

Results of a Preimpoundment Water-Quality Study of Swatara Creek, Pennsylvania

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 85-4023



**Prepared in cooperation with the
PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL RESOURCES,
BUREAU OF STATE PARKS**



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By David K. Fishel and John E. Richardson

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PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL RESOURCES,
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Harrisburg, Pennsylvania

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

<u>Multiply inch-pound unit</u>	<u>By</u>	<u>To obtain SI unit</u>
<u>Length</u>		
inch (in.)	2.540	centimeter (cm)
	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
<u>Area</u>		
square mile (mi ²)	2.590	square kilometer (km ²)
<u>Flow</u>		
cubic foot per second (ft ³ /s)	0.02832	cubic meter per second (m ³ /s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m ³ /s)
<u>Volume</u>		
gallon (gal)	3.785	liter (L)
	3,785	milliliter (mL)
acre-foot (acre-ft)	1,233	cubic meter (m ³)
<u>Mass</u>		
pound per day (lb/d)	0.4545	kilograms per day (Kg/d)
ton per day, short	0.9072	megagram per day (Mg/d)
ton per square mile per year [(ton/mi ²)/yr]	0.3503	metric ton per square kilo- meter per year [(t/km ²)/annum]
<u>Specific conductance</u>		
micromhos per centimeter at 25° Celsius (μmho/cm at 25°C)	1.000	microsiemens per centimeter at 25° Celsius (μS/cm at 25°C)
<u>Temperature</u>		
degree Fahrenheit (°F)	C=5/9 (°F-32)	degree Celsius (°C)
<u>Density</u>		
pounds per cubic feet (lb/ft ³)	16.05	kilograms per cubic meter (Kg/m ³)

RESULTS OF A PREIMPOUNDMENT WATER-QUALITY STUDY
OF SWATARA CREEK, PENNSYLVANIA

By David K. Fishel and John E. Richardson

ABSTRACT

The water quality of Swatara Creek prior to impoundment by the proposed Swatara Creek Reservoir in south-central Pennsylvania was studied from July 1981 through October 1982. This report, done in cooperation with the Pennsylvania Department of Environmental Resources (PaDER), Bureau of State Parks, presents information on existing water-quality conditions. A discussion of possible water-quality conditions in and downstream from the planned impoundment is also included.

Precipitation measured near the study area at Lebanon, Pennsylvania from October 1981 through September 1982 was 8 percent below normal. Streamflow for the same period at Swatara Creek at Harper Tavern just downstream from the study area was 15 percent below the average annual flow. Swatara Creek above Highway 895 has been degraded by acid mine drainage. The main inflow to the planned impoundment has 2.1 times the discharge of Lower Little Swatara Creek--a forested and agricultural basin that is also tributary to the proposed impoundment. During the 1982 water year, 17,400 tons of suspended sediment were transported from the study area. About 46 percent of the annual load was transported during 3 days of high flow. Inflows to the planned impoundment from both Lower Little Swatara Creek and Swatara Creek above Highway 895 were poorly buffered. Measured concentrations of alkalinity and acidity were usually less than 10 mg/L (milligrams per liter) and 5 mg/L as CaCO₃, respectively. The inflows contain high concentrations of nutrients and metals that would probably stratify in a reservoir. Maximum concentrations of dissolved nitrate and total phosphorus were 2.6 mg/L and 0.31 mg/L, respectively, at Lower Little Swatara Creek; these concentrations are well above those needed for growth of algae. Maximum observed concentrations for total recoverable iron, aluminum, and manganese at Swatara Creek above Highway 895 at Pine Grove were 100,000 µg/L (micrograms per liter), 66,000 µg/L and 2,300 µg/L, respectively.

Large increases in metal concentrations along with simultaneous decreases in pH and increases in acidity confirm that mine drainage continues to degrade the water quality of Swatara Creek and may have a large impact on water quality of the planned impoundment. Iron, lead, copper, and zinc concentrations periodically exceeded the U.S. Environmental Protection Agency (U.S. EPA) criteria for freshwater aquatic life. Concentrations of manganese and lead also exceeded the U.S. EPA criteria for domestic water supplies and human health, respectively.

The water quality of the Swatara Creek Reservoir will depend on characteristics such as (1) the detention time of water in the lake, (2) the timing and extent of thermal and chemical stratification, (3) sedimentation,

and (4) the chemical loading and concentrations in the lake. Each of these characteristics may depend in part, on streamflow.

The impoundment will act as a sediment trap and thus reduce the concentrations of total phosphorus, iron, aluminum, lead, copper, and zinc immediately downstream from the impoundment. Large storm discharges and releases from the hypolimnion of the reservoir to attain the winter-pool level may contain low oxygen concentrations and elevated concentrations of iron, aluminum, lead, copper, and zinc. Unless conservation releases from the multi-level release gates are carefully controlled, low dissolved-oxygen levels and high metal concentrations may degrade the downstream water quality and be detrimental to the aquatic community.

INTRODUCTION

The PaDER (Pennsylvania Department of Environmental Resources), Bureau of State Parks plans to build a multipurpose reservoir in Swatara State Park in southcentral Pennsylvania (fig. 1). The primary uses of the reservoir will be for recreation and as a supplemental water supply for Lebanon and downstream communities. The reservoir's potential use for hydropower generation is also being investigated by the PaDER.

The proposed impoundment is to be built downstream from areas extensively mined for anthracite during the past two centuries. Large amounts of culm^{1/} and sediment have been and continue to be transported by Swatara Creek from abandoned and active mines, culm piles and breaker plants. Acid mine drainage from the Swatara Creek headwaters and high nutrient loads from downstream tributaries flow into the proposed impoundment area.

The U.S. Geological Survey, in cooperation with the PaDER, Bureau of State Parks, began collecting hydrologic data in June 1981 to characterize the water and sediment entering the planned Swatara Creek impoundment and to estimate the effect of the impoundment on water quality. Data from the study will be used to design and operate an impoundment that will provide optimum water quality in and downstream from it.

Purpose and Scope

This report describes the results of a study to (1) determine the concentrations of sediment, nutrients, and constituents common to acid mine drainage in the waters of Swatara Creek, and the average annual load of the same constituents transported to the planned impoundment area; (2) determine the concentration of nutrients and metals in the streambed material and soils in the impoundment area; and (3) to estimate the future water quality in and downstream from the impoundment.

1/ Refuse coal screenings

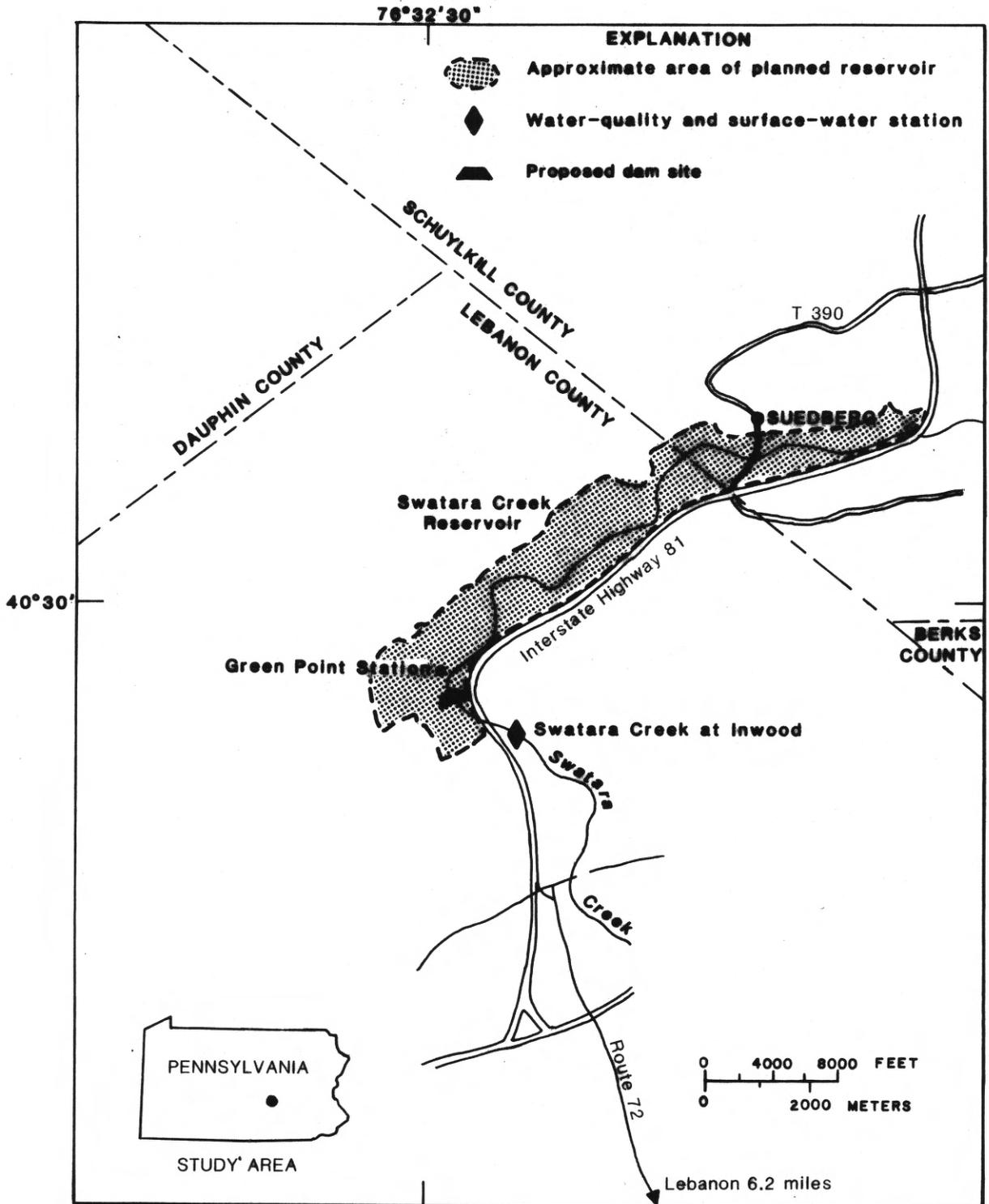


Figure 1.--Location of planned Swatara Creek Reservoir.

The report provides preliminary information on the concentrations of sediment, nutrients, dissolved ions, metals and bacteria transported by Swatara Creek to the planned impoundment area during July 1981 through October 1982. It includes discussions on the relation between chemical constituent concentrations and discharges, streamflow, and suspended sediment. Measured concentrations of nutrients and metals in streambed material also are included. Lastly, a preliminary estimation is made of the water quality of the planned reservoir, and the possible effects of streamflow, and effects of the reservoir on downstream water quality.

Proposed Swatara Creek Reservoir

Plans for Swatara Creek Reservoir began in July 1968 when \$2 million was authorized by the Pennsylvania General Assembly legislation (Act 220) for dam and reservoir construction, to be administered by the Pennsylvania Department of General Services (DGS Project No. 152-1). The initial plans included building a multipurpose recreation and water-supply impoundment. Recreational activities included were boating, swimming, and fishing. Water supply was designated for Lebanon and downstream communities. More recently, designs for the reservoir have added the potential for hydropower generation, however, no additional water storage or release would be allocated for power generation.

The recommended location of the dam shown in figure 1 is at latitude 40°28'59" and longitude 76°32'07", approximately 0.6 mi upstream from Interstate Highway 81. The site is near the village of Green Point Station in Lebanon County.

The dam will be a concrete gravity type with a 445-foot non-gated spillway (Terraqua Resources Corporation, 1982). The spillway crest, at an elevation of 473.0 feet above sea level, will impound 10,500 acre-ft of water and create a lake area of 775 acres. About 7,000 acre-ft of water in the reservoir, below elevation 468 ft, will be allocated for sediment deposition, recreation, fish, and wildlife. Another 3,500 acre-ft, from elevation 468 to 473 ft, will be designated for a 10 Mgal/d water supply for Lebanon, low flow releases to Swatara Creek, and evaporation. Water may be released from the surface, from two intermediate levels, or from the bottom of the lake to enhance downstream water quality. The approximate reservoir depth at the dam will be 40 ft, and the reservoir length will be about 6.8 mi.

A subimpoundment was recommended by the Pennsylvania Fish Commission to reduce the suspended-sediment load to the reservoir (Hoopes 1981). This structure, with total drawdown capability, could be located near township road 390 at Suedberg. The subimpoundment could retard bedload transport and reduce the amount of suspended metals and nutrients transported to and trapped in the reservoir.

Previous Studies

Several investigators have reported on the hydrology of Swatara Creek basin. These investigations include water-quality studies, basin-wide hydrologic investigations, mine drainage abatement studies, and fisheries surveys.

McCarren and others (1961 and 1964) studied the water quality of the basin. They reported that ground water had a dominant influence on the quality of surface water during low flows. Their field tests also showed all ground water in the basin was non-acidic. However, the surface water above Ravine was found to be acidic. Sources of the acid drainage were identified as overflows from unworked coal mines. Water quality was reported to improve downstream near Pine Grove as acidic water was diluted and neutralized by inflows from Upper and Lower Little Swatara Creeks. Their study determined that a high percentage of the sediment load carried by streams in the Swatara Creek basin is transported during a few storms each year.

Stuart and others (1967) evaluated the hydrologic system of the Swatara Creek basin. Eight hydrologic zones, based on runoff, natural use of the water, and chemical characteristics of the water were defined in their study. Boundaries of the zones were generally the same as those for geologic formations transecting the basin.

Berger Associates Inc. (1972) determined sources and amounts of mine drainage entering the Swatara Creek headwaters. Their study identified five abandoned deep-mine pool overflows as the primary source of acid mine drainage in a 14.9-mi² area. The combined average acid discharge for the five overflows was 5,909 lb/d. Coal mine refuse piles were the second largest source of acid, and strip mines were the third largest source.

Potter and others (1976) surveyed fishes of the Swatara Creek as part of a study to determine effects due to operation of Three Mile Island Nuclear Station on aquatic life in the Susquehanna River. The surveys found no fish above Swatara Creek at Ravine where pH values below 6.0 were measured. They concluded that the moderate to low diversity indices throughout the Swatara drainage basin was probably due to poor water quality, and that the headwaters were biologically degraded by iron compounds, mine drainage, and coal dust.

Location of Study Area and Sampling Sites

The 169-mi² watershed for the Swatara Creek Reservoir lies in Schuylkill and Lebanon Counties in southcentral Pennsylvania (fig. 2). The headwaters originate in Broad Mountain and flow southwesterly about 29 mi before reaching Inwood, just below the proposed dam.

Streamflow and suspended-sediment data collection began in July 1981, and chemical-quality data collection began in December 1981 at three sites. Two of the sites were selected upstream of the proposed dam to characterize discharges entering the impoundment area. The most upstream site is on the mainstem of Swatara Creek, 0.3 mi. upstream from Highway 895 at Pine Grove. The predominant land use in this 72.6-mi² drainage basin is coal mining. The second site is on Lower Little Swatara Creek at Highway 501, about 0.6 mi. upstream from the confluence with Swatara Creek. This basin area is 34.3 mi² and is mostly forest and agriculture. A third site is located at Inwood, 11 mi. below the confluence of Swatara and Lower Little Swatara Creeks about 0.8 mi. downstream from the proposed dam. Data collected from this site reflect the suspended sediment and chemical constituents transported by Swatara Creek downstream of the impoundment prior to reservoir construction.

Bottom-material samples were collected from the streambed at three additional sites (fig. 2) on Swatara Creek. These sites are within the proposed impoundment area, and data at these sites will be used to characterize the initial chemistry of the proposed impoundment bottom.

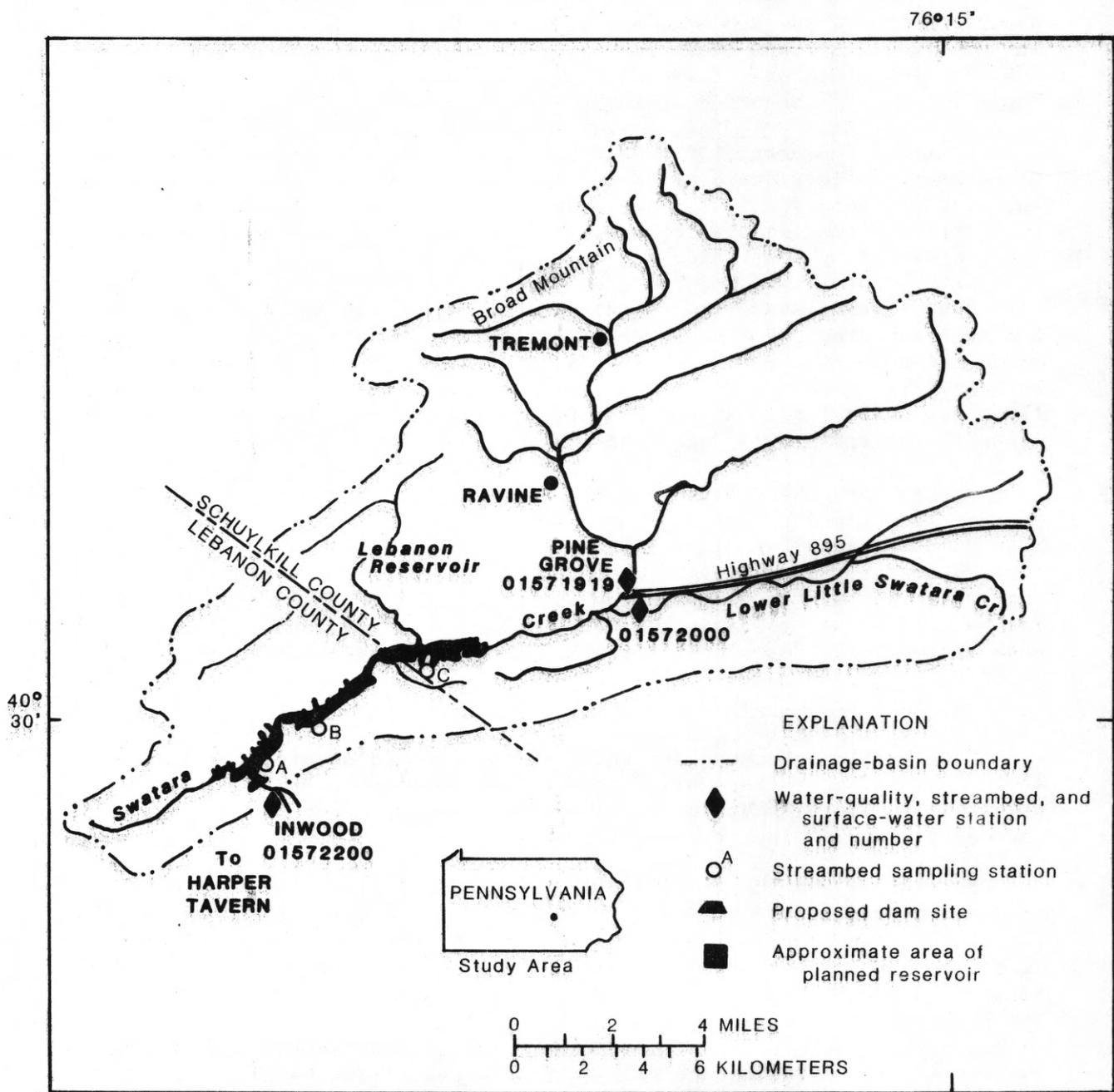


Figure 2.--Location of Swatara Creek Reservoir and sampling sites.

FACTORS AFFECTING WATER QUALITY OF SWATARA
CREEK RESERVOIR STUDY AREA

Climate and Precipitation

Climate and precipitation are two factors which greatly affect the water quality of a stream. Climate is often described in terms of air temperature, which directly affects the water temperature and, therefore, the rates of chemical reactions occurring in a body of water. Warmer temperatures result in faster rates of chemical reactions. Precipitation through its relationship with runoff has a direct effect on water quality. Generally, the greater the precipitation, the greater the amount of runoff that increases chemical-constituent discharges to the streams.

The climate of the study area reflects the temperate conditions in Pennsylvania. Seasonal climatic differences are evident by a growing season beginning in April and ending in October. Air temperatures from winter to spring often differ by more than 100°F (56°C). Air temperatures for October 1981 to September 1982 ranged from -6°F (-21°C) to 94°F (34°C); the average was 51.7°F (10.9°C) at Lebanon. In the middle of the study area, at Pine Grove, the average air temperature for the same period was 49.1°F (9.5°C). The annual normal air temperature at Lebanon is 52.1°F (11.2°C) (National Oceanic and Atmospheric Administration, 1982).

Precipitation is greatly influenced by the orographic effects of the Appalachian Mountains. Table 1 gives a comparison of precipitation measured at Pine Grove near the middle of the study area in the valley and ridge area, with that measured at Lebanon just south of Blue Mountain and the study area. Precipitation data has not been collected long enough to determine a long-term annual precipitation for the Pine Grove station; however, total precipitation at Lebanon for the 1982 water year was 8 percent drier than that for 1931-60. About 30 percent more precipitation, 11.9 in. was measured at Pine Grove than at Lebanon in the 1982 water year. Much of the difference in total precipitation between the stations resulted from a local storm on August 8, 1982 which dropped 6.5 in. of rain at Pine Grove within 12 hours. A precipitation event of this intensity and duration has a 100-year recurrence interval. February, April, May and June 1982 were wetter than normal with June being 121 percent above normal (8.70 in. of precipitation measured at Lebanon).

