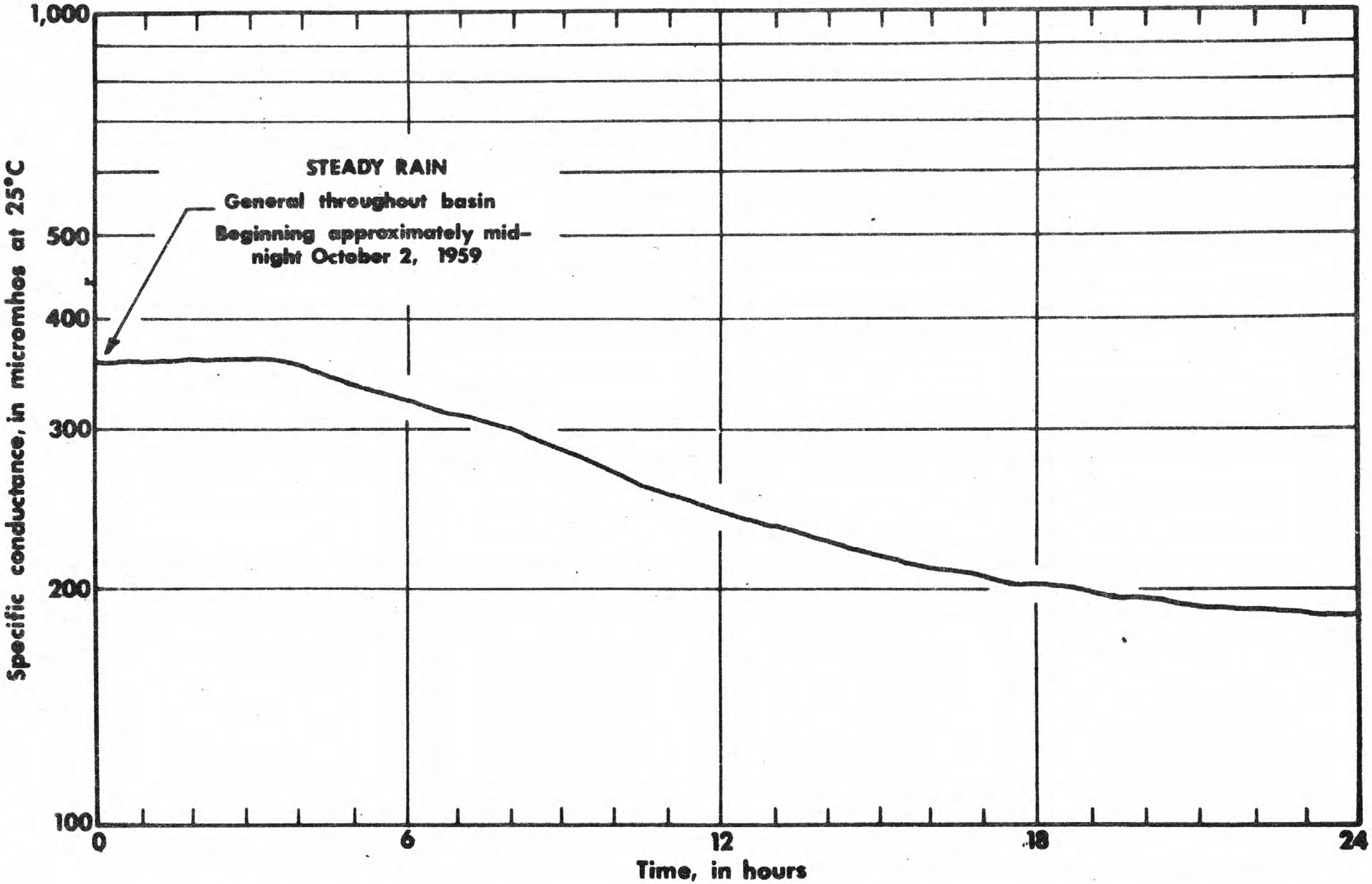


Figure 23 Continuous instrument record showing specific conductance variations after steady rain, Swatara Creek at Middletown, Pa.