Total precipitation for the three storms during which water-quality samples were collected and the antecedent soil conditions for each storm are listed in table 2. Although each storm had nearly the same amount of total precipitation, the streamflow hydrographs in figure 3 indicate gage heights and, therefore, corresponding runoff for each storm varied according to rainfall intensities, durations, and antecedent soil conditions. The sharp rise in gage height at Lower Little Swatara Creek (station 01572000) on February 2, 1982 was due to ice conditions that were present prior to the storm which began on February 3. As a result of the ice conditions, the gage height indicated flow greater than the actual discharge; Swatara Creek above Highway 895 (station 01571900) had no ice during this particular event.

Table 1.--Precipitation data for Swatara Creek study area
[National Oceanic and Atmospheric Administration, 1981-82]

	Pine Grove (inches)	Lebanon (inches)	Lebanon, normal- 1931-60 (inches)	Lebanon, variation from normal (inches)	Lebanon, percent variation from normal
October 1981	4.09	2.61	3.55	-0.94	-26
November	1.34	1.17	3.36	-2.19	-65
December	2.75	2.10	3.28	-1.18	-36
January 1982	3.37	2.48	3.10	- .62	-20
February	3.02	3.12	2.59	.53	20
March	2.59	2.94	3.75	- .81	-22
April	5.43	4.51	3.65	.86	24
May	5.29	4.78	4.23	.55	13
June	8.28	8.70	3.93	4.77	121
July	3.05	2.80	4.39	-1.59	-36
August	9.66	1.30	4.27	-2.97	-70
September	3.29	3.75	3.89	- .14	- 4
Total	52.16	40.26	43.99	-3.73	- 8

Table 2.--Summary of storm precipitation tabulated from data collected in
Pine Grove by the National Oceanic and Atmospheric Administration

Storm	Date	Total precipitation (inches)	Antecedent soil conditions
1	February 2-5, 1982	1.39	frozen ground
2	April 26-27, 1982	1.75	preplanting (dry-unplowed)
3	August 24-26, 1982	1.45	midsummer (dry, vegetative cover)

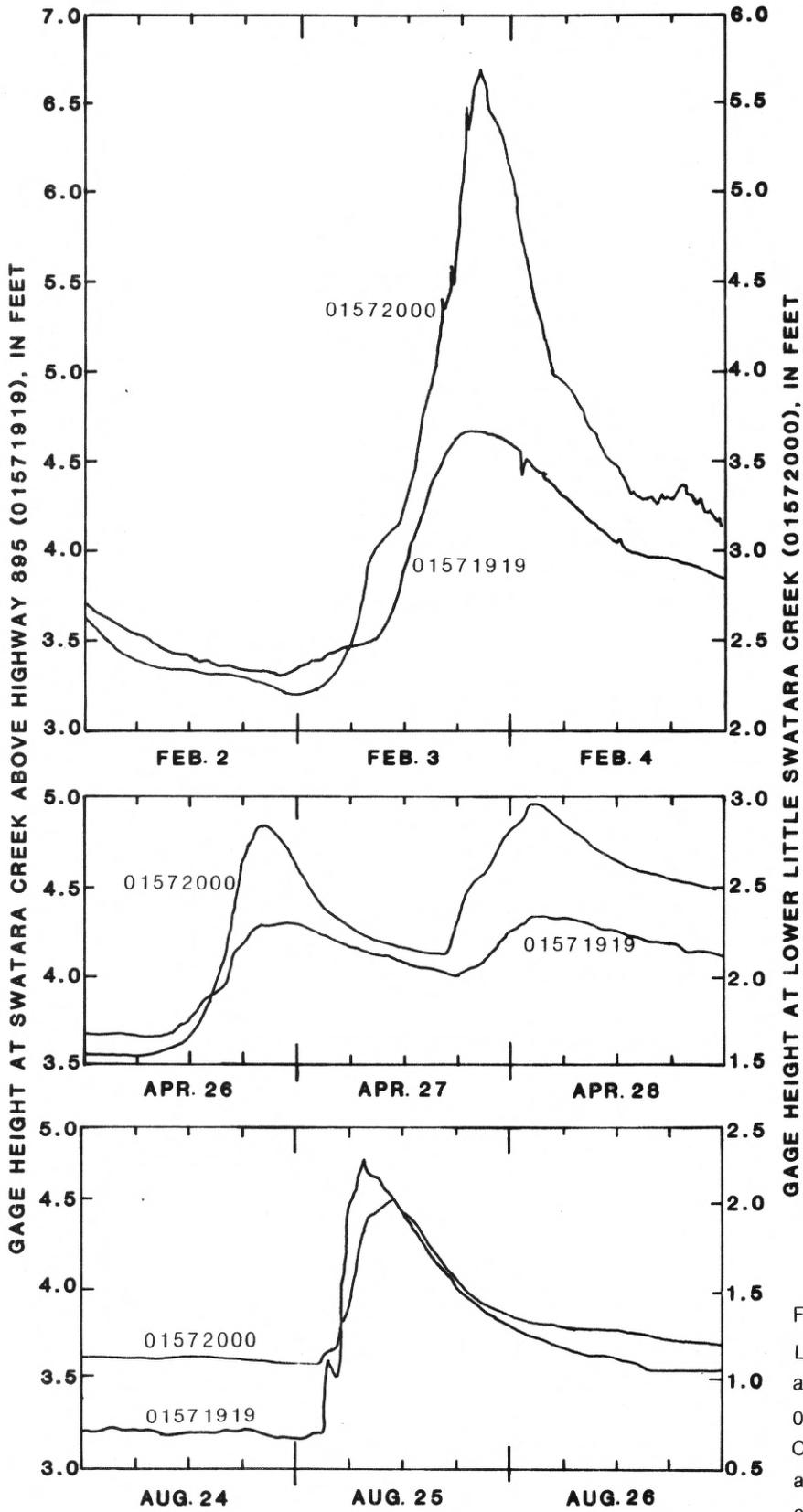


Figure 3.--Streamflow for Lower Little Swatara Creek at Pine Grove (station 01572000) and Swatara Creek above Highway 895 at Pine Grove (station 01571919) during storms.

Topography, Geology, and Soils

The entire study area lies in the Valley and Ridge physiographic province, which is characterized by steep rugged ridges and valley terrain that trends to the northeast above Inwood. Elevations in the area range from 450 ft above sea level near Inwood to about 1,700 ft above sea level near Tremont. The Swatara Creek descends rapidly at a gradient of 78 ft/mi between the headwaters and Pine Grove. The gradient flattens to about 6 ft/mi from Pine Grove to Inwood. Deposition of suspended material occurs in this flat reach. The process of deposition is particularly visible during low-flow conditions in the late summer and early fall.

The geology and soils in the headwaters differ from those downstream and largely influence the water quality of Swatara Creek. In the headwaters, Swatara Creek flows primarily over Paleozoic sedimentary rocks of Pennsylvanian age. The rock layers consist of shale, sandstone, conglomerate, and anthracite. As the rocks weather, the residual and colluvial materials form soils that are then washed into the stream during storms. Soluble materials within the sedimentary rocks and soils include calcium, magnesium, carbonate, sulfate, aluminum, iron, manganese, copper, and phosphate. Their presence in Swatara Creek are reflected by the high dissolved solid concentrations, whereas low pH values, measured upstream of Tremont, indicate the presence of acidic discharges from the anthracite. Between Tremont and Inwood, alternating layers of sandstone, shale, and conglomerate form steep ridges and narrow valleys. Soils here are composed of residue from sandstone and siltstone. Tributaries in this area that contain low concentrations of dissolved solids enter Swatara Creek and begin to dilute and neutralize the acid mine drainage.

Land Use and Population

Changes in land use and population may increase sedimentation and, therefore, degrade water quality. As the study area becomes highly urbanized, the demand for potable water will increase. Previous investigations have predicted urbanization and water use to greatly increase east of Harrisburg and near Lebanon from 1960 to 2000. Population densities were expected to reach 500 people per square mile and water use to rise to 2.0 (Mgal/d)mi² (Stuart and others, 1967). Population in the Swatara Creek basin was expected to increase 60 percent, thus increasing demands for water from Swatara Creek. However, population densities have not reached predicted levels.

Table 3 lists total population and land use for the Swatara Creek basin from 1960 through 1980. The table shows a small shift in land use from agricultural, forested, and public uses to urban and mining uses as population increased 6 percent from 1960 through 1980. Note also that population increased by 59 percent for a density of about 349 people per square mile.

Table 3.--Population and land use changes in Swatara Creek basin, 1960-80

Year	Population	Land use, as percent of basin		
		Agricultural forested, and public	Urban (residential, commercial, and industrial)	Mining (strip and quarries)
1960 ^{1/}	126,200	95.3	3.3	1.4
1970 ^{2/}	156,000	----	---	---
1980 ^{3/}	201,100	91.2	6.4	2.4

^{1/} Stuart, W. T., Schneider, W. V., and Crooks, J. W., (1967, p. 18-21).

^{2/} Wright, S. K., (1976, p. 58).

^{3/} Commonwealth of Pennsylvania (1982, p. V-25).

Streamflow

The effects of streamflow on the water quality of the Swatara Creek Reservoir study area is especially important during periods of high and low flows. The Swatara Creek has a long history of repeated flooding. Streamflow records from 1919-81 indicate that overbank flooding, beginning at a discharge of 5,000 ft³/s, has occurred 187 times in Swatara Creek at Harper Tavern, 16 mi. downstream of the study area. Floods at Harper Tavern often occur in March, April, and May and are associated with basin-wide frontal storms. Local flooding occurs in the summer and is due to heavy precipitation accompanying local thunderstorms. This was the case during the study on August 8, 1982 when 6.5 in. of rain fell within 12 hours causing extensive flooding of homes and businesses in Pine Grove. Most of the suspended metals and nutrients are transported from the study area during high flows.

Low flows in the study area often occur from August through November. Inflow to the planned impoundment during this period may not be capable of completely exchanging the water in the planned reservoir, and thermal and chemical stratification may intensify. For example, at a typical flow of 40 ft³/s, as recorded during October and November 1981 and September 1982, the planned reservoir would require 204 days for a complete exchange of water.

DATA COLLECTION AND METHODOLOGY

Streamflow Data

Streamflow data were collected at the three stations shown in figure 2, and are published in the Survey's "Water Resources Data for Pennsylvania, Volume 2, Water Year 1982." Continuous streamflow data were collected beginning July 1981 for Lower Little Swatara Creek at Pine Grove and October 1981 for Swatara Creek above highway 895 at Pine Grove. These gaging stations are equipped with analog to digital-stage recorders and continuous strip-chart stage recorders. A partial-record station was established at Swatara Creek at Inwood in November of 1981.

Stage-discharge relationships were defined at each station by measuring streamflow over a wide range of stream stages including base flow and storm conditions using a Price current meter. Stage-discharge relations were used to determine instantaneous streamflows when water-quality samples were collected. These streamflows were then used to compute chemical constituent discharges.

Streamflow data for Lower Little Swatara Creek and Swatara Creek at Harper Tavern have been collected for 13 and 63 years, respectively. Streamflow records from these stations were used to characterize the flow conditions during the study period.

Water-quality Data

Suspended-sediment data collection began in July 1981 at Lower Little Swatara Creek at Pine Grove and in October 1981 at Swatara Creek above Highway 895 at Pine Grove. Daily suspended-sediment samples were collected manually at these stations during baseflow conditions. During storms, samples were collected more frequently with a U.S. Geological Survey PS-69 automatic pumping sampler. Suspended-sediment samples were collected manually each month and during storms at Swatara Creek at Inwood. During storms at each station, additional samples were collected manually for analysis of percentages of sand and fine particles or for a complete particle-size analysis.

Analyses for suspended sediment were done in the Survey's sediment laboratory in Harrisburg, PA., by methods described by Guy (1969). Daily values for suspended-sediment concentration and discharge were computed using the techniques of Porterfield (1972).

Chemical-quality data collection began in December 1981 at each of the three stations. Samples were collected monthly during base-flow conditions and at selected stages during storms to develop transport curves for chemical constituents. Storms were selected so that the water quality at each station could be related to different phases of the growing season. Chemical-quality samples were collected using depth-integrating samplers and the equal-width increment procedure (Guy and Norman, 1970). Bacteriological and dissolved oxygen samples, and water temperature measurements were taken at the centroid of flow at each station.

Chemical-quality samples were analyzed or preserved for analysis immediately after collection at the sampling location. Field analyses included measurements of water temperature, pH, alkalinity, acidity, specific conductance, dissolved oxygen, fecal coliform, and fecal streptococcal bacteria. Samples analyzed for dissolved constituents were filtered in the field using a 0.45 micron membrane filter mounted in a peristaltic filter assembly. Samples for dissolved organic carbon were filtered through a 0.45 micron silver filter in a stainless steel pressure filtration unit. Bacteriological analyses were done during base flow in the field by techniques described by Greeson and others (1977). Bacteriological samples collected during base flow and storms also were packed on ice and delivered to the PaDER, Bureau of Laboratories in Harrisburg, PA for analysis within 24 hours of sample collection. Table 4 lists the physical, chemical, and bacteriological analyses performed on water-quality samples.

Statistical analysis of water-quality data was performed using the computer package "Statistical Analysis System" (Helwig, 1978). Basic univariate statistics for water-quality characteristics were calculated, including maximum, minimum, and median concentrations, and maximum and minimum instantaneous discharges. Preliminary regression statistics using the least-squares method were computed for constituents determined to be normally distributed and whose means and variances were not directly related. Logarithmic transformations using $\log(X)$ or $\log(X+1)$ were used when needed to meet the assumption of normal distributions. Chemical constituent hydrographs were plotted to determine trends during the study period. Storm hydrographs were used to show relationships between chemical concentrations and streamflow.

HYDROLOGY OF SWATARA CREEK

Water quality is highly variable and either beneficial or detrimental depending on the designated use of the water. Because the water in the proposed Swatara Creek Reservoir is designated for water supply, fishing, swimming, and boating, the impoundment's influence on the physical, sediment, chemical, and bacteriological characteristics of the water will be important. Although no additional water is designated for possible hydro-power generation, current plans call for an intake which will draw water from the bottom of the reservoir for this function; therefore, the impact of this operation on the water-quality characteristics also may be important. The results presented in this report are those observed prior to impoundment construction. The data are listed in the back of the report in table 9.

Streamflow

Streamflow records at Harper Tavern were examined to determine flow conditions during the study since the stations in the study area did not have long records. Annual flow for 1982 at Swatara Creek at Harper Tavern was 15 percent below the average annual flow computed for the previous 63 years. Based on this analysis, it is assumed that the annual flows measured in the study area during the 1982 water year are about 15 percent less than that expected over a long period.

Table 4.-- Physical, chemical, and bacteriological analyses performed on water-quality samples

Physical and other related analyses

acidity (mg/L as CaCO₃)
alkalinity (mg/L as CaCO₃)
oxygen, dissolved (mg/L)
pH (units)
specific conductance (μS/cm at 25°C)
water temperature (°C)
chemical oxygen demand (mg/L)
turbidity (FTU)

Chemical Analyses

Nutrients (mg/L)

nitrogen, nitrite dissolved
nitrogen, nitrite total
nitrogen, nitrate dissolved
nitrogen, nitrate total
nitrogen, ammonia dissolved
nitrogen, ammonia total
nitrogen, Kjeldahl dissolved
nitrogen, Kjeldahl total
phosphorus, orthophosphate dissolved
phosphorus, orthophosphate total
phosphorus, dissolved
phosphorus, total
carbon, organic

Metals (μg/L)

aluminum, dissolved
aluminum, total-recoverable
chromium, total-recoverable
copper, total-recoverable
iron, dissolved
iron, total-recoverable
lead, total-recoverable
manganese, dissolved
manganese, total-recoverable
mercury, total-recoverable
zinc, total-recoverable

Dissolved ions (mg/L)

calcium
chloride
magnesium
silica
sodium
sulfate
potassium

Bacteriological Analyses

fecal coliform (colonies/100 mL)
fecal streptococci (colonies/100 mL)

Daily mean streamflow hydrographs and monthly streamflow bar charts for Lower Little Swatara Creek and Swatara Creek above Highway 895, shown in figures 4 and 5, reflect the similarity in streamflow characteristics of these two stations. Annual discharge from Swatara Creek above Highway 895 was 2.1 times greater than that from Lower Little Swatara Creek during the 1982 water year. This ratio is nearly equal to the 2.12 ratio for the drainage areas of the two basins, so the discharge per square mile from each stream is about equal. About 47 percent of the annual flows for both stations occurred during April, May, and June. Maximum and minimum monthly flows occurred during June and October, respectively, for both stations. Maximum daily flows during the study for both stations occurred on June 6; streamflow was 526 ft³/s at Lower Little Swatara Creek and 884 ft³/s at Swatara Creek above Highway 895. Minimum daily flows for both stations occurred in October and were 3.1 ft³/s for Lower Little Swatara Creek, and 21 ft³/s for Swatara Creek above Highway 895.

A flow-duration curve (fig. 6) was computed for Lower Little Swatara Creek based on 14 years of records (1920-32, 1982). The 1982 flow-duration curve is similar to the 1920-32 curve. The maximum daily flow of 526 ft³/s measured at Lower Little Swatara Creek on June 6 will recur less than 0.6 percent of the time based on the flow-duration curve. However, this figure could be slightly higher when a long-term record is considered since Swatara Creek at Harper Tavern annual flow for 1982 was 15 percent below the average annual flow.

Instantaneous flows at Lower Little Swatara Creek were compared for 1982 and the period of record. A maximum instantaneous flow of 1,370 ft³/s for 1982 occurred on August 8; this flow was only 9 percent less than the maximum flow for the period of record.

Results of regression analysis using the least-squares method show a good relationship ($r^2 = 0.95$) exists between the common logarithm of the instantaneous flow measured at Swatara Creek at Inwood and the common logarithm of the flow recorded at Swatara Creek above Highway 895 at Pine Grove for a range of flows at Inwood from 53.5 ft³/s to 1770 ft³/s. Figure 7 shows the relation between the flows at the two stations based on 15 measurements over a range of flows. The equation for the regression line in figure 7 based on preliminary data was used to determine the daily discharges at Inwood and is as follows:

$$\text{Log } Q_I = 1.1756 (\text{Log } Q_{895}) - 0.0286 \quad (1)$$

where $\text{Log } Q_I$ = the logarithm of the instantaneous flow of Swatara Creek at Inwood, in ft³/s

1.1756 = the slope of the regression line,

$\text{Log } Q_{895}$ = the logarithm of the instantaneous flow of Swatara Creek, above Highway 895 at Pine Grove, in ft³/s

-0.0286 = the intercept of the regression line

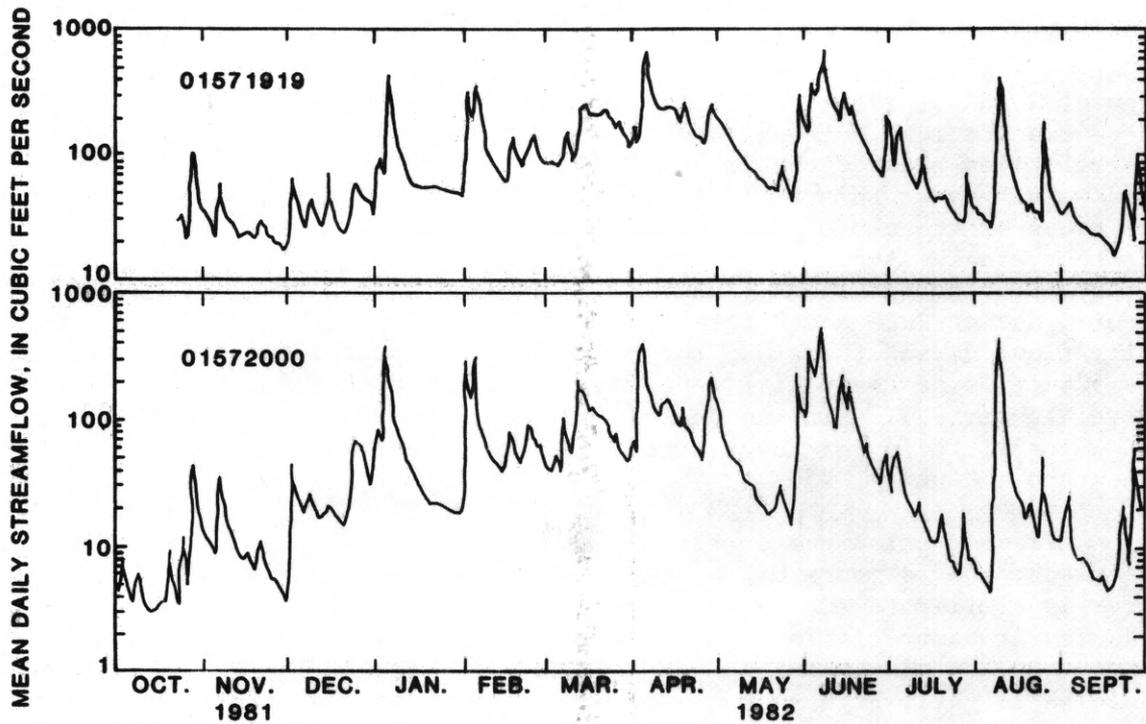


Figure 4.--Mean daily streamflow for Swatara Creek above Highway 895 (station 01571919) and Lower Little Swatara Creek at Pine Grove (station 01572000), 1982 water year.