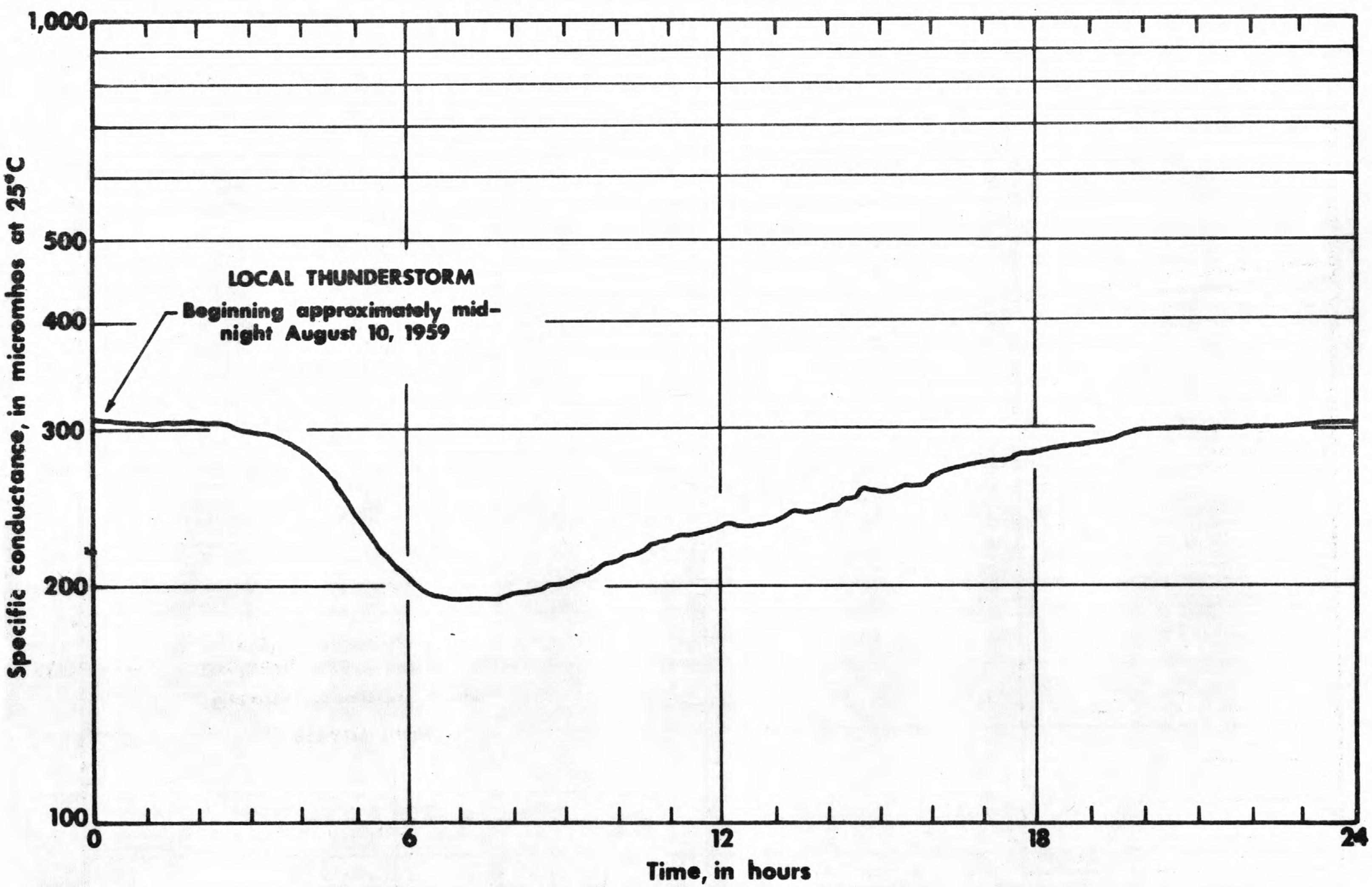


Figure 24 Continuous instrument record showing specific conductance variations after local thunderstorm, Swatara Creek at Middletown, Pa.