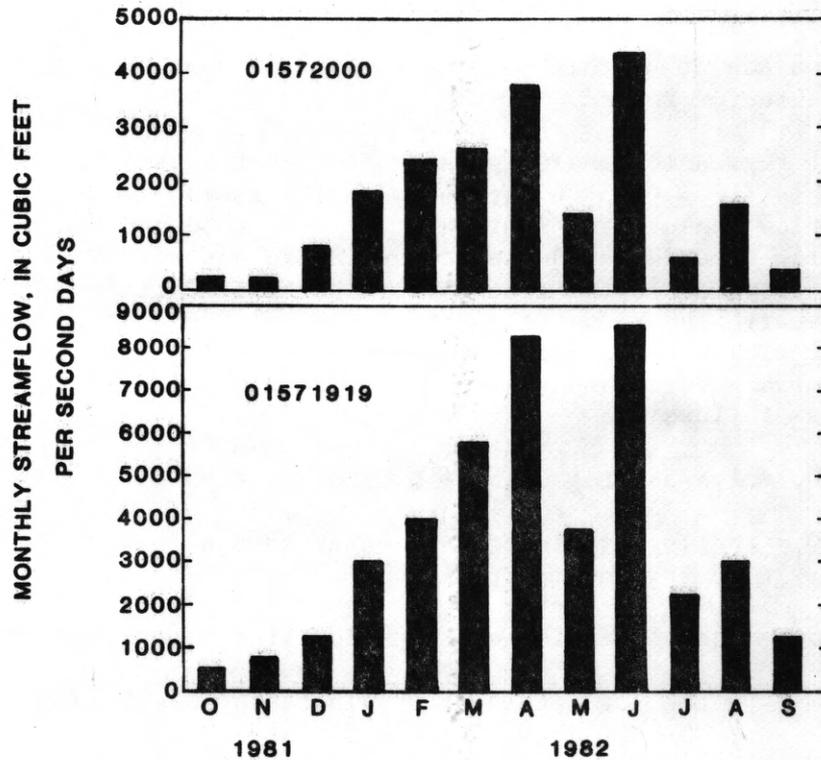


Figure 5.--Monthly streamflow for Lower Little Swatara Creek at Pine Grove (station 01572000) and Swatara Creek above Highway 895 (station 01571919), 1982 water year.

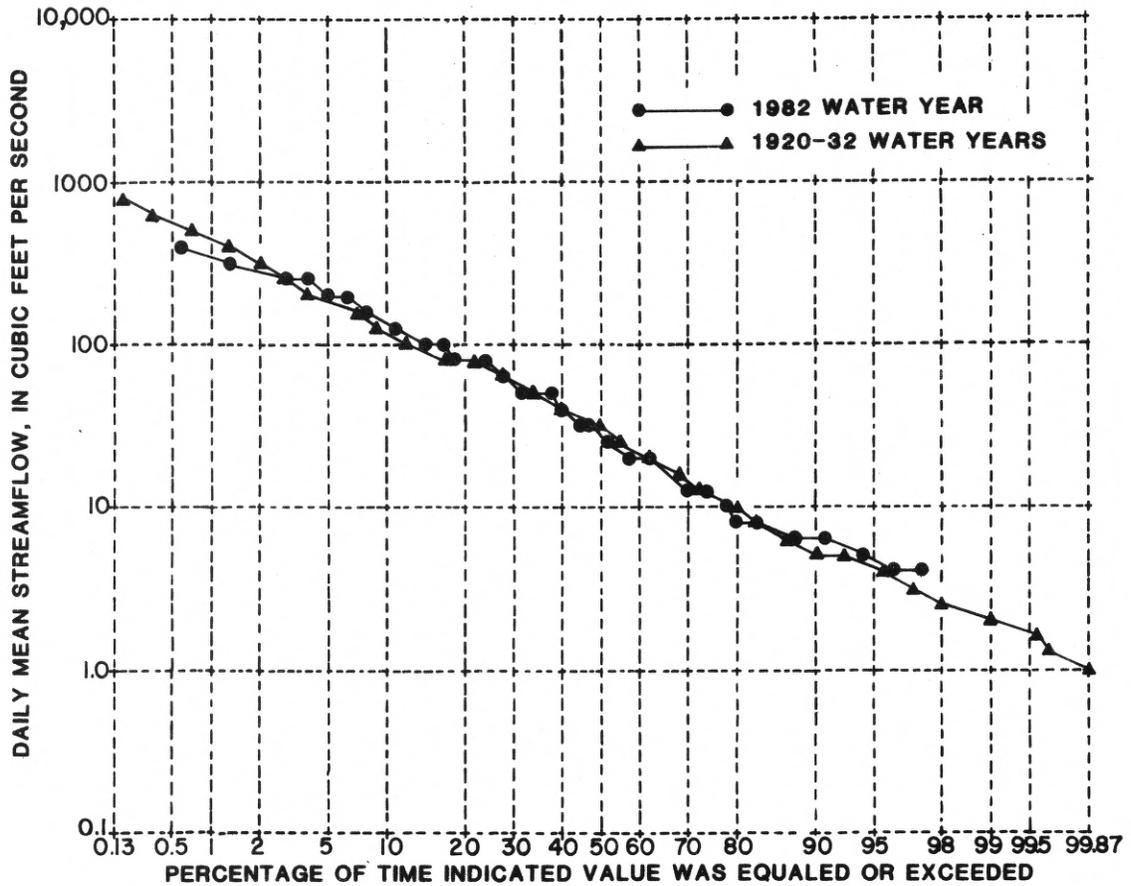


Figure 6.--Flow-duration curves for Lower Little Swatara Creek at Pine Grove.

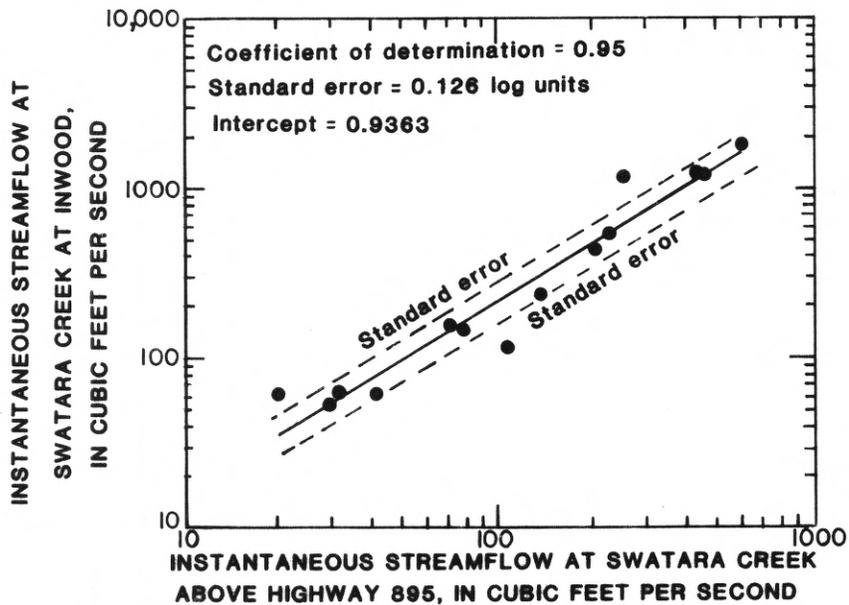


Figure 7.--Relation between instantaneous streamflow at Swatara Creek at Inwood and instantaneous streamflow at Swatara Creek above Highway 895 at Pine Grove.

Water Quality

Table 5 lists basic statistics for instantaneous water-quality concentrations and discharges measured at each station from October 1981 to September 1982. Concentrations and discharges listed in these tables are from manually collected depth-integrated composite samples and are used for discussions throughout this report. Qualitative relationships between water-quality constituents and streamflow are given, but available data are inadequate to report results quantitatively.

Table 5.--Ranges and medians of water-quality characteristics, constituent concentrations, and instantaneous discharges, 1982 water year

		Location					
Characteristic or constituent	Statistic	Swatara Creek above highway 895 at Pine Grove		Lower Little Swatara Creek at Pine Grove		Swatara Creek at Inwood	
		[Concentration in milligrams per liter and discharge in tons per day except as noted]					
Acidity	Median concentration	4.0		2.0		3.0	
	Number of samples	19		21		16	
	Min - max concentration	.0	21.0	.0	10.0	0.0	12.0
	Min - max discharge	.00	21.09	.00	17.98	0.00	13.91
Alkalinity	Median concentration	4.0		7.0		6.0	
	Number of samples	21		21		16	
	Min - max concentration	.0	8.0	1.0	15	1.0	9.0
	Min - max discharge	0	6.39	.15	4.88	.46	13.82
pH	Median	6.5		7.0		6.6	
	Number of samples	21		21		16	
	Minimum - maximum	5.6	7.2	6.2	8.4	6.3	6.9
Specific conductance (μ S/cm at 25°C)	Median	164		72		132	
	Number of samples	21		21		16	
	Minimum - maximum	123	348	59	88	93	205
Water temperature (°C)	Median	12.0		12.0		13.0	
	Number of samples	21		21		16	
	Minimum - maximum	.5	22.0	.5	23.5	.5	24.5
Dissolved oxygen	Median	10.4		10.2		10.3	
	Number of samples	21		21		16	
	Minimum - Maximum	5.6	13.5	7.0	14.0	7.2	13.6
Chemical oxygen demand	Median concentration	22		15		10	
	Number of samples	16		15		12	
	Min - max concentration	<10	405	<10	56	<10	556
	Min - max discharge	.73	407	.15	46.75	1.46	967

Table 5.--Ranges and medians of water-quality characteristics, constituent concentrations, and instantaneous discharges, 1982 water year--continued

		[Concentration in milligrams per liter and discharge in tons per day except as noted]		
Characteristic or constituent	Statistic	Location		
		Swatara Creek above highway 895 at Pine Grove	Lower Little Swatara Creek at Pine Grove	Swatara Creek at Inwood
Turbidity (FTU)	Median	16.5	13	9.0
	Number of samples	20	19	15
	Minimum - maximum	3.0 - 840	2.5 - 120	1.4 - 230
Sediment, suspended	^{2/} Median concentration	26	22	14
	Number of samples	21	21	16
	Min - max concentration	6 - 3,900	1 - 201	2 - 652
	Min - max discharge	.44 - 3,920	.06 - 361	.40 - 1,130
Streamflow (ft ³ /s)	^{2/} Median	225	68	219
	Number of samples	21	21	16
	Minimum - maximum	27.1 - 592	5.69 - 666	54 - 1,280
Nitrate, dissolved	Median concentration	0.79	1.4	0.90
	Number of samples	21	20	16
	Min - max concentration	.31 - 1.80	.53 - 2.6	.47 - 1.70
	Min - max discharge	.03 - 2.88	.01 - 2.52	.08 - 5.53
Nitrate, total	Median concentration	.79	1.4	.90
	Number of samples	21	21	16
	Min - max concentration	.31 - 1.80	.53 - 2.6	.47 - 1.70
	Min - max discharge	.03 - 2.88	.01 - 2.52	.08 - 5.53
Nitrite, dissolved	Median concentration	.01	.01	.01
	Number of samples	21	20	16
	Min - max concentration	< .01 - .02	< .01 - .02	< .01 - .01
	Min - max discharge	< .01 - .02	< .01 - .02	< .01 - .03
Nitrite, total	Median concentration	.01	.01	.01
	Number of samples	21	21	16
	Min - max	< .01 - .02	< .01 - .02	< .01 - .02
	Min - max discharge	< .01 - .03	< .01 - .05	< .01 - .07
Ammonia, dissolved	Median concentration	.15	.03	.08
	Number of samples	21	21	16
	Min - max concentration	.07 - .82	.01 - .26	.01 - .18
	Min - max discharge	.03 - .40	< .01 - .47	< .01 - .62

^{2/} Values for these characteristics were determined for samples which were collected manually.

Table 5.--Ranges and medians of water-quality characteristics, constituent concentrations, and instantaneous discharges, 1982 water year--continued

[Concentration in milligrams per liter and discharge in tons per day except as noted]

Characteristic or constituent	Statistic	Location		
		Swatara Creek above highway 895 at Pine Grove	Lower Little Swatara Creek at Pine Grove	Swatara Creek at Inwood
Ammonia, total	Median concentration	0.15	0.04	0.09
	Number of samples	21	21	16
	Min - max concentration	.07 - .82	.02 - .30	.01 - .20
	Min - max discharge	.03 - .04	< .01 - .54	< .01 - .69
Organic nitrogen, dissolved	Median concentration	.70	.75	.60
	Number of samples	20	21	16
	Min - max concentration	.23 - 1.20	.19 - 1.2	.01 - 1.0
	Min - max discharge	.03 - 1.24	.01 - .51	.05 - 3.18
Organic nitrogen, total	Median concentration	.78	.80	.77
	Number of samples	20	21	15
	Min - max concentration	.23 - 2.20	.29 - 1.4	.23 - 2.4
	Min - max discharge	.05 - 2.21	.01 - 1.07	.08 - 4.17
Ammonia + organic nitrogen, dissolved	Median concentration	.85	.83	.70
	Number of samples	20	21	16
	Min - max concentration	.30 - 1.60	.30 - 1.3	.30 - 1.20
	Min - max discharge	.06 - 3.80	.01 - .81	.06 - 3.80
Ammonia + organic nitrogen, total	Median concentration	.98	.83	.90
	Number of samples	20	21	15
	Min - max concentration	.30 - 2.40	.35 - 1.5	.30 - 2.60
	Min - max discharge	.08 - 4.52	.01 - 1.34	.08 - 4.52
Nitrogen, dissolved	Median	1.7	2.1	1.9
	Number of samples	19	19	7
	Min - max concentration	.45 - 2.9	.94 - 3.3	1.3 - 2.7
	Min - max discharge	.11 - 3.68	.02 - 3.42	.38 - 9.33
Nitrogen, total	Median	1.9	2.3	2.0
	Number of samples	19	20	7
	Min - max concentration	.49 - 2.9	.94 - 3.5	1.4 - 2.7
	Min - max discharge	.14 - 4.00	.02 - 3.78	.40 - 9.33
Ortho-phosphate, dissolved	Median concentration	<.01	.01	<.01
	Number of samples	20	20	16
	Min - max concentration	<.01 - .01	<.01 - .04	<.01 - .01
	Min - max discharge	<.01 - .02	<.01 - .05	<.01 - .03
Ortho-phosphate, total	Median concentration	<.01	.01	<.01
	Number of samples	20	19	15
	Min - max concentration	<.01 - .06	.01 - .05	<.01 - .03
	Min - max discharge	<.01 - .10	<.01 - .09	<.01 - .04

Table 5.--Ranges and medians of water-quality characteristics, constituent concentrations and instantaneous discharges, 1982 water year--continued

		[Concentration in milligrams per liter and discharge in tons per day except as noted]		
		Location		
Characteristic or constituent	Statistic	Swatara Creek above highway 895 at Pine Grove	Lower Little Swatara Creek at Pine Grove	Swatara Creek at Inwood
Phosphorus, dissolved	Median concentration	0.02	0.03	0.02
	Number of samples	21	21	16
	Min - max concentration	.01 - .06	<.01 - .10	.01 - .04
	Min - max discharge	<.01 - .07	<.01 - .18	<.01 - .10
Phosphorus, total	Median concentration	.05	.07	.04
	Number of samples	21	21	16
	Min - max concentration	.03 - .28	.02 - .31	.02 - .25
	Min - max discharge	<.01 - .32	<.01 - .56	<.01 - .55
Organic carbon, dissolved	Median concentration	2.3	2.0	2.0
	Number of samples	15	16	11
	Min - max concentration	<1.0 - 7.0	1.1 - 7.0	1.0 - 4.4
	Min - max discharge	.17 - 7.67	.02 - 12.6	.20 - 15.2
Organic carbon, total	Median concentration	2.2	2.1	1.3
	Number of samples	13	15	11
	min - max concentration	<1.0 - 7	<1.0 - 8.8	<1.0 - 4.9
	Min - max discharge	.10 - 8.95	.02 - 15.82	.17 - 16.93
Aluminum, * dissolved	Median concentration	100	110	100
	Number of samples	20	19	16
	Min - max concentration	30 - 500	<10 - 330	20 - 560
	Min - max discharge	< .01 - .53	< .01 - .16	.01 - .81
Aluminum, * total	Median concentration	1,100	670	450
	Number of samples	21	21	16
	Min - max concentration	300 - 66,000	70 - 3,400	90 - 13,000
	min - max discharge	.02 - 66.29	< .01 - 6.11	.03 - 22.6
Chromium, * total	Median concentration	10	10	10
	Number of samples	12	11	7
	Min - max concentration	<10 - 40	<10 - 50	<10 - 20
	Min - max discharge	< .01 - .04	< .01 - .09	< .01 - .07
Copper, * total	Median concentration	20	20	20
	Number of samples	12	12	7
	Min - max concentration	10 - 220	10 - 30	10 - 60
	Min - max discharge	.01 - .22	< .01 - .05	.01 - .10
Iron, * dissolved	Median concentration	430	85	70
	Number of samples	21	20	16
	Min - max concentration	40 - 1,500	40 - 210	30 - 270
	Min - max discharge	.01 - 8.0	< .01 - .18	.01 - .38

* Concentrations for these constituents are in micrograms per liter.

Table 5.--Ranges and medians of water-quality characteristics, constituent concentrations, and instantaneous discharges, 1982 water year--continued

[Concentration in micrograms per liter and discharge in tons per day except as noted]

Characteristic or constituent	Statistic	Location		
		Swatara Creek above highway 895 at Pine Grove	Lower Little Swatara Creek at Pine Grove	Swatara Creek at Inwood
Iron, total	Median concentration	2,200	850	760
	Number of samples	21	21	16
	Min - max concentration	410 - 100,000	100 - 7,900	70 - 21,000
	Min - max discharge	.03 - 100	< .01 - 14.2	.01 - 36.5
Lead, total	Median concentration	19	5.8	9.3
	Number of samples	12	12	7
	Min - max concentration	4 - 172	< 5 - 40	5 - 52
	Min - max discharge	< .01 - .17	< .01 - .02	< .01 - .08
Manganese, dissolved	Median concentration	640	20	330
	Number of samples	21	20	16
	Min - max concentration	350 - 2,000	10 - 150	210 - 610
	Min - max discharge	.10 - 2.31	< .10 - .27	.05 - .73
Manganese, total	Median concentration	740	50	350
	Number of samples	21	21	16
	Min - max concentration	410 - 2,300	30 - 670	230 - 710
	Min - max discharge	1.02 - 7.53	< .01 - .56	.05 - 1.28
Mercury, total	Median concentration	< 2.0	< 2.0	< 2.0
	Number of samples	12	12	7
	Min - max concentration	< 2.0 - 2.0	< 2.0 - < 2.0	< 2.0 - < 2.0
	Min - max discharge	< .01 - < .01	< .01 - < .01	< .01 - .01
Zinc, total	Median concentration	85	20	60
	Number of samples	12	11	7
	Min - max concentration	<10 - 310	10 - 50	<10 - 120
	Min - max discharge	.01 - .31	< .01 - .07	.01 - .38
Calcium, ** dissolved	Median concentration	11	4.6	8.6
	Number of samples	21	20	16
	Min - max concentration	7.9 - 20	2.5 - 6.1	5.7 - 14
	Min - max discharge	1.46 - 12.6	.06 - 6.83	2.04 - 19.7
Chloride, ** dissolved	Median concentration	8.0	6.0	7.5
	Number of samples	21	21	16
	Min - max concentration	6.0 - 21	5.0 - 8.0	6.0 - 12
	Min - max discharge	.66 - 23.6	.09 - 12.59	1.17 - 34.6

** Concentrations for these constituents are in milligrams per liter.

Table 5.--Ranges and medians of water-quality characteristics, constituent concentrations, and instantaneous discharges, 1982 water year--continued

Characteristic or constituent		Statistic	Location					
			Swatara Creek above highway 895 at Pine Grove		Lower Little Swatara Creek at Pine Grove		Swatara Creek at Inwood	
Magnesium, dissolved	Median concentration		6.8		2.2		5.0	
	Number of samples		21		20		16	
	Min - max concentration		3.9	- 18	1.6	- 5.1	2.7	- 12
	Min - max discharge		.10	- .79	.03	- 2.88	1.22	- 9.33
Potassium, dissolved	Median concentration		1.2		1.2		1.2	
	Number of samples		21		20		16	
	Min - max concentration		.80	- 3.4	.70	- 3.8	.78	- 2.8
	Min - max discharge		.13	- 4.64	.01	- 6.83	.20	- 8.99
Silica, dissolved	Median concentration		5.9		4.5		5.5	
	Number of samples		21		20		16	
	Min - max concentration		2.9	- 7.1	.50	- 6.2	2.4	- 6.9
	Min - max discharge		.52	- 6.76	.03	- 3.78	.49	- 12.4
Sodium, dissolved	Median concentration		5.8		3.0		5.3	
	Number of samples		21		20		16	
	Min - max concentration		4.0	- 13	2.3	- 4.7	3.4	- 8.3
	Min - max discharge		.73	- 14.6	.05	- 6.83	.82	- 21.1
Sulfate, dissolved	Median		50		5		30	
	Number of samples		21		21		16	
	Min - max concentration		25	- 130	< 5	- 25	15	- 60
	Min - max discharge		6.59	- 50.2	.08	- 18.0	5.83	- 52.2
Hardness, dissolved	Median		55		21		40	
	Number of samples		21		21		16	
	Min - max concentration		36	- 140	16	- 43	25	- 71
Fecal Coliform (colonies/ 100 mL)	Median concentration		31		140		25	
	Number of samples		10		10		9	
	Min - max concentration		K3	- 570	16	- 800	< 2	- 180
Fecal Streptococci (colonies/ 100 mL)	Median concentration		105		185		78	
	Number of samples		10		10		10	
	Min - max concentration		K21	- 3,500	K61	- 2,000	K4	- 240

K = Value based on non-ideal colony count

Physical and Other Related Characteristics

Physical and other related characteristics measured include water temperature, dissolved oxygen, pH, alkalinity, acidity, specific conductance, chemical oxygen demand and turbidity. Figures 8 to 15 show monthly variations of the physical characteristics measured during base flow.

Water temperatures for all three sites (fig. 8) were very similar ranging from 0°C at Lower Little Swatara Creek to 24.5°C at Swatara Creek at Inwood. Maximums occurred in July and minimums in December and January.

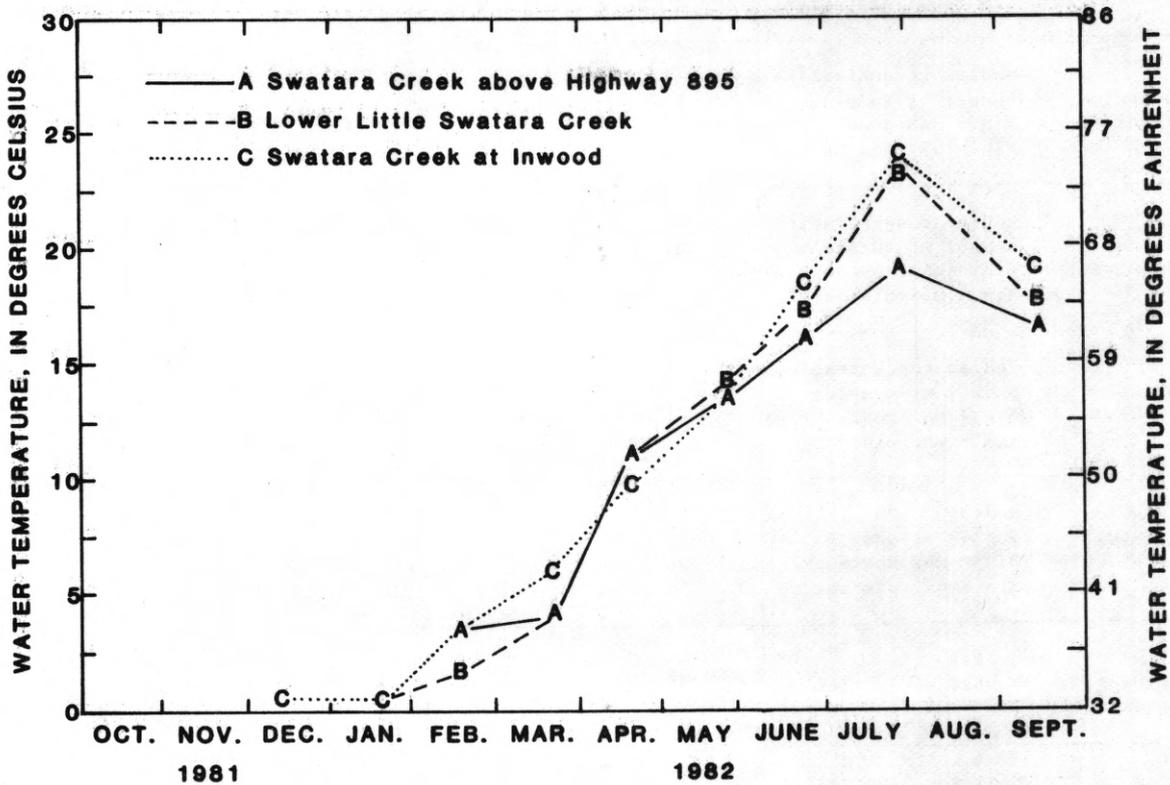


Figure 8.--Monthly variation of water temperature during baseflow.

Base flow dissolved oxygen values ranged from 8.0 to 14.0 mg/L, and showed the expected inverse relationship with water temperature as maximums occurred in December and minimums in July (fig. 9). Dissolved oxygen concentrations were generally higher at Lower Little Swatara Creek because depths were shallower allowing greater reaeration and photosynthetic activity. The percent saturation of oxygen was greater than 84 percent at each station at every measurement during base flow. However, during high flow on August 25, the percent saturation dropped as low as 64 percent at Swatara Creek above Highway 895, 76 percent at Lower Little Swatara Creek, and 78 percent at Swatara Creek at Inwood due to high concentrations of chemical oxygen demand. Detecting these sudden decreases in oxygen will be important to the successful management of the aquatic biota in the study area. Continuous monitoring for dissolved oxygen upstream from and within the impoundment area would be helpful in detecting these sudden changes.

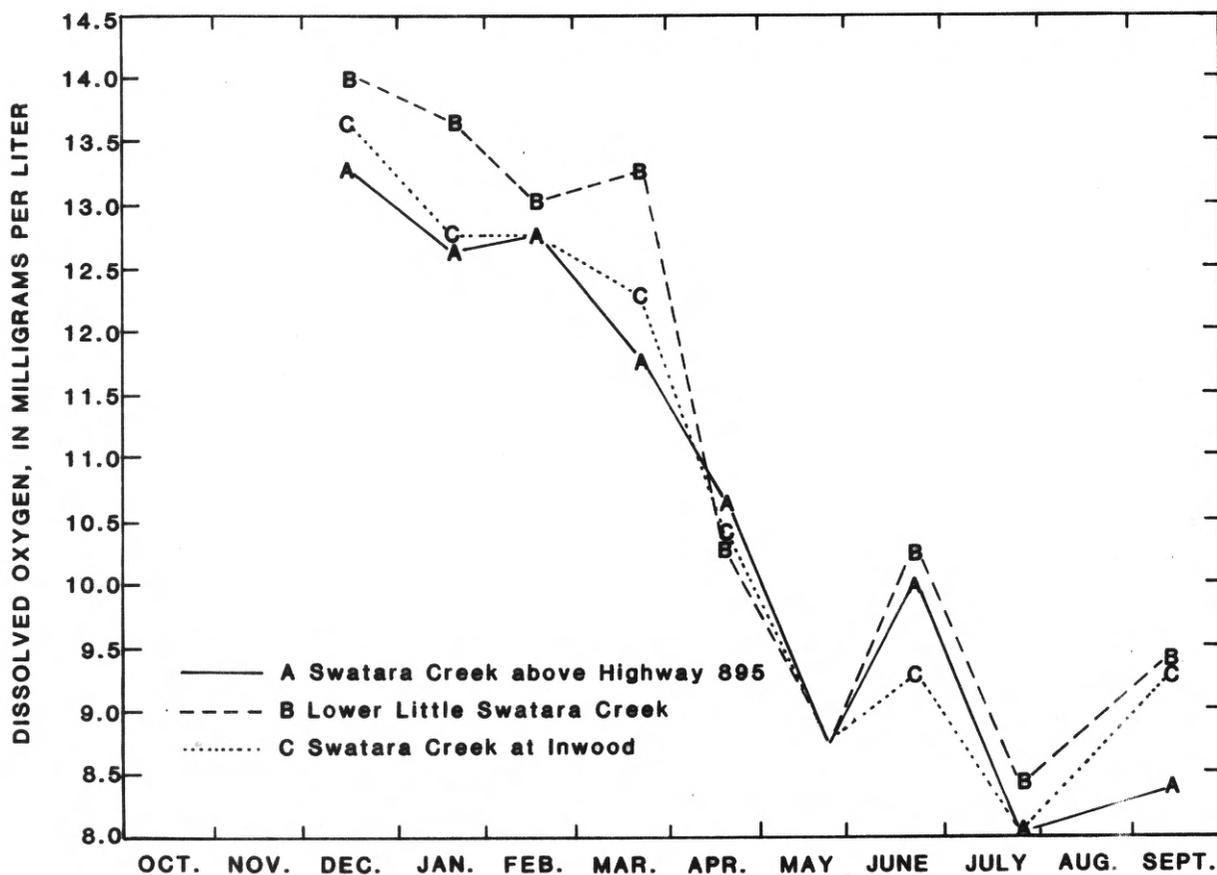


Figure 9.--Monthly variation of dissolved oxygen during baseflow.

Alkalinity, acidity, and pH are important in determining buffer capacity or the ability to neutralize an acid or base discharged into a given body of water (figs. 10-12). Water with a pH between 4.5 and 8.3 has both alkalinity and acidity, and therefore, can neutralize both acids and bases. Because the Swatara Creek headwaters originate in an area heavily mined for anthracite, the ability of the water to neutralize the acidic mine drainage is important. The buffering capacity of Swatara Creek and Lower Little Swatara Creek is low; alkalinity was usually less than 10 mg/L as CaCO₃, and acidity was less than 5.0 mg/L as CaCO₃. The addition of any acid or base into the Swatara Creek may rapidly alter the pH and, therefore, be detrimental to the aquatic biota. Preliminary data indicate that a pH of 6.0, necessary to support a warm-water fishery (Moran and Wentz, 1974), is narrowly met at all three stations during base-flow conditions. At Lower Little Swatara Creek the pH steadily increased during the warmer months when photosynthetic activity increased and dissolved carbon dioxide was taken up by aquatic organisms. During periods of high flow, pH dropped to 5.6, at Swatara Creek above Highway 895, whereas corresponding alkalinity and acidity were 4.0 mg/L and 21.0 mg/L as CaCO₃, respectively. The simultaneous decrease in pH and increase in acidity, sulfate, iron, aluminum, and manganese concentrations above Highway 895 are indicative of the acidic discharges from the mining areas entering Swatara Creek during storms.

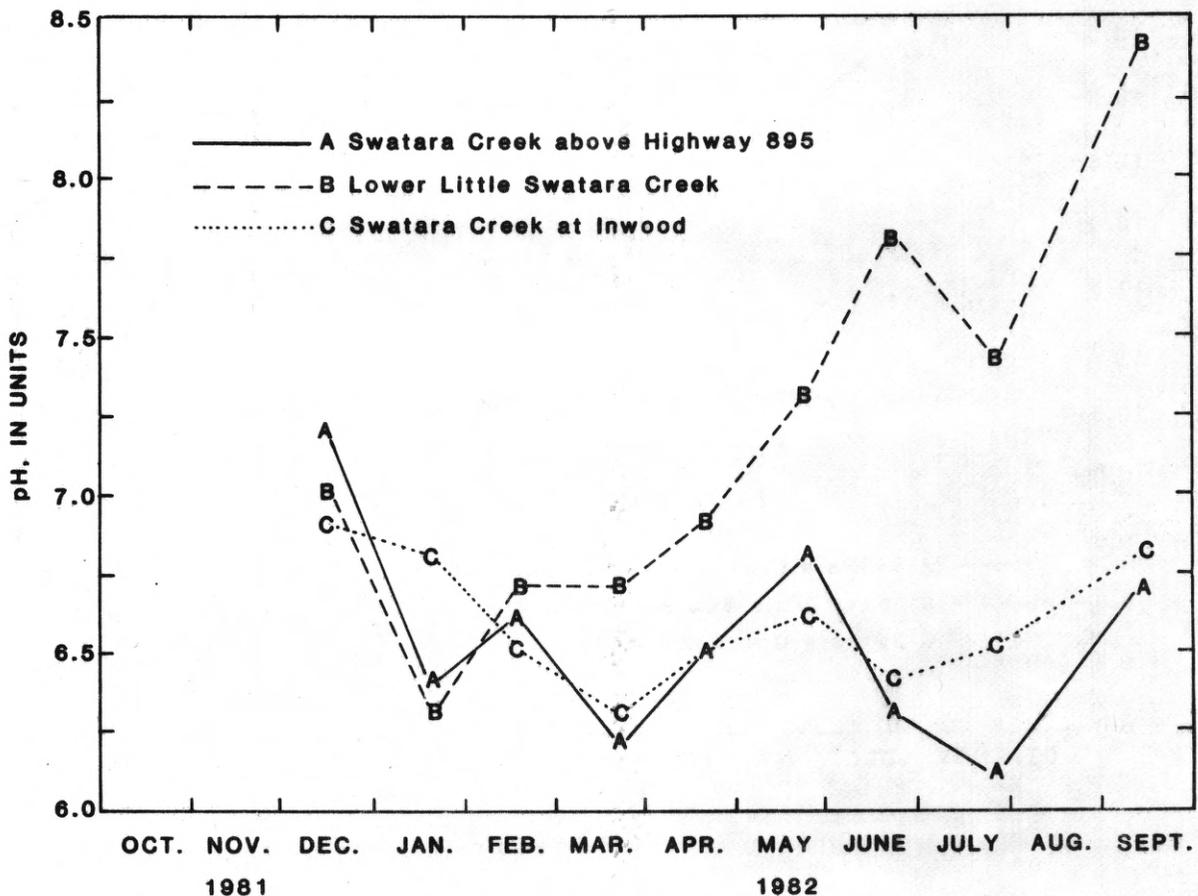


Figure 10.--Monthly variation of pH during baseflow.

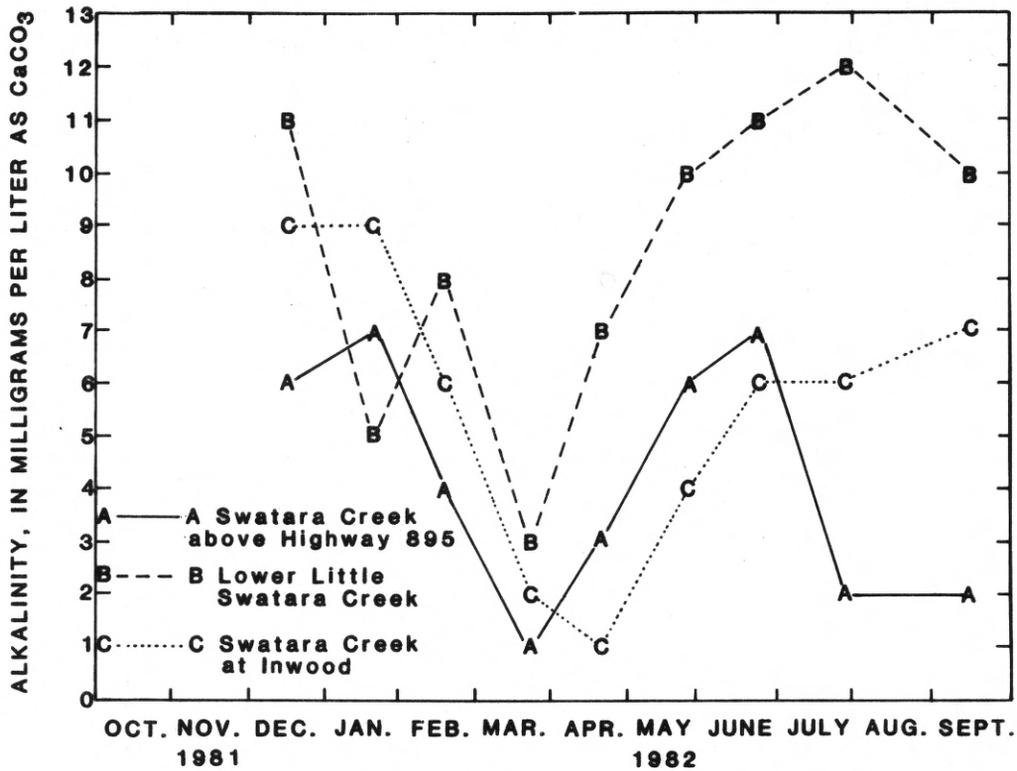


Figure 11.--Monthly variation of alkalinity during baseflow.

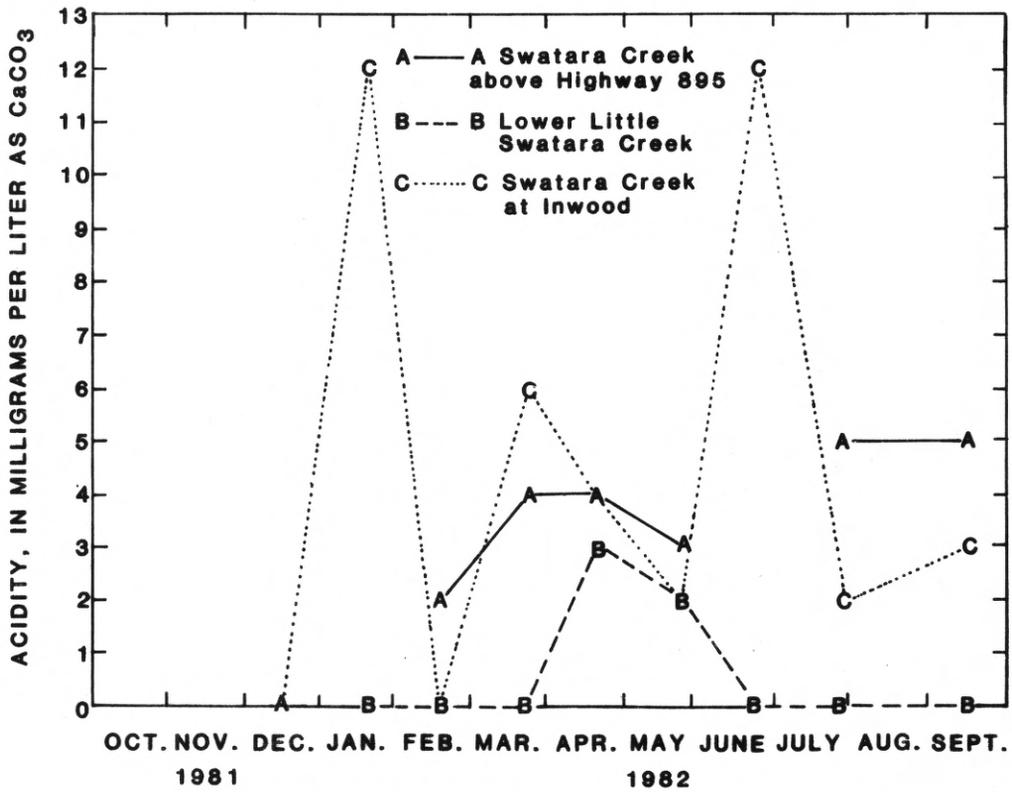


Figure 12.--Monthly variation of acidity during baseflow.

Specific conductance--the ability of a substance to conduct an electrical current--is an indication of the presence of ions such as calcium, magnesium, sodium, potassium, chloride, sulfate, and metallic ions in solution. Specific conductance for Swatara Creek above Highway 895 (fig. 13) was about three times greater than Lower Little Swatara Creek during base flow due to the discharges from the mining areas. The median value for Swatara Creek above Highway 895 was 164 $\mu\text{S}/\text{cm}$ compared to 72 $\mu\text{S}/\text{cm}$ at Lower Little Swatara Creek. Dilution by Lower Little Swatara Creek and other tributaries resulted in a median value of 132 $\mu\text{S}/\text{cm}$ downstream at Swatara Creek at Inwood.