Table 17.--Specific conductance, Swatara Creek at Middletown, Pa.,

July 30 - December 10, 19[illegible]

(Micromhos at 25°C)

| Day | July Max. | July Min. | August Max. | August Min. | September Max. | September Min. | October Max. | October Min. | November Max. | November Min. | December Max. | December Min. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | 365 | 323 | 250 | 227 | 367 | 350 | 216 | 212 | 159 | 145 |
| 2 | | | 370 | 348 | 290 | 212 | 361 | 185 | 195 | 195 | 161 | 150 |
| 3 | | | 373 | 363 | 212 | 109 | 190 | 185 | 202 | 196 | 180 | 161 |
| 4 | | | 367 | 351 | 168 | 109 | 220 | 190 | 210 | 200 | 183 | 180 |
| 5 | | | 351 | 303 | 195 | 168 | 248 | 220 | 216 | 210 | 190 | 183 |
| 6 | | | 350 | 305 | 240 | 195 | 271 | 248 | 218 | 216 | 195 | 190 |
| 7 | | | 350 | 331 | 233 | 217 | 280 | 271 | 222 | 218 | 201 | 167 |
| 8 | | | 350 | 292 | 244 | 233 | 295 | 276 | 223 | 220 | 167 | 140 |
| 9 | | | 310 | 263 | 259 | 244 | 300 | 284 | 223 | 220 | 160 | 140 |
| 10 | | | 308 | 194 | 270 | 244 | 309 | 274 | 223 | 220 | 163 | 160 |
| 11 | | | 299 | 263 | 272 | 215 | 274 | 244 | 235 | 223 | | |
| 12 | | | 301 | 282 | 270 | 247 | 262 | 244 | 242 | 235 | | |
| 13 | | | 294 | 232 | 275 | 257 | 270 | 262 | 243 | 240 | | |
| 14 | | | 325 | 294 | 287 | 268 | 277 | 265 | 246 | 243 | | |
| 15 | | | 340 | 325 | 300 | 287 | 297 | 277 | 247 | 241 | | |
| 16 | | | 391 | 335 | 312 | 299 | 299 | 294 | 243 | 226 | | |
| 17 | | | 338 | 323 | 318 | 306 | 310 | 293 | 226 | 220 | | |
| 18 | | | 343 | 317 | 332 | 312 | 310 | 290 | 221 | 207 | | |
| 19 | | | 350 | 317 | 337 | 330 | 316 | 310 | 220 | 212 | | |
| 20 | | | 319 | 300 | 339 | 330 | 319 | 312 | 225 | 214 | | |
| 21 | | | 368 | 319 | 332 | 315 | 324 | 320 | 225 | 220 | | |
| 22 | | | 338 | 310 | 341 | 320 | 323 | 317 | 233 | 224 | | |
| 23 | | | 348 | 330 | 353 | 341 | 317 | 306 | 233 | 223 | | |
| 24 | | | 351 | 331 | 354 | 343 | 306 | 155 | 233 | 229 | | |
| 25 | | | 369 | 317 | 349 | 340 | 155 | 126 | 234 | 215 | | |
| 26 | | | 359 | 330 | 358 | 349 | 155 | 140 | 215 | 187 | | |
| 27 | | | 337 | 272 | 349 | 342 | 167 | 155 | 192 | 167 | | |
| 28 | | | [illegible] | [illegible] | 343 | 337 | 176 | 167 | 200 | 192 | | |
| 29 | | | 289 | 274 | 340 | 336 | 187 | 176 | 133 | 123 | | |
| 30 | 356 | 349 | 275 | 234 | 360 | 340 | 197 | 187 | 148 | 133 | | |
| 31 | 357 | 356 | 273 | 197 | | | 212 | 197 | | | | |

# SUMMARY

Weathering processes and man's activities affect the chemical quality of surface water. In the Swatara Creek basin, rainwater and ground water dissolve minerals from the rocks and soils. This weathering process is influenced by farming or mining and the development of towns and industries. When communities and industries discharge their waste into Swatara Creek, further changes in the chemical quality of the Creek occur.

For many years the acidic effluents from coal mines in Pennsylvania have affected the quality of receiving streams. This study of water quality in the Swatara Creek basin shows that natural processes tend to dilute and to neutralize acid mine drainage in streams and to retard their effects on downstream segments.

In Swatara Creek basin, mining wastes are derived mostly from underground pools where acidic water is impounded in the excavations of now unworked mines. After World War II the gradual curtailment of mining activities throughout the anthracite fields of eastern Pennsylvania minimized the loads of acidic wastes released to surface streams. The rate of release of this highly mineralized acidic water from mines may vary when water levels of pools are raised by infiltrated water or seepage from other underground sources, but generally releases at the mine overflow are uniform throughout the year. Therefore, it was possible to observe the hydrologic processes of dilution, changes in chemical composition of mine overflow water, and the neutralization of the acidic segments of Swatara Creek by natural means.

Of the 11 pools in unworked mines within the Swatara Creek basin, 6 overflow into the headwater's streams. Within the mines, chemical reaction produces sulfuric acid as the sulfuritic materials are dissolved in water. In the mines it is highly probable that sulfuric acid is formed in the following way:

$$2FeS_2 + 2H_2O + 7\ O_2 \rightarrow 2FeSO_4 + 2H_2SO_4$$

This acidic water overflows or seeps from the inactive mines to surface streams flowing into Swatara Creek. At times, fine coal is washed in from breakers. Mine drainage and breaker wash more noticeably affect the quality of the Upper Swatara downstream as far as Harper Tavern, where the principal constituent of the water is the sulfate ion.

Near Pine Grove, water from the Upper and Lower Little Swatara Creeks merges with the Swatara and begins to dilute and to neutralize the acid-bearing water draining the anthracite region. The water from these streams is a calcium bicarbonate type, low in dissolved solids. Below the confluence of the Upper and Lower Little Swatara Creeks with Swatara Creek, the Little Swatara Creek enters at Jonestown. The Little Swatara is the largest tributary to Swatara Creek and contributes a calcium bicarbonate water that dilutes the effluents from coal mining wastes. The three streams provide sources of good water for public supply and industrial requirements in the upper basin. Their impoundment during periods of high flow and controlled release during times of water scarcity would help to maintain flow in the Swatara and probably would improve its quality downstream.

Quittapahilla Creek, which enters the Swatara downstream at Brindnagles, and Spring Creek, which flows in at Union Deposit, drain a limestone region. The water in these streams is a calcium bicarbonate type. Hardness of water in the Quittapahilla at Syner was about 245 ppm of miscellaneous samples obtained during the period of April 1958 to October 1959. The dissolved solids averaged about 340 ppm. Specific conductance for average conditions of flow generally exceeded 500 micromhos. The pH ranged from 7.3 to 7.9. Alkaline water from the Quittapahilla neutralizes part of the acidity of Swatara Creek, when it is acidic, but increases also the dissolved solids downstream at Valley Glen.

The effects of acid wastes on the Swatara become less severe as water moves downstream. If mining should be resumed in the basin however, acidic effluents from mines might extend farther downstream beyond Jonestown, but the alkaline water of the Quittapahilla would help to check the effects of acid wastes by neutralization.

Farther downstream several other small tributaries drain geologic regions of Martinsburg Shale and Beekmantown Limestone. Analyses of ground-water samples from aquifers in the Quittapahilla basin show dissolved solids and calcium carbonate hardness to be generally more concentrated than in surface streams. From these aquifers water seeps to the stream and contributes additional solutes.

The pH of Swatara Creek in general increases progressively downstream from Pine Grove to its mouth at Middletown, regardless of the quantities of water being discharged.