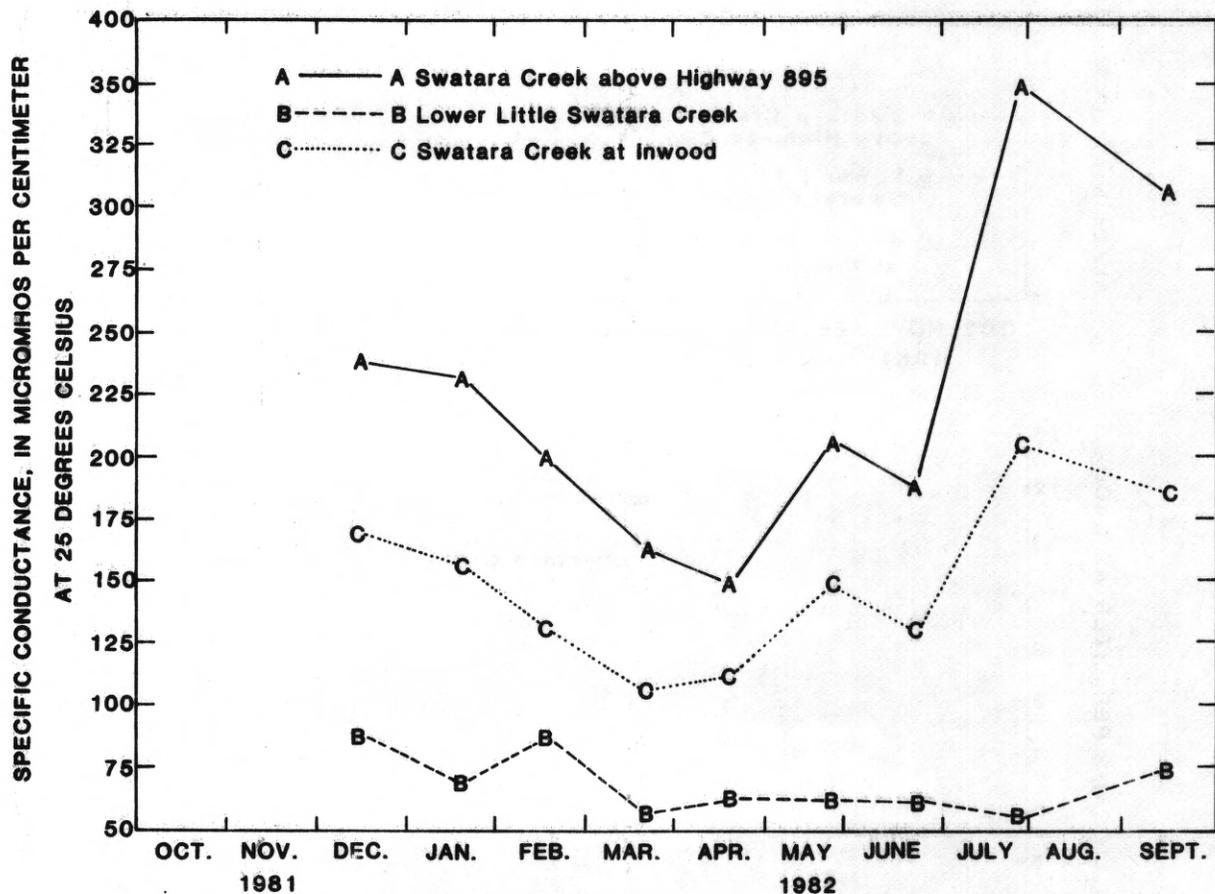


Figure 13.--Monthly variation of specific conductance during baseflow.

Chemical oxygen demand is a measure of the materials that can be oxidized in the waters, and is a helpful tool in determining the amount of organic and reducing material present. The high chemical oxygen demand concentrations at all three sites on June 22 (fig. 14), were measured during a high base flow when large amounts of organic material, sewage, were observed floating in the streams. Preliminary data also indicate substantial organic material is discharged into the Swatara Creek above Highway 895 during high flows. On August 25, a maximum chemical oxygen demand of 405 mg/L was measured at Swatara Creek above Highway 895 and 556 mg/L at Swatara Creek at Inwood. These values were 40 to 50 times greater than the 10 mg/L commonly measured during base flow.

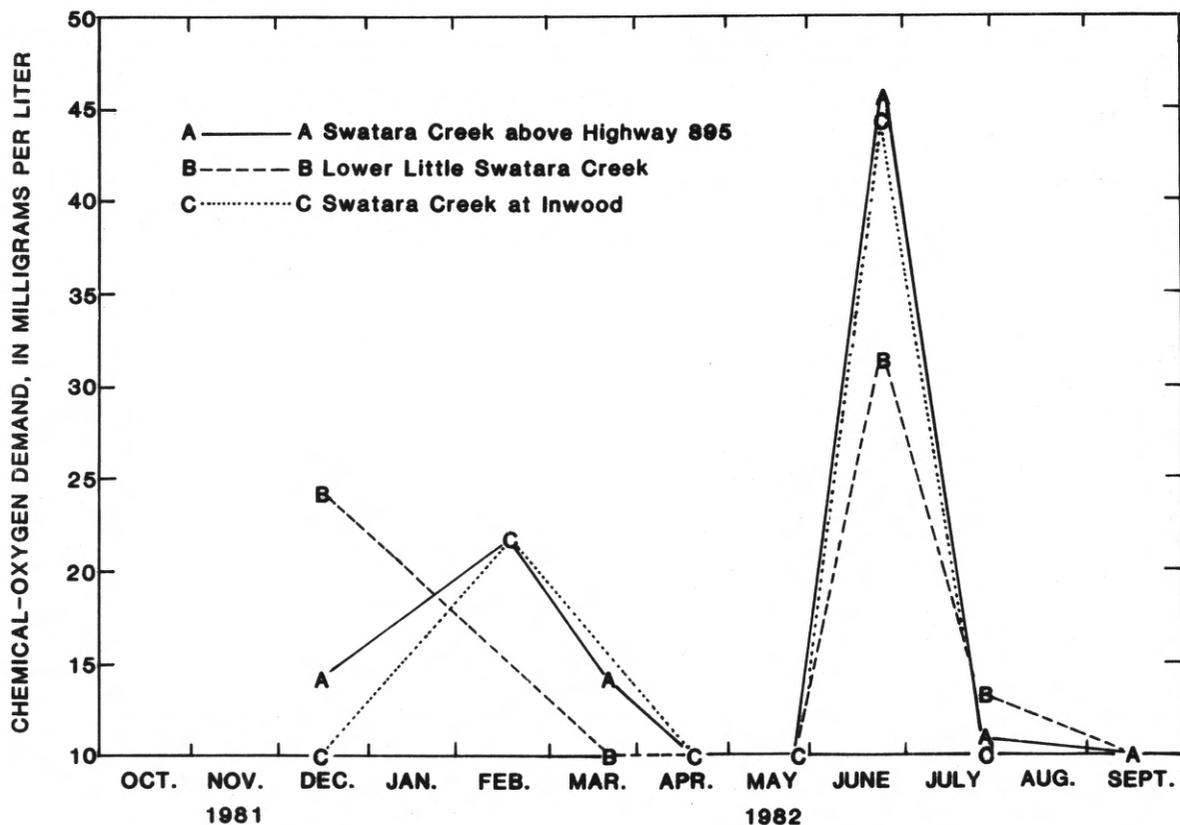


Figure 14.--Monthly variation of chemical oxygen demand during baseflow.

Turbidity is a measure of the ability of the suspended or colloidal material in a solution to reduce light penetration. Excessive turbidity degrades the aesthetic value of recreational water, is a safety hazard in swimming, diving, and boating, and interferes with light penetration required for photosynthesis and plant growth. Turbidity of the Swatara Creek and Lower Little Swatara Creek during base flow (fig. 15) was usually below 15 NTU (Nephelometric turbidity units). Turbidity increased to a maximum of 840 NTU during high flow on August 25, 1982 at Swatara Creek at Inwood.

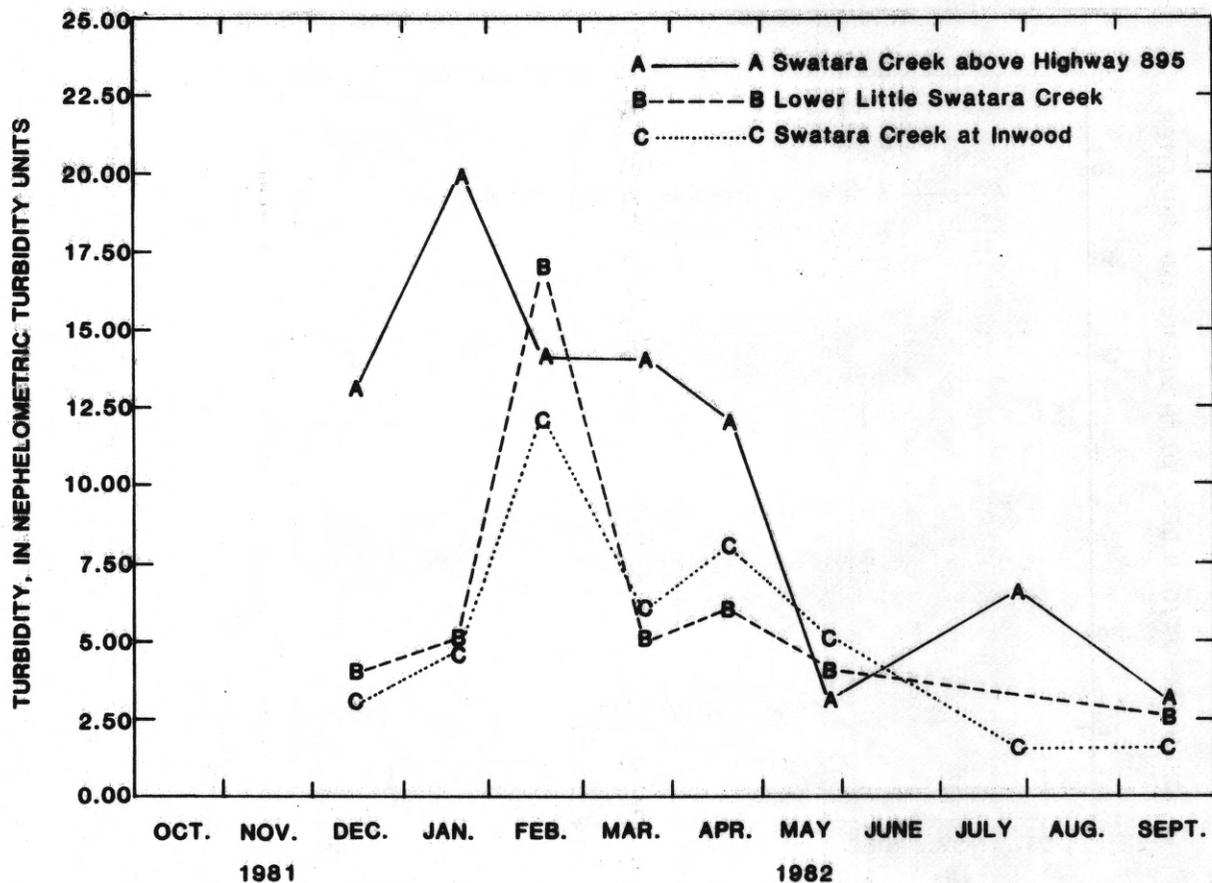


Figure 15.--Monthly variation of turbidity during baseflow.

Sediment

Most fluvial sediment studies report the concentrations and discharges of suspended sediment transported in a given time period. However, the amount of bedload transported by a stream is also important in reservoir studies. A significant amount of the total sediment load transported to the Swatara Creek impoundment may be the result of bedload transport, because much of the sediment is coal and its low specific gravity (1.65) permits it to be transported readily.

Recently, O'Leary and Beschta (1981) measured the bedload of a small forested watershed, and made several observations that apply to the Swatara Creek study area. They stated, "...large fluctuations in bedload transport rates over time intervals during which streamflow did not appreciably change seems an important characteristic of bedload transport in a mountain stream. Our data further indicate that these temporal fluctuations occur rapidly - within minutes." Their study found that stream characteristics that influence bedload fluctuations include nonuniform channel geometry, nonuniform particle size, and nonuniform streamflows. Each of these characteristics are evident in Swatara Creek and greatly affect the sediment available for bedload transport. Pool and riffle channel configurations result in sudden changes in stream velocities and cause some deep stream reaches with slow velocities to fill with organic debris and culm while other reaches are shallow, have faster velocities, and have only bedrock present. Bed material ranges from sand to coarse gravel and cobbles. The size of particles transported and streamflows sharply rise and fall within several hours in response to precipitation. Thus, the amount of bedload measured and used to develop a bedload transport curve for one storm will not necessarily estimate the bedload accurately for another storm even at similar flow conditions.

As no actual measurements of bedload transport during the preliminary study have been made for Swatara Creek or Lower Little Swatara Creek, a bedload transport rating curve has not been made for Swatara Creek. Bedload transport in Swatara Creek probably occurs only during large storms of short duration.

Suspended-Sediment Concentrations and Loads

Daily mean suspended-sediment concentrations from October 1981 through September 1982 (table 5) ranged from 1 to 947 mg/L at Swatara Creek above Highway 895 and from 1 to 614 mg/L at Lower Little Swatara Creek. Suspended-sediment discharges for the same period ranged from 0.14 to 2,620 ton/d at Swatara Creek above Highway 895 and 0.02 to 1,260 ton/d at Lower Little Swatara Creek. During this 1-year period the combined suspended-sediment load from the study area above the planned reservoir was about 16,000 tons.

The streamflow relation developed earlier between the continuous recording station at Swatara Creek above Highway 895 and the partial record station at Inwood, was used to estimate daily flows for Inwood. These daily streamflows, along with the preliminary equation (2) developed by regressing instantaneous sediment discharge versus streamflow at Inwood, were used to determine the sediment discharges for Swatara Creek at Inwood. The ranges of flows and suspended-sediment discharges used to develop the equation were

from 54 to 1,280 ft³/s and 0.40 to 1,130 con/d, respectively, and therefore the equation should not be used to estimate discharges above these values. The annual sediment load was then calculated by summing the estimated daily sediment discharges, by the following relationship:

$$\text{Log } S_I = 2.1982 (\text{Log } Q_I) - 4.1988 \quad (2)$$

where $\text{Log } S_I$ = the logarithm of the daily sediment discharge at Inwood
in tons/d

2.1982 = the slope of the regression line

$\text{Log } Q_I$ = the logarithm of the water (average daily) discharge at
Inwood in ft³/s

and -4.1988 = the intercept of the regression line

Results from this method are not accurate for short periods of record particularly if high flow days are to be subdivided as in this case; however, they do indicate that at least 17,400 tons of suspended sediment were transported by Swatara Creek at Inwood from October 1981 to September 1982. These results are about half the 35,000 ton average annual sediment load estimated by Terraqua Resources Corporation (1982), and are due in part to the 15-percent below-normal streamflows during the study. The quantities and yields of sediment for the stations are listed below in table 6.

Table 6.--Summary of annual suspended-sediment loads and yields, 1982 Water Year

Station	Drainage area (mi ²)	Load (tons)	Yield (ton/mi ²)
Swatara Creek above Highway 895	72.6	11,300 ^{1/}	157
Lower Little Swatara Creek at Pine Grove	34.3	4,700	137
Swatara Creek at Inwood	169	17,400	103

^{1/} Sediment records at this station began on October 23, 1981. However, no storms occurred between October 1 and October 23, 1981; therefore the annual sediment load would not have been significantly different.

The low sediment yield at Inwood compared to that at the other stations is due to several factors. First, there is a large increase in forest cover between Pine Grove and Inwood that reduces the amount of sheet erosion and the amount of sediment transported from tributaries entering below Pine Grove. Secondly, some of the sediment discharged by Lower Little Swatara Creek and Swatara Creek at Pine Grove may be deposited in the relatively flat stretch of channel between Pine Grove and Inwood. Thirdly, the main tributary entering Swatara Creek below Pine Grove at Suedberg flows through Lebanon Reservoir,

which traps much of the suspended material before it reaches Swatara Creek and the planned impoundment area at Inwood. In summary, about 17,400 tons of suspended sediment were transported to the planned impoundment area in the 1982 water year, and 65 percent of the suspended sediment was transported by Swatara Creek above Highway 895 which occupies 43 percent of the drainage area.

Particle-Size Distribution

Assuming that the discharge weighted particle-size analyses (table 9) are representative, 32 percent of the suspended sediment is clay, 37 percent is silt, and 31 percent is sand at Swatara Creek above Highway 895. Sand and silt analyses of the suspended sediment from Swatara Creek at Inwood also show a similar composition. At Lower Little Swatara Creek, 41 percent of the suspended sediment is clay, 51 percent silt, and only 8 percent is sand. Therefore, of the 17,400 ton suspended-sediment load transported from the study area, about 6,000 consisted of clay, 7,100 tons of silt, and 4,300 tons of sand.

Chemistry of Bottom Material

The streambed at and above Inwood contains high concentrations of metals that are contributed primarily by the Swatara Creek headwaters (table 7 and fig. 2). As shown in the table, concentrations of aluminium, iron, and manganese were 7, 4, and 2 times greater, respectively, at Swatara Creek above Highway 895 than at Lower Little Swatara Creek. These conditions are caused by acid mine drainage and the associated precipitation and sorption of metals to bottom material in Swatara Creek. Concentrations of these metals are not conducive to aquatic biota.

Table 7.--Metals and nutrients associated with bottom material on September 14, 1982
[constituent concentrations in µg/g except as footnoted]

Location	Aluminum	Iron	Manganese	Carbon ^{1/} inorganic as C	Carbon ^{1/} organic as C	Nitrogen organic as N	Nitrogen nitrite plus nitrate as N	Nitrogen Ammonia as N	Phosphorus as P
Swatara Creek above highway 895	5,600	13,000	650	<0.1	420	7,800	5	11	170
Lower Little Swatara Creek at Pine Grove	900	2,900	340	.2	16	2,000	4	4	250
Swatara Creek at Suedberg (site C on fig. 2)	580	2,500	220	< .1	97	1,400	<2	<0.4	72
Swatara Creek 2.3 miles upstream from Inwood site (site B on fig. 2)	660	2,800	370	< .1	69	1,900	<2	.6	260
Swatara Creek 1.6 miles upstream from Inwood (site A on fig. 2)	1,700	5,700	1,000	.5	290	1,400	3	2	130
Swatara Creek at Inwood	870	3,300	720	< .1	280	6,000	<2	0.5	51

^{1/} Concentrations for these constituents are g/Kg.

In addition to the metals, substantial quantities of nutrients are found in the bottom material in the study area. The highest concentrations of organic nitrogen were found in the bottom material at Swatara Creek above Highway 895 and Swatara Creek at Inwood (table 7). Organic nitrogen and ammonia nitrogen concentrations were at least 2.5 times greater at Swatara Creek above Highway 895 than at any other site except for organic nitrogen at Inwood. Organic carbon was also significantly higher at Swatara Creek above Highway 895 than any other site. Phosphorous was highest at site B on Swatara Creek, 2.3 miles upstream of Inwood and at Lower Little Swatara Creek.

The sewage-treatment plant at Pine Grove has secondary treatment facilities, but untreated sewage from outside the borough is discharged into Swatara Creek. Visible quantities of sewage have been observed during routine visits to Swatara Creek above Highway 895. Presence of this sewage accounts for the high nutrient content of bottom material in Swatara Creek.

Chemical Characteristics

Nutrients

The two major nutrients required for algal growth are dissolved nitrogen and phosphorus. When these two constituents are coupled with proper light intensities and water temperatures, excessive algal growth may occur. The literature suggests 0.3 mg/L of inorganic nitrogen and 0.01 mg/L of phosphorus are critical concentrations which, when exceeded, can stimulate excessive growth of algae (McKee and Wolf, 1963; Harms and others, 1974). The U.S. Environmental Protection Agency (1976) recommends that total phosphorus should not exceed 0.05 mg/L at the point where it enters any lake or reservoir.

Measured nitrogen concentrations for discharges from both Swatara Creek above 895 and Lower Little Swatara Creek exceeded the critical values during the entire study period. Most nitrogen at both Swatara Creek above Highway 895 and Lower Little Swatara Creek was transported as dissolved nitrate; however, the concentrations varied greatly between the two stations as indicated by the median values in table 5 and figure 16. The median concentration for dissolved ammonia nitrogen of 0.15 mg/L at Swatara Creek above Highway 895 was five times greater than the median for Lower Little Swatara Creek, and the median concentration for dissolved nitrate nitrogen of 1.4 mg/L at Lower Little Swatara Creek was almost twice the median of Swatara Creek above Highway 895. Median total organic nitrogen concentrations were similar at both Lower Little Swatara Creek and Swatara Creek above Highway 895 as values were 0.80 mg/L and 0.78 mg/L, respectively. Median dissolved organic and ammonia nitrogen concentrations measured downstream at Swatara Creek at Inwood indicate both decrease between Pine Grove and Inwood. The median concentration at Inwood was 0.90 mg/L for dissolved nitrate nitrogen and 0.08 mg/L for dissolved ammonia nitrogen. The median total organic nitrogen concentration of 0.77 mg/L for Inwood was similar to that calculated for both upstream stations.

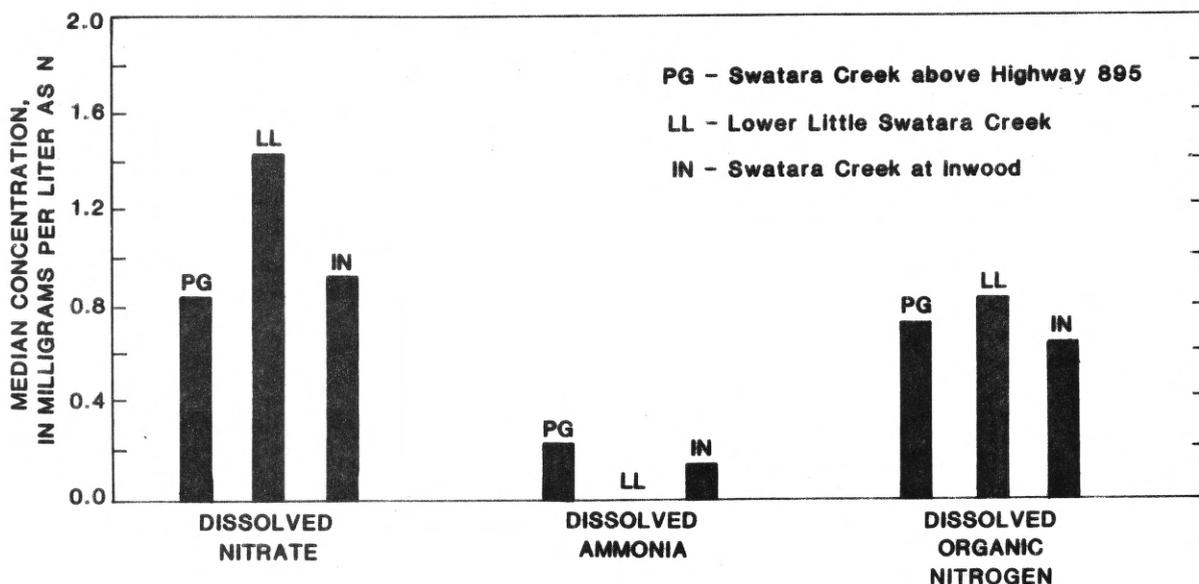


Figure 16.--Median concentrations of dissolved nitrate, ammonia, and organic nitrogen.

The maximum instantaneous ammonia nitrogen concentration of 0.82 mg/L at Swatara Creek above Highway 895 occurred during low flow in September and was 40 times greater than the concurrent concentration measured at Lower Little Swatara Creek and 80 times greater than the concurrent concentration measured at Swatara Creek at Inwood. The source of these high ammonia concentrations may be due to sewage discharges or other point sources upstream from Highway 895. Maximum ammonia nitrogen concentrations at Lower Little Swatara Creek occurred during high flow in February. Maximum concentrations for dissolved nitrate of 2.6 mg/L were measured in January and February at Lower Little Swatara Creek, whereas, corresponding measurements at Swatara Creek above Highway 895 were 1.1 and 1.6 mg/L, respectively. The maximum total organic nitrogen concentration, however, was much higher at Swatara Creek above Highway 895 (2.2 mg/L); whereas a maximum of 1.4 mg/L was measured at Lower Little Swatara on the same day, August 25, 1982.

Instantaneous discharges for nitrogen constituents ranged from less than 0.01 ton/d for total nitrite nitrogen at all three stations to 5.53 ton/d for dissolved nitrate nitrogen at Swatara Creek at Inwood. Maximum nitrite, nitrate, and ammonia nitrogen discharges at Swatara Creek above Highway 895 were nearly equal to those at Lower Little Swatara Creek (table 5). However, the maximum dissolved and total organic nitrogen discharges of Swatara Creek above Highway 895 of 1.24 ton/d and 2.21 ton/d were over two times greater than the maximum discharges at Lower Little Swatara Creek.

In summary, most of the nitrogen transported by the Swatara Creek above Highway 895 and Lower Little Swatara Creek is dissolved nitrate, which will be available for biological uptake. The high ammonia concentrations in Swatara Creek above Highway 895 indicate the presence of sewage discharges or other point-source discharges upstream from the sampling site. Substantial quantities of dissolved and suspended organic nitrogen will be transported to the impoundment from the Swatara Creek above Highway 895.

Measured dissolved phosphorus concentrations were commonly 0.01 mg/L or less, indicating that phosphorus may be the limiting nutrient for plant growth. Total phosphorus concentrations measured at both the Swatara Creek above Highway 895 and Lower Little Swatara Creek were usually two to three times greater than dissolved concentrations, indicating that much of the phosphorus transported in the study area is associated with the suspended sediment. The median total phosphorus concentrations for Lower Little Swatara Creek and Swatara Creek above Highway 895 were 0.07 mg/L and 0.05 mg/L, respectively; while corresponding median dissolved phosphorus concentrations were 0.03 mg/L and 0.02 mg/L. Similar results were seen downstream at Inwood where the median total phosphorus concentration was 0.04 mg/L and the median dissolved phosphorus concentration was 0.02 mg/L. Conservation efforts to reduce the phosphorus, especially that attached to the suspended sediment, discharged from Lower Little Swatara Creek probably would greatly reduce the phosphorus available for algal growth.

The maximum instantaneous total phosphorus concentrations for both upstream stations occurred during the storm of February 2 to 5, 1982 when 0.31 mg/L was measured at Lower Little Swatara Creek and 0.28 mg/L at Swatara Creek above Highway 895. The maximum total phosphorus concentration measured for Swatara Creek at Inwood was 0.25 mg/L during the storm of August 24 to 26, 1982.

Instantaneous total phosphorus discharges ranged from less than 0.01 ton/d at all three stations to 0.56 ton/d at Lower Little Swatara Creek. Dissolved phosphorus discharges ranged from less than 0.01 ton/d at all three stations to 0.18 ton/d at Lower Little Swatara Creek at Pine Grove.

Thus, unlike nitrogen, most of the phosphorus transported by Swatara Creek is suspended, and therefore may deposit to the stream bottom. During high flows, resuspension and resolution of this phosphorus may occur, making it available as nutrients for plant growth. Brown and others (1983) say that generally 20 to 40 percent of sediment phosphorus from agricultural watersheds is bioavailable, and Young and others (1982) indicate 55 percent of particulate phosphorus in municipal wastewaters is available in the short term and 63 percent is ultimately available.

Metals

Aluminum, iron, and manganese are often contained within coal-bearing formations, and therefore are common to acid-mine drainage. Iron and manganese concentrations measured in Swatara Creek at both Pine Grove and Inwood exceeded the recommended U.S. EPA criteria (U.S. Environmental Protection Agency, 1976, 1980) and Pennsylvania water-quality standards (PaDER, 1979). The concentrations and discharges in table 5 reflect the large differences in metal concentrations between the mine drainage of Swatara Creek above Highway 895 and the forested and agricultural drainage of Lower Little Swatara Creek. These results confirm that mine drainage affects the water quality at both Pine Grove and Inwood.

In the past, aluminum was thought to be harmless because it is the most abundant metal on earth and usually occurs as complex aluminum silicates such as feldspar. By using treatment processes, these suspended forms of aluminum

can readily be removed from water to be used for drinking. Subsequently, no criterion for aluminum has been established by the U.S. EPA, and the Pennsylvania water-quality standard states that aluminum should not be greater than 0.1 of the 96-hr LC 50 (lethal concentration for 50 percent of the specific species if maintained for 96 hours) for representative important species. The 96-hr LC 50 value has not been determined for many fish species and may be quite different depending on other characteristics of the native water such as pH. Thus, water with high suspended aluminum concentrations, like that which enters the planned impoundment area, is generally felt to be safe for drinking after treatment. However, recent investigations at Cornell University, Dartmouth College, and the University of Vermont, have linked free aluminum, caused by the effects of acid rain, with potentially toxic concentrations in mountain soil, water, and streams (Davis, 1983). Further studies need to be done to determine what concentrations constitute toxic levels and the possible effects on public health.

Differences between the median dissolved and total aluminum concentrations in table 5 indicate most aluminum is transported in the suspended phase and is deposited on the streambed before reaching Inwood. The median total aluminum concentration at Inwood of 450 $\mu\text{g/L}$ was less than half the median for Swatara Creek above Highway 895 (fig. 17 and table 5). The median concentration of 1,100 $\mu\text{g/L}$ for total aluminum at Swatara Creek above Highway 895 was nearly twice the median concentration of 670 $\mu\text{g/L}$ at Lower Little Swatara Creek. The median concentration for dissolved aluminum was about 100 $\mu\text{g/L}$ for all three stations. Figure 18 illustrates the direct relation between concentrations of total aluminum and suspended sediment during high flows at each station. Maximum concentrations for total aluminum at Swatara Creek above Highway 895 and at Inwood of 66,000 $\mu\text{g/L}$ and 13,000 $\mu\text{g/L}$, respectively, were measured during the storm of August 25, 1982, which occurred during the mid-summer growing phase. The maximum total aluminum concentration of 3,400 $\mu\text{g/L}$ for Lower Little Swatara Creek was measured during the storm in February when the ground was frozen. Conversely, the maximum dissolved aluminum concentrations were highest at the mine drainage sites above Highway 895 and at Inwood during the colder months, and highest at Lower Little Swatara Creek during the storm in August.

The maximum instantaneous discharge for total aluminum at Swatara Creek above Highway 895 was 66.3 ton/d, more than 10 times greater than the maximum for Lower Little Swatara Creek and three times greater than the maximum of 22.6 ton/d measured at Swatara Creek at Inwood.

The U.S. EPA criteria (U.S. Environmental Protection Agency, 1976, 1980) for iron concentrations are 0.3 mg/L for domestic water supplies and 1.0 mg/L for freshwater aquatic life. The Pennsylvania water-quality standard states, "total iron concentrations should not be more than 1.5 mg/L and dissolved iron concentrations more than 0.3 mg/L." The U.S. EPA criteria for domestic water supplies were exceeded by 100 percent and 71 percent of the samples, respectively, for total and dissolved iron at Swatara Creek above Highway 895. The U.S. EPA criteria for freshwater aquatic life were exceeded by 90 percent and 10 percent of the samples, respectively, for total and dissolved iron at Swatara Creek above Highway 895, whereas 71 percent of the samples for both total and dissolved iron exceeded the Pennsylvania water-quality standard. At both Lower Little Swatara Creek and Swatara Creek at Inwood,

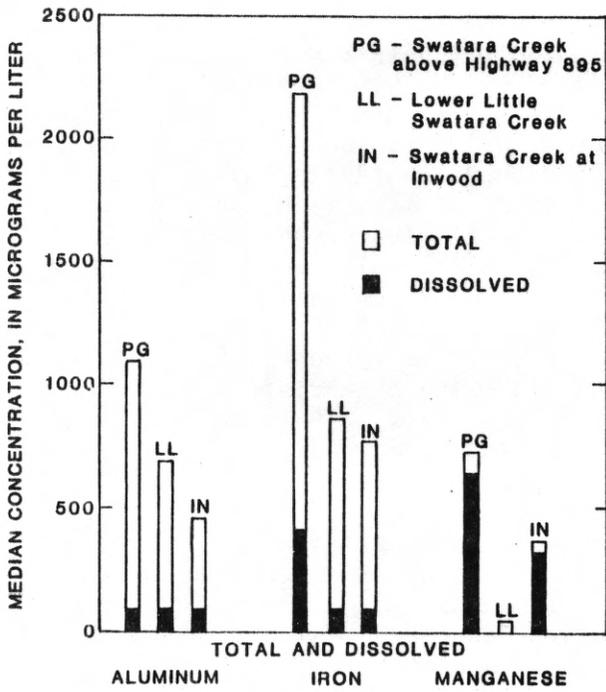


Figure 17.--Median concentrations of total and dissolved aluminum, iron, and manganese.

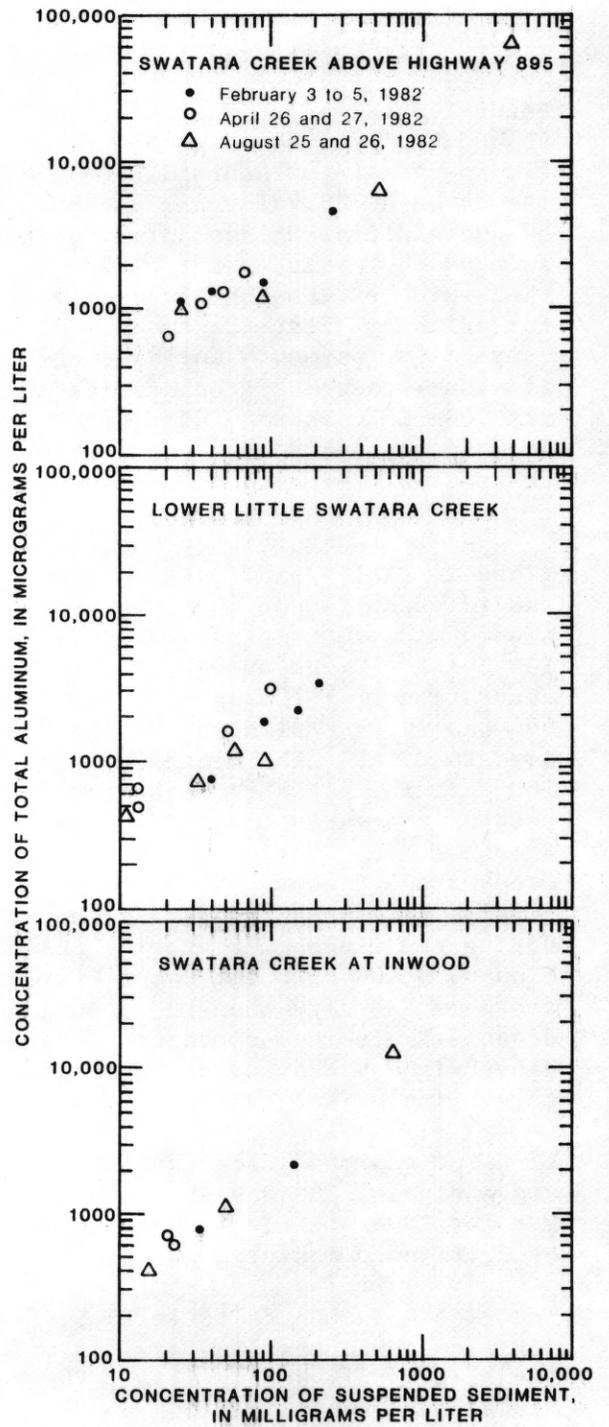


Figure 18.--Relation between concentrations of total aluminum and suspended sediment during high flows.

25 percent of the total iron samples exceeded the Pennsylvania standard and 75 percent of the samples exceeded the U.S. EPA criterion for domestic water supplies.

Like aluminum, differences between the total and dissolved median iron concentrations indicate most of the iron is transported in the suspended phase (fig. 17). The median total iron concentration measured at Inwood was less than one-third of that measured above Highway 895 (fig. 16), indicating that iron may be deposited on the streambed between Pine Grove and Inwood. The median concentrations for total iron at Swatara Creek above Highway 895 (2,200 $\mu\text{g/L}$) was significantly higher than the median concentration at Lower Little Swatara Creek (850 $\mu\text{g/L}$). The median concentration for dissolved iron was over five times greater at Swatara Creek above Highway 895 (430 $\mu\text{g/L}$) than at Lower Little Swatara Creek at Pine Grove (85 $\mu\text{g/L}$).

Figure 19 illustrates the direct relation between total iron and suspended sediment during high flows at each station. The maximum total iron concentration for Swatara Creek above Highway 895 of 100,000 $\mu\text{g/L}$ was measured during the midsummer storm of August 25, 1982, whereas the maximum for Lower Little Swatara Creek (7,900 $\mu\text{g/L}$) was measured during the storm of February 3, 1982.

Dissolved-iron concentrations, also like aluminum, were highest during the colder months at Swatara Creek above Highway 895 and at Inwood, whereas dissolved iron concentrations at Lower Little Swatara Creek showed less variation throughout the year.

The maximum instantaneous discharge for total iron of 100 ton/d measured at Swatara Creek above Highway 895 was more than seven times greater than the maximum of 14 ton/d measured for Lower Little Swatara Creek and 2.7 times greater than that measured for Swatara Creek at Inwood.

The U.S. EPA criterion for manganese is 50 $\mu\text{g/L}$ for domestic water supplies. The Pennsylvania water-quality standard states, "manganese should not be greater than 1.0 mg/L." These values were not established on toxicological basis, but were established primarily to reduce aesthetic damage and prevent objectional tastes in beverages. Removal of manganese from water for domestic uses requires special treatment such as pH adjustment, aeration, superchlorination, or chemical precipitation.

All measured concentrations of dissolved and total manganese at Swatara Creek above Highway 895 and at Inwood exceeded the U.S. EPA criterion. Forty-five percent of the samples for total manganese and 19 percent of the samples for dissolved manganese from Lower Little Swatara Creek exceeded U.S. EPA criteria.

Median total and dissolved manganese concentrations in figure 17 and table 5 show that most manganese transported at Swatara Creek above Highway 895 and at Inwood is dissolved and most at Lower Little Swatara Creek is suspended. The median concentrations for total and dissolved manganese were 740 $\mu\text{g/L}$ and 640 $\mu\text{g/L}$, respectively, at Swatara Creek above Highway 895. They were about two times greater than median concentrations at Inwood and more than 14 times greater than the median at Lower Little Swatara Creek. Figure 20 illustrates that the relation between total manganese and suspended-sediment at Lower Swatara Creek is well defined, but the relations at Swatara

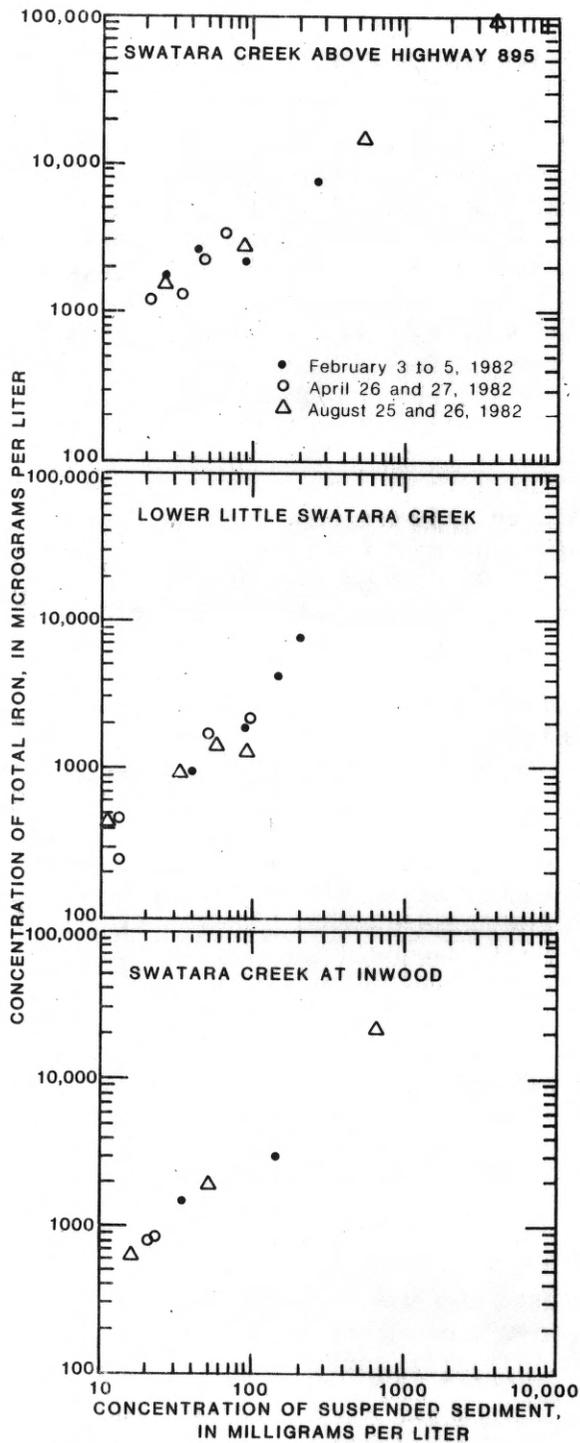


Figure 19.--Relation between concentrations of total iron and suspended sediment during high flows.

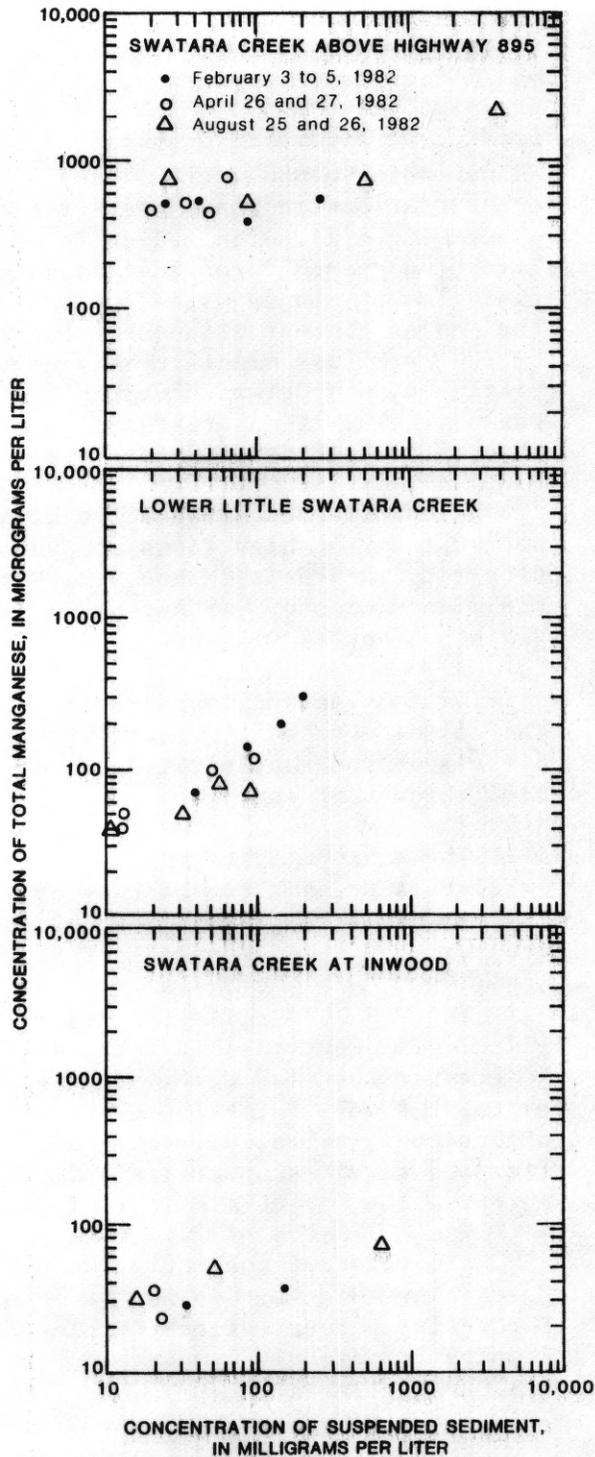


Figure 20.--Relation between concentrations of total manganese and suspended sediment during high flows.