In April 1958, at a time when flow in Swatara Creek was relatively high, the bicarbonate concentration increased from zero concentration at Pine Grove to 60 ppm at Middletown. During a relatively low-flow period in July of the same year the concentration of bicarbonate between these locations increased from zero concentration to 90 ppm. However, for the same periods, the sulfate concentration decreased. The decrease is sharp from Pine Grove to Jonestown but gradual from Jonestown to Middletown. The specific conductance during the period of low flow decreased between these locations from 315 micromhos to 160 micromhos. During the high-flow period specific conductance was 200 micromhos at Pine Grove and approximately 100 micromhos at Middletown.

Although Swatara Creek at Harper Tavern is a calcium sulfate water resembling water from the mines, and fine coal deposits are visible on the banks and in the stream bed, only a moderate amount of treatment is required to make it acceptable for general purposes and for use by industries requiring selective water. At Harper Tavern, from October 1, 1958, to September 30, 1959, the maximum dissolved solids of composited daily samples was 165 ppm. Hardness did not exceed 95 ppm, and specific conductance did not exceed 253 micromhos. The specific conductance exceeded 230 micromhos about 5 percent of the time. Water temperatures were less than 55°F half the time, and the pH ranged from 6.0 to 7.4.

Chemical quality of the stream at Middletown was also compared for two different periods of flow in 1959; in the high-flow period the rate of discharge was twice that in the low-flow period. The concentrations of individual solutes were greater during low flow than during the higher flow, with several exceptions--the nitrate concentration more than doubled during high flow, and iron and manganese in solution increased from zero concentration at low flow to 0.14 ppm and 0.04 ppm, respectively, during the high flow. Probably some nitrate fertilizers were washed from the soil. At low flow the dissolved-solids content was approximately 32 percent greater than at high flow.

The principal cation in Swatara Creek at Middletown was calcium. during a high and low flow period (April 23 and October 7, 1959, respectively) the concentration of calcium, in equivalents per million, represented 32 and 30 percent, respectively, of the dissolved solids analyzed. The ratio of calcium to magnesium in equivalents per million is about 2.5 to 1. Hardness of water was 1.4 times greater than average during the low-flow period.

Most of the dissolved minerals in Swatara Creek at Middletown are of natural origin. The principal anion is the bicarbonate ion. During the high and low flow study, bicarbonate represented approximately 25 percent of the determined dissolved solids. Together, the bicarbonate and sulfate anions constituted more than 43 percent of the equivalents per million of anions determined. The ratio of bicarbonate to sulfate was approximately 1.3 to 1. The sulfate in Swatara Creek was caused mostly by headwaters' tributaries carrying acidic water from the unworked coal mines.

Although at Middletown the concentrations of most solutes are at their maximum during the summer months and periods of low flow, the Swatara is not acidic at its confluence with the Susquehanna River.

The quantities of suspended sediment in streams of the Swatara Creek basin are influenced by the pattern of runoff and by land use. A high percentage of the total sediment carried by streams is transported during a few storms each year. Mean daily sediment concentrations at Harper Tavern generally range from 2 to 500 ppm. The higher concentrations occur during storms and lower concentrations occur during periods of sustained low flow. Estimates of the duration of sediment concentrations indicate that the concentration of sediment equals or exceeds 230 ppm about 10 percent of the time.

Suspended material in streams in the basin is composed of both natural sediments and wastes from the coal industry. Analyses of water samples collected at Harper Tavern show that during high flows a significant amount of the coarse material (0.062-.25 mm) was coal. Particle size analyses indicate that the suspended material during high flows is about 36 percent clay size, 50 percent silt size, and 14 percent sand size.

The average daily sediment discharge of Swatara Creek at Harper Tavern during the period May 8 to September 30, 1959, was 109 tons per day. The computed annual suspended-sediment discharge was 450 tons per square mile. This value probably is higher than the true average annual discharge.

Hydrologic data point to a significantly decreasing trend in the sediment discharge of Swatara Creek. The enforcement of regulations pertaining to the discharge of coal-mining waste into streams in the basin reduced the average turbidity of the Swatara at Jonestown from about 3,000 to 6 turbidity units during the period 1946-60.

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