Creek above Highway 895 and at Inwood are not well defined. These results may be due in part to the changes in the solubility of manganese at the mine-drainage sites where pH is lower and the oxidation potential higher and is consistent with work presented by Hem (1970). Maximum concentrations for total manganese at Swatara Creek above highway 895 and at Inwood were 2300 $\mu\text{g/L}$ and 710 $\mu\text{g/L}$, respectively, and occurred during the midsummer storm of August 25, 1982. The maximum for Lower Little Swatara Creek was 670 $\mu\text{g/L}$ and occurred in June.

The maximum instantaneous total manganese discharge at Swatara Creek above Highway 895 (7.53 ton/d) was more than 13 times greater than the maximum for Lower Little Swatara Creek at Pine Grove and almost 6 times greater than that for Swatara Creek at Inwood.

The U.S. EPA criterion for total lead for freshwater aquatic life in water with a hardness of 100 mg/L as CaCO_3 is 3.8 $\mu\text{g/L}$, and the human-health criterion is 50 $\mu\text{g/L}$. At both Swatara Creek above Highway 895 and Lower Little Swatara Creek, more than 50 percent of the samples analyzed for total lead exceeded the U.S. EPA criterion for freshwater aquatic life. The human-health criterion was exceeded at both Swatara Creek above Highway 895 and at Inwood during a storm on August 25, 1982. Preliminary data in figure 21 suggest that the primary source of lead is from Swatara Creek above Highway 895, and a direct relationship exists between total lead and suspended sediment during particular storms. Median lead concentrations (fig. 22) were greatest at Swatara Creek above Highway 895 (19.0 $\mu\text{g/L}$) and decreased from dilution downstream to Swatara Creek at Inwood (9.3 $\mu\text{g/L}$). Because lead does not naturally occur in the concentrations measured, there may be a point source that contributes lead to Swatara Creek above Highway 895.

Maximum instantaneous concentrations for total lead measured at Swatara Creek above Highway 895 and at Inwood were 172 $\mu\text{g/L}$ and 52 $\mu\text{g/L}$, respectively, and occurred during the August 25, 1982 storm. The maximum total lead concentration measured at Lower Little Swatara Creek (40 $\mu\text{g/L}$) also occurred during the August 25, 1982 storm.

The maximum instantaneous total lead discharge at Swatara Creek above Highway 895 of 0.17 ton/d was 8 times greater than the maximum measured for Lower Little Swatara Creek at Pine Grove and 2 times greater than that at Swatara Creek at Inwood.

Copper and zinc concentrations at Swatara Creek above Highway 895 and at Inwood also occasionally exceeded the respective U.S. EPA criteria for fresh-water aquatic life. The U.S. EPA criterion for total copper states, that copper concentrations should not exceed 22 $\mu\text{g/L}$ at any time, if water has a hardness of 100 mg/L as CaCO_3 , and total zinc should not exceed 47 $\mu\text{g/L}$ as a 24-hour average (U.S. Environmental Protection Agency 1980). The maximum concentrations for copper measured at Swatara Creek above Highway 895 and at Inwood were 220 and 60 $\mu\text{g/L}$, respectively. Median concentrations were below the U.S. EPA criterion. Maximum zinc concentrations measured at Swatara Creek above Highway 895 and at Inwood were 310 and 120 $\mu\text{g/L}$, respectively. The median concentrations for total zinc of 85 $\mu\text{g/L}$ and 60 $\mu\text{g/L}$, at these sites, respectively, also exceeded the criterion.

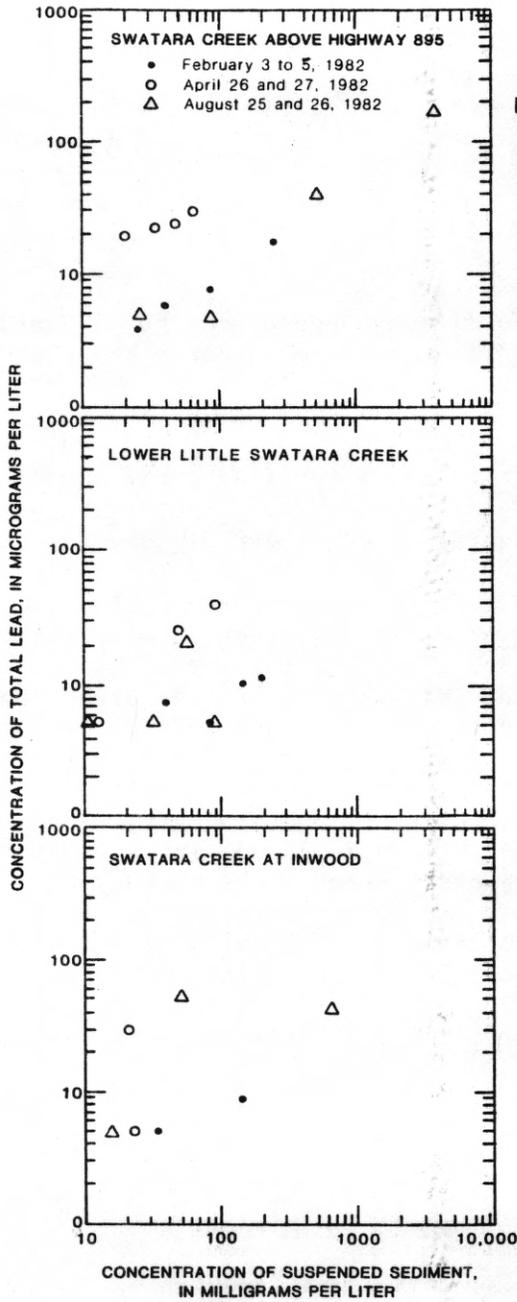


Figure 21.--Relationship between concentrations of total lead and suspended sediment during high flows.

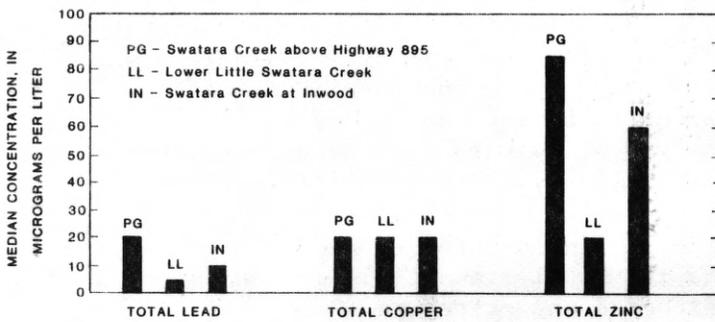


Figure 22.--Median concentrations of total lead, copper, and zinc.

Major Dissolved Ions

The ionic composition of Swatara Creek changes from above Highway 895 to Inwood. These changes result mostly from dilution of Swatara Creek by the inflow of Lower Little Swatara Creek. The median sulfate concentration is 10 times higher for mine drainage from Swatara Creek above Highway 895 than agricultural and forested drainage from Swatara Creek (table 5). Stiff diagrams that depict the median concentrations of each major ion (fig. 23), show the differences in ionic composition at the three sites. The water at Swatara Creek above Highway 895 is a mixed cation-sulfate type, whereas Lower Little Swatara Creek is a mixed cation and mixed anion type. Lower Little Swatara Creek water mixes with Swatara Creek, thereby reducing the concentrations of all ions, particularly sulfate, at Inwood.

Major-ion concentrations at all three sites indicate that water in the Swatara Creek State Park Reservoir is generally soft, with hardness values usually less than 70 mg/L as CaCO_3 for Swatara Creek and 30 mg/L as CaCO_3 for Lower Little Swatara Creek. No ions exceeded U.S. EPA criteria or Pennsylvania water-quality standards. However, instantaneous and median sulfate concentrations and discharges (table 5) indicate that most sulfate in

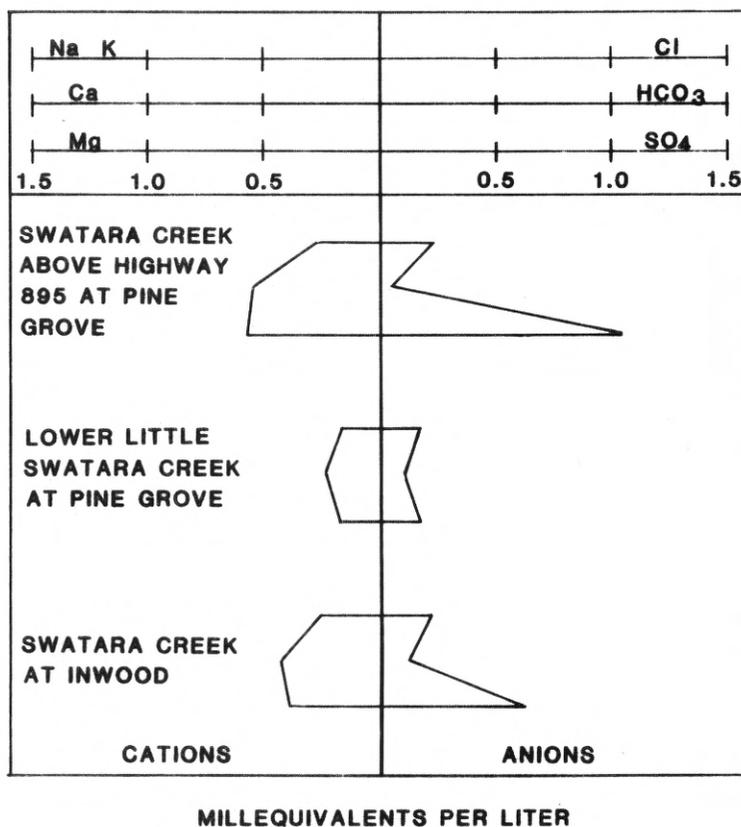


Figure 23.--Stiff diagrams of major ions for Swatara Creek Reservoir sampling sites.

Swatara Creek originates from the mine drainage upstream from Highway 895. The maximum measured sulfate concentration was 130 mg/L at Swatara Creek above Highway 895 and 25 mg/L at Lower Little Swatara Creek. Median concentrations were 50 and 5 mg/L, respectively. Downstream at Inwood, the maximum concentration was 60 mg/L and the median concentration was 30 mg/L. Instantaneous maximum sulfate discharges for Swatara Creek above Highway 895, Lower Little Swatara Creek, and Swatara Creek at Inwood were 50.2, 18.0, and 52.2 ton/d, respectively.

Bacteriological Characteristics

Fecal coliform concentrations in Swatara Creek and Lower Little Swatara Creek were usually below the U.S. EPA criterion of 200 colonies per 100 mL of water for bathing waters. Bacteria concentrations, however, exceeded the criterion and persisted at high levels for several days during and after a storm.

Table 8 lists bacteriological data collected during the 1982 water year. Samples analyzed in the field commonly had higher bacteria concentrations, probably due to the increased die off of bacteria in samples that were held up to 24 hours before being analyzed by PaDER laboratory personnel. Concentrations for both FC (fecal coliform) and FS (fecal streptococci bacteria) were usually higher at Lower Little Swatara Creek than at Swatara Creek above highway 895 and at Inwood. Although the FC:FS ratio^{1/} is commonly used to differentiate animal and human sources of bacteria, it cannot be used for these sites because the acid mine drainage in Swatara Creek probably reduces the survival rate of the bacteria (Hackney and Bissonnette, 1978). If conservation measures are taken to reduce or neutralize the acid mine drainage entering the Swatara Creek headwaters, bacteria concentrations at Swatara Creek above Highway 895 and at Inwood may significantly increase, and the FC:FS ratio may be useful in determining the sources of bacterial contamination.

PRELIMINARY ESTIMATION OF THE WATER QUALITY OF THE PLANNED SWATARA CREEK RESERVOIR

In order to predict the water quality of the planned Swatara Creek Reservoir, numerous characteristics of the lake must be considered. These characteristics include the detention time of water in the lake, the timing and extent of thermal and chemical stratification, sedimentation within the lake, the chemical loads entering the lake, and the chemical concentrations in the lake. These factors, which are at least partly related to streamflow, are discussed below.

Any land use or water treatment above the lake may significantly affect future water quality in the lake. For example, if mine drainage into Swatara Creek is reduced and if corresponding improvements in sewage treatment are not made, fecal coliform and fecal streptococci bacteria concentrations above Highway 895 may increase and have a detrimental impact on the lake.

^{1/} If FC:FS is less than 0.7, then animal source is suspected; if FC:FS is greater than 4.0, then human source is suspected.

Table 8.--Summary of bacteriological data, 1982 water year

Date	Time	Fecal coliform (colonies/100 mL)		Fecal Streptococci (colonies/100 mL)	
		Field	Laboratory	Field	Laboratory
<u>Swatara Creek above Highway 895 at Pine Grove</u>					
December 15, 1981	0850	34	40	220	40
January 20, 1982	1230	K8	10	80	40
February 3, 1982	1345		900		4,200
February 3, 1982	2130		1,000		3,600
February 4, 1982	1050		600		3,100
February 5, 1982	1400	K570		K3500	
February 16, 1982	1135	32	140	240	50
March 23, 1982	0900	<4	10	K21	10
April 20, 1982	1130	K3	25	54	25
April 26, 1982	1630		25		300
April 26, 1982	2345		420		620
April 27, 1982	0220		120		380
April 27, 1982	0945		340		340
May 25, 1982	1150	K39	30	100	80
June 22, 1982	0900	30	10	88	50
July 27, 1982	0945	K4	10	110	50
August 25, 1982	0615		9,200		2,200
August 25, 1982	1030				
August 25, 1982	1815		2,400		4,800
August 26, 1982	1415		40		40
September 14, 1982	0900	44	20	800	3
<u>Lower Little Swatara Creek at Pine Grove</u>					
December 15, 1981	1115	25	80	100	20
January 20, 1982	1500	16	110	84	60
February 3, 1982	1830		2,900		22,000
February 4, 1982	0150		1,900		21,000
February 4, 1982	1245		1,000		2,700
February 5, 1982	1110	K260	340	2,000	340
February 16, 1982	0915	800	2,100	>240	5,100
March 23, 1982	1130	100	10	K61	10
April 20, 1982	1345	K32	75	170	25
April 26, 1982	1430		180		120
April 26, 1982	2000		2,800		2,200
April 27, 1982	0100		2,400		1,500
April 27, 1982	1215		780		2,500
May 25, 1982	1330	400	410	200	220
June 22, 1982	1200	260	260	280	20
July 27, 1982	1300	160	140	270	
August 25, 1982	0430		1,400		4,000
August 25, 1982	1110				48,000
August 25, 1982	1635		21,000		23,000
August 26, 1982	1145		6,100		1,800
September 14, 1982	1130	120	120	67	190
<u>Swatara Creek at Inwood</u>					
December 15, 1981	1330	K6	10	18	10
January 20, 1982	1000	<2	10	K6	10
February 4, 1982	0745		1,000		5,200
February 5, 1982	1615	K130		42	370
February 16, 1982	1435	K25	100	>240	280
March 3, 1982	1455	<4	10	K4	10
April 20, 1982	0745	K9	25	160	25
April 26, 1982	1830		600		100
April 27, 1982	1500		270		110
May 25, 1982	0845	180	200	110	50
June 22, 1982	1400		30	94	90
July 27, 1982	1445	39	50	200	10
August 25, 1982	0745		7,000		17,000
August 25, 1982	1430		3,500		4,000
August 26, 1982	1645		1,700		100
September 14, 1982	1445	K67	70	62	40

< = less than > = greater than K = based on non-ideal colony count

Detention Time

The detention time of water in the planned lake will be much longer than in the fast-moving water of Swatara Creek. This will allow slow physical and chemical reactions to come closer to completion (Hem, 1970). The detention time in the Swatara Creek Reservoir will be longest during low flows, which usually occur from August through November. For example, at a typical flow of 40 ft³/s, recorded during October and November 1981, and September 1982, the planned lake will require 204 days for a complete exchange of water. As a result, the lake will become a holding basin in which thermal and chemical stratification may occur. At high flows of about 1,000 ft³/s an exchange would occur in about 8 days.

Thermal and Chemical Stratification

As the morphometric characteristics of the planned Swatara Creek Reservoir will be similar to those at nearby Blue Marsh Lake, the lake's processes of thermal stratification are expected to be similar (Barker, J. L., oral commun. 1983). However, because the chemical composition of the inflows for these impoundments is different, chemical stratification in Swatara Creek Reservoir will probably be different from Blue Marsh Lake and can only be discussed qualitatively as suggested by Flippo (1970).

Like many lakes in the temperate zone, the planned Swatara Creek Reservoir can be expected to thermally stratify in response to the seasonal conditions found in this area. Base-flow water temperatures reflected these seasonal differences in the 1982 water year. Water temperatures ranged from 0.0° C in the winter to 24.5° C in the summer. During spring base flow, as the detention time of the water in the lake increases and the lake becomes calm, solar radiation will be absorbed by the surface of the lake. As the surface water of the lake becomes warmer and less dense, a thermal resistance to mixing will develop. Gradually, three regions of different temperatures and densities (epilimnion-upper, metalimnion-middle, hypolimnion-lower) can be expected to form. Wetzel (1975) states, "When streamflow enters a lake or reservoir, the incoming water will flow into the density layer in the lake which is most similar to its density; this process is governed by temperature, dissolved material and suspended sediment." In early summer, warm base flow will flow over top of the denser, cooler impounded water. In contrast, the winter base flow will be cooler and denser than summer base flow, and will create little mixing in the shallow upstream part of the lake. The main part of these discharges flow down the slope of the reservoir bed, to a depth where its density is in equilibrium with that of the impounded water, and then flow horizontally to the point of outflow.

In the narrow Swatara Creek Reservoir, the introduction of the cooler base flows during the winter and late spring will result in an accumulation of organic nitrogen, phosphorus, and metals in the hypolimnion. If large amounts of oxidizable material are transported to the planned lake during storms and base flow, and if organic material is deposited in the spring and summer from the epilimnion, dissolved oxygen in the hypolimnion may be depleted as early as mid-June. Hydrogen sulfide may also be generated in the anaerobic part of the lake as organic material decomposes in the summer and winter. Dissolved-metal concentrations in the hypolimnion can be expected to increase as anoxic

conditions persist and increased retention times during low flows permit reduction and leaching of the lake sediments. As low base flows persist during the summer, dissolved nitrate and phosphorus concentrations may decrease in the warmer epilimnion due to consumption by algae and other aquatic plants. As the algae die and settle into the hypolimnion, decomposition of the organic matter will use oxygen.

Sedimentation

Data from the investigation showed 46 percent of the annual suspended-sediment load at both Swatara Creek above Highway 895 and Lower Little Swatara Creek was transported during three days: April 3, June 29, and August 28, 1982; these results support McCarren's (1964) conclusion that a high percentage of suspended sediment carried by streams in the Swatara Creek basin is transported during a few storms each year. Therefore, during storms, the proposed impoundment will be impacted by sudden discharges of suspended material. During base flow, much of the suspended material may be trapped in the lake.

The amount of sedimentation that would have occurred in the planned Swatara Creek Reservoir during the 1982 water year was estimated using techniques described by Brune (1953). Assuming the suspended sediment has a density of 55 lb/ft³ and the reservoir has a 78 percent trap efficiency, 494,000 ft³ or 11.4 acre-ft of suspended sediment would have been trapped in the impoundment from October 1981 to September 1982. Because 7,000 acre-ft of the reservoir is designated for sediment deposition, the preliminary data indicate that life expectancy of the lake would be about 614 years. Because streamflows for this part of the study were 15 percent below normal, the average annual suspended-sediment load transported to the planned impoundment may be higher, which would shorten the life expectancy of the lake. Although preliminary data indicate a subimpoundment is not necessary to reduce the suspended-sediment load to the reservoir, a subimpoundment may provide other beneficial water-quality improvements. The deposition and precipitation of sediment, coal fines, and associated metals during low flows will probably be greater in the shallow inflow sections of the lake where velocities are insufficient to keep the particulate matter suspended. As a result, the lake bottom probably will be largely covered by particulate coal. Preliminary data indicate that storm discharges and wave action along the shore line of the lake may resuspended this material and increase the turbidity of the lake substantially.

Initial information also indicates that large storms probably transport significant quantities of coal as bedload in the Swatara Creek. The impact of bedload transport into the planned impoundment will probably be sudden but infrequent.

Chemical Loads and Concentrations

Water-quality data collected during this preliminary investigation show the chemical loads entering and chemical concentrations in the planned impoundment area will largely depend on flow conditions. Base flow water-quality data indicate that the lake will probably be poorly buffered because

measured concentrations of alkalinity and acidity were usually less than 10 mg/L and 5 mg/L as CaCO₃, respectively. As a consequence, the lake may be impacted by acid mine discharges from Swatara Creek above Highway 895, like those measured during storms when the pH dropped to 5.6 and acidity and metal concentrations simultaneously increased. In the absence of acid mine drainage and in response to the consumption of carbon dioxide by photosynthesis in the epilimnion, the pH of portions of the lake may increase substantially higher than the median of 6.5 measured at Inwood.

Nitrogen concentrations measured during both base flows and storms at inflows to the planned lake exceeded the critical values necessary for algal growth during the entire study period. As most of the nitrogen was dissolved, it will be available for biological uptake in and downstream from the planned impoundment. Dissolved phosphorus concentrations were commonly 0.01 mg/L or less, indicating that phosphorus may become a limiting nutrient for plant growth in the lake, especially during base flows from March through July. However, a significant loading of phosphorus and organic nitrogen associated with the suspended sediment occurs during storms. Storms of sufficient magnitude, as those measured in February, April, and August 1982, may resuspend these nutrients and transport them to the planned lake, where they may be trapped along with sediments in the lake's bottom material. Ultimately, these nutrients may become available for resolution, plant enrichment, and algal growth. Brown and others (1983) report that generally 20 to 40 percent of sediment phosphorus from agricultural watersheds is available to aquatic life, and Young and others (1982) indicate 55 percent of particulate phosphorus in municipal wastewaters is available in the short term; 63 percent is ultimately available. Measured base-flow concentrations of dissolved and suspended organic and ammonia nitrogen and bottom-material data indicate that most of the organic and ammonia nitrogen is transported from Swatara Creek above Highway 895. Although sewage from the borough of Pine Grove undergoes secondary treatment, visible discharges of untreated sewage from outside the borough were observed during base flows in Swatara Creek. The high biological oxygen demand created from such high concentrations of nutrients may result in low dissolved oxygen concentrations similar to the case on August 25, 1982 at 6:15 a.m. when 5.6 mg/L (64 percent saturation) of dissolved oxygen was measured.

Water-quality data collected during the 1982 water year indicated that most metal loads to the planned impoundment area were transported during storms and associated with suspended sediment. High concentrations of aluminum, iron, and manganese transported from the Swatara Creek headwaters to the study area were also measured in the bottom material of Swatara Creek at low flows. Like phosphorus, much of the iron, aluminum, lead, copper, and zinc was suspended and may be trapped in the lake and deposited on the lake bottom.

HYPOTHETICAL EFFECTS OF THE RESERVOIR ON DOWNSTREAM WATER QUALITY

As suggested during the preceding discussion, the water quality of Swatara Creek in and downstream from the impoundment will need to be monitored closely. Because the reservoir will stratify thermally and chemically in the summer and autumn, releases during this part of the year will have the most impact on downstream water quality. Conservation releases need to be care-

fully controlled from the release gates, so that water from the hypolimnion with low dissolved oxygen levels and high dissolved metal concentrations will not degrade the downstream water-quality conditions and be detrimental to the aquatic community.

The reservoir will act as a sediment trap and, therefore, reduce the concentrations of total phosphorus, iron, aluminum, lead, copper, and zinc discharged immediately downstream of the impoundment during low and medium flows. Because streamflows at Harper Tavern and other points downstream of Inwood will be affected by the impoundment, and peak flows will probably be reduced, the reservoir is expected to reduce the frequency of large discharges of nutrients and metals such as those currently being measured at Inwood.

When storm discharges are large or when the winter-pool level is to be maintained by releasing water from the hypolimnion, rapid flushing of high concentrations of iron, aluminum, lead, copper, and zinc that may occur could have an adverse effect on the downstream aquatic community.

Acid conditions similar to those reported by the Pennsylvania Fish Commission for Tioga-Hammond Lakes (Baltimore Corps of Engineers, oral commun., 1984) also may occur in the Swatara Creek reservoir. If severe ice buildup occurs on the lake, little mixing may occur because the inflow current will be constricted. When acidic storm discharges from Swatara Creek above Highway 895 enter the lake, they may be trapped in pockets or accumulate near the release structure. This acid buildup may be detrimental to fish in the lake, and release of this water may kill fish downstream.

SUMMARY AND CONCLUSIONS

The preimpoundment water-quality of the proposed Swatara Creek Reservoir was studied and preliminary results for the period June 1981 to October 1982 are summarized below.

Precipitation and streamflow data for the 1982 water year indicate that preliminary data collection was performed during atypical conditions. Near the study area at Lebanon, precipitation in Pennsylvania was 8 percent below normal. Streamflow for the same period just downstream at Swatara Creek at Harper Tavern was 15 percent below the average annual flow.

During this 1-year period, about 2.1 times more discharge entered the planned impoundment area from the coal mining region of the Swatara Creek headwaters above Highway 895 than that from the forested and agricultural area of Lower Little Swatara Creek.

Swatara Creek reservoir will probably result in a poorly buffered lake with inflows containing high concentrations of nutrients and metals that will probably chemically stratify during the summer. Measured concentrations of alkalinity and acidity for Lower Little Swatara Creek and Swatara Creek above Highway 895 were usually less than 10 and 5 mg/L as CaCO₃, respectively. Dissolved inorganic nitrogen and phosphorus concentrations flowing to the planned impoundment area were measured as high as 2.6 and 0.10 mg/L, respec-

tively. The critical concentrations for dissolved inorganic nitrogen and phosphorus of 0.3 mg/L and 0.01 mg/L, respectively, which are necessary to stimulate excessive algal growth, were commonly exceeded. Phosphorus may become the limiting nutrient for algal growth from March through July; however, phosphorus in the bottom material will be available for re-solution, plant enrichment, and algal growth. Even if substantial amounts of organic nitrogen are prevented from being discharged into the Swatara Creek and transported to the planned impoundment area, oxygen depletion may occur which will be harmful to the aquatic life in and downstream of the impoundment. High metal concentrations, including maximums of 66,000 µg/L for total aluminum, 100,000 µg/L for total iron, and 2,300 µg/L for total manganese, along with simultaneous decreases in pH and increases in acidity, indicate that mine drainage continues to degrade the water-quality of Swatara Creek. Concentrations of iron, lead, copper, and zinc concentrations in inflows to the planned impoundment occasionally exceeded U.S. EPA freshwater aquatic-life criteria. Concentrations of manganese and lead also exceeded U.S. EPA water-quality criteria for domestic water supplies and human health, respectively. The water quality of the planned Swatara Creek reservoir will depend largely on the (1) detention time of water in the lake; (2) the timing and extent of thermal and chemical stratification; (3) sedimentation; and (4) chemical loads to, and concentrations in the lake; each factor is influenced, in part, by the frequency of occurrence of particular streamflows.

The impoundment will act as a sediment trap and, therefore, reduce the concentrations of total phosphorus, iron, aluminum, lead, copper, and zinc immediately downstream from the impoundment. Large storm discharges from the Swatara Creek headwaters, and releases from the hypolimnion to maintain a winter-pool level, may contain low oxygen concentrations and high concentrations of iron, aluminum, lead, copper, and zinc. Unless conservation releases are controlled carefully from the multilevel release gates, low dissolved-oxygen levels and high metal concentrations may degrade the downstream water quality and be detrimental to the aquatic community.

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Table 9.--Surface-water and water-quality data, July 1981 through September 1982

01571919 SWATARA CREEK ABOVE HIGHWAY BRIDGE 895 AT PINE GROVE, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Time	Stream-flow, instantaneous (ft ³ /s)	Specific conductance (µS/cm)	pH (Units)	Temperature (°C)	Turbidity (FTU)	Oxygen, dissolved (mg/L)	Oxygen demand, chemical (high level) (mg/L)	Coliform, fecal, 0.7 UM-MF (Cols./100 mL)	Streptococci fecal, KF Agar (Cols. per 100 mL)	Hardness (mg/L as CaCO ₃)
DEC											
15...	0850	86	237	7.2	0.5	13	13.2	14	34	220	94
JAN											
20...	1230	60	231	6.4	.5	20	12.6	--	K8	80	104
FEB											
03...	1345	417	154	6.3	1.0	90	13.2	68	--	--	38
03...	2130	592	123	6.6	1.0	27	12.0	34	--	--	36
04...	1050	388	145	6.3	2.0	22	13.0	15	--	--	41
05...	1400	224	157	6.2	2.0	18	13.6	<10	K570	K3,500	45
16...	1135	106	199	6.6	4.0	14	12.8	22	32	240	62
MAR											
23...	0900	225	164	6.2	4.5	14	11.8	14	<4	K21	55
APR											
20...	1130	196	147	6.5	11.5	12	10.6	<10	K3	K54	53
26...	1630	239	193	6.4	12.5	29	10.4	--	--	--	55
26...	2345	333	125	6.7	12.0	17	10.4	--	--	--	40
27...	0220	314	134	6.6	12.0	15	10.4	--	--	--	49
27...	0945	298	130	6.8	14.0	10	10.4	--	--	--	46
MAY											
25...	1150	73	208	6.8	14.0	3.0	8.8	10	K39	100	69
JUN											
22...	0900	126	190	6.3	16.5	--	10.0	46	30	88	69
JUL											
27...	0945	34	348	6.1	19.5	6.4	8.0	11	K4	110	140
AUG											
25...	0615	372	188	5.6	22.0	840	5.6	405	--	--	68
25...	1030	393	156	6.5	18.5	125	7.6	258	--	--	48
25...	1815	230	158	6.7	20.0	21	7.4	86	--	--	47
26...	1415	99	204	6.4	19.5	16	7.6	388	--	--	65
SEP											
14...	0900	27	305	6.7	17.0	3.0	8.4	<10	44	800	110

K = Results based on non-ideal colony count.

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01571919 SWATARA CREEK ABOVE HIGHWAY BRIDGE 895 AT PINE GROVE, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Acidity (mg/L as CaCO ₃)	Calcium dis- solved (mg/L as Ca)	Magne- sium, dis- solved (mg/L as mg)	Sodium, dis- solved (mg/L as Na)	Percent Sodium	Sodium ad- sorp- tion ratio	Potas- sium, dis- solved (mg/L as K)	Alka- linity field (mg/L as CaCO ₃)	Sulfate dis- solved (mg/L as SO ₄)	Chlo- ride, dis- solved (mg/L as Cl)	Silica, dis- solved (mg/L as SiO ₂)
DEC											
15...	0.0	18	12	6.9	14	0.3	1.4	6	80	10	6.9
JAN											
20...	--	12	18	9.8	17	.4	.9	7	80	10	7.1
FEB											
03...	4.0	8.2	4.3	13	40	.9	3.4	0	30	21	6.0
03...	5.0	7.9	3.9	8.3	31	.6	2.9	4	25	13	3.9
04...	8.0	8.3	5.0	7.3	26	.5	2.8	4	35	11	3.9
05...	4.0	9.2	5.4	6.1	22	.4	2.5	3	35	10	4.2
16...	2.0	12	7.6	10	26	.6	.9	4	55	12	6.7
MAR											
23...	4.0	11	7.0	5.3	17	.3	.9	1	54	8.0	5.9
APR											
20...	4.0	11	6.8	4.8	16	.3	.9	3	50	8.0	6.2
26...	6.0	11	6.8	5.5	17	.3	1.0	4	55	8.0	6.0
26...	3.0	8.4	4.7	4.2	18	.3	1.0	4	30	6.0	5.5
27...	4.0	10	5.8	4.0	15	.2	.8	5	35	6.0	5.5
27...	3.0	9.1	5.6	4.0	16	.3	.9	5	30	6.0	5.7
MAY											
25...	3.0	14	9.8	6.8	16	.3	.8	6	60	7.0	6.5
JUN											
22...	--	14	9.2	5.8	15	.3	1.0	7	60	6.0	3.4
JUL											
27...	5.0	20	18	9.2	14	.4	1.4	2	130	8.0	6.8
AUG											
25...	21	12	7.5	4.1	12	.2	1.5	4	50	7.0	5.2
25...	5.0	10	5.3	4.2	16	.3	1.3	6	35	7.0	5.9
25...	3.0	10	5.4	4.8	18	.3	1.2	8	30	8.0	6.6
26...	5.0	13	7.8	5.3	15	.3	1.4	6	75	7.0	2.9
SEP											
14...	5.0	20	14	10	16	.4	3.3	2	90	9.0	7.1

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01571919 SWATARA CREEK ABOVE HIGHWAY BRIDGE 895 AT PINE GROVE, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Nitro- gen, nitrate total (mg/L as N)	Nitro- gen, nitrate dis- solved (mg/L as N)	Nitro- gen, nitrite total (mg/L as N)	Nitro- gen, nitrite dis- solved (mg/L as N)	Nitro- gen, ammonia total (mg/L as N)	Nitro- gen, ammonia dis- solved (mg/L as N)	Nitro- gen, organic total (mg/L as N)	Nitro- gen, organic dis- solved (mg/L as N)	Nitro- gen,am- monia + organic total (mg/L as N)	Nitro- gen,am- monia + organic dis. (mg/L as N)	Nitro- gen, total (mg/L as N)
DEC											
15...	0.81	0.79	0.010	0.010	0.200	0.200	0.30	0.30	0.50	0.50	1.3
JAN											
20...	1.1	1.10	.010	.010	.180	.180	.65	.43	.83	.61	1.9
FEB											
03...	1.5	1.50	.020	.020	.290	.290	1.1	1.1	1.40	1.4	2.9
03...	1.8	1.80	.020	.010	.250	.250	.35	.28	.70	.53	2.5
04...	1.6	1.60	.020	.010	.290	.290	.31	.31	.60	.60	2.2
05...	1.2	1.20	.010	.010	.150	.150	.62	.62	.77	.77	2.0
16...	1.1	1.10	.020	.020	.110	.110	.69	.49	.80	.60	1.9
MAR											
23...	.58	.56	<.010	<.010	.070	.070	.23	.23	.30	.30	.90
APR											
20...	.89	.89	.010	.010	.120	.120	1.1	1.1	1.20	1.2	2.1
26...	.63	.61	.010	.010	.250	.250	1.0	1.0	1.20	1.2	1.8
26...	.79	.79	.010	.010	.120	.120	.83	.83	.95	.95	1.8
27...	.65	.65	.010	.010	.120	.120	.78	.78	.90	.90	1.6
27...	.75	.75	.010	.010	.080	.080	.72	.72	.80	.80	1.6
MAY											
25...	.35	.35	.010	.010	.220	.220	1.4	1.2	1.60	1.4	2.0
JUN											
22...	1.1	1.10	<.010	<.010	.130	.130	.87	.87	1.00	1.0	--
JUL											
27...	.31	.31	.010	.010	.620	.620	.60	.30	1.20	.92	1.5
AUG											
25...	.51	.49	.010	.010	.170	.170	2.2	.83	2.40	1.0	2.9
25...	.58	.58	.020	.010	.130	.130	.87	.67	1.00	.80	1.6
25...	.78	.78	.020	.020	.110	.110	1.2	.69	1.30	.80	2.1
26...	.89	.87	.010	.010	.150	.150	--	--	--	--	--
SEP											
14...	.45	.45	.010	.010	.820	.820	.78	.78	1.60	1.6	2.1

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01571919 SWATARA CREEK ABOVE HIGHWAY BRIDGE 895 AT PINE GROVE, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Nitrogen dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Aluminum, total recoverable (µg/L as Al)	Aluminum, dissolved (µg/L as Al)	Chromium, total recoverable (µg/L as Cr)	Copper, total recoverable (µg/L as Cu)	Iron, total recoverable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)
DEC											
15...	1.3	0.070	0.040	<0.010	--	1,000	100	--	--	2,500	860
JAN											
20...	1.7	.060	.030	.010	.010	1,200	40	--	--	3,100	1,500
FEB											
03...	2.9	.280	.060	.010	.010	4,700	470	30	20	7,700	440
03...	2.3	.130	.040	.060	.010	1,500	90	20	20	2,200	210
04...	2.2	.120	.020	.020	.010	1,300	140	10	20	2,600	760
05...	2.0	.070	.020	.030	.010	1,100	100	20	30	1,700	630
16...	1.7	.040	.020	.010	.010	680	100	--	--	1,800	1,000
MAR											
23...	.90	.030	.010	<.010	<.010	660	70	--	--	2,600	1,100
APR											
20...	2.1	.040	.020	.010	.010	620	90	--	--	1,800	650
26...	1.8	.060	.010	<.010	<.010	1,800	130	<10	10	3,400	800
26...	1.8	.050	.020	<.010	<.010	1,300	500	<10	10	2,200	340
27...	1.6	.040	.010	<.010	<.010	1,100	--	40	20	1,300	400
27...	1.6	.040	.020	--	<.010	640	330	<10	30	1,200	430
MAY											
25...	1.8	.030	.010	<.010	<.010	580	90	--	--	970	310
JUN											
22...	--	.040	.020	<.010	<.010	500	50	--	--	1,100	300
JUL											
27...	1.2	.050	.010	<.010	<.010	690	30	--	--	1,200	430
AUG											
25...	1.5	.280	.020	<.010	<.010	66,000	120	40	220	100,000	40
25...	1.4	.250	.020	.010	<.010	6,700	240	<10	60	15,000	90
25...	1.6	.120	.020	<.010	<.010	1,200	150	<10	20	2,800	120
26...	--	.030	.030	.010	.010	960	60	<10	20	1,600	460
SEP											
14...	2.1	.040	.040	.010	.010	300	40	--	--	410	70

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01571919 SWATARA CREEK ABOVE HIGHWAY BRIDGE 895 AT PINE GROVE, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Lead, total recov- erable ($\mu\text{g/L}$ as Pb)	Manga- nese, total recov- erable ($\mu\text{g/L}$ as Mn)	Manga- nese, dis- solved ($\mu\text{g/L}$ as Mn)	Mercury total recov- erable ($\mu\text{g/L}$ as Hg)	Zinc, total recov- erable ($\mu\text{g/L}$ as Zn)	Carbon, organic total (mg/L as C)	Carbon, organic dis- solved (mg/L as C)	Sedi- ment, sus- pended (mg/L)	Sedi- ment, dis- charge, sus- pended (ton/d)	Sed. susp. sieve diam. percent finer than 0.062 mm
DEC										
15...	--	1,200	1,200	--	--	1.7	1.3	22	5.1	--
JAN										
20...	--	1,100	1,100	--	--	2.2	2.2	28	4.5	--
FEB										
03...	18	570	400	<2.0	100	5.0	--	265	298	77
03...	8	410	350	<2.0	60	5.6	4.8	89	142	68
04...	6	550	540	<2.0	90	4.5	4.5	42	44	91
05...	4	540	530	<2.0	80	--	7.0	26	9.8	93
16...	--	740	720	--	--	2.6	2.5	14	4.0	--
MAR										
23...	--	640	640	--	--	--	--	20	12	--
APR										
20...	--	580	550	--	--	1.7	1.7	21	12	--
26...	30	790	790	<2.0	60	--	2.2	66	43	77
26...	24	460	460	<2.0	<10	--	2.4	48	43	66
27...	23	540	510	<2.0	60	--	2.4	34	29	70
27...	20	470	460	<2.0	90	1.3	<1.0	21	17	61
MAY										
25...	--	830	830	--	--	<1.0	<1.0	8	1.6	--
JUN										
22...	--	770	670	--	--	<1.0	--	22	7.5	--
JUL										
27...	--	2,000	2,000	--	--	1.1	--	9	.83	--
AUG										
25...	172	2,300	790	<2.0	310	7.0	--	3,900	3,920	82
25...	40	770	530	<2.0	130	--	--	523	555	73
25...	<5	540	540	<2.0	80	--	3.2	88	55	82
26...	<5	800	720	<2.0	110	4.0	1.4	26	6.9	88
SEP										
14...	--	1,300	1,300	--	--	--	2.3	6	.44	--

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01571919 SWATARA CREEK ABOVE HIGHWAY BRIDGE 895 AT PINE GROVE, PA

PARTICLE-SIZE DISTRIBUTION OF SUSPENDED SEDIMENT, OCTOBER 1981 TO SEPTEMBER 1982

Date	Time	Stream-flow, instantaneous (ft ³ /s)	Temperature (°C)	Sediment, suspended (mg/L)	Sediment, discharge, suspended (ton/d)	Sed. susp. fall. diam. percent finer than 0.004 mm	Sed. susp. fall. diam. percent finer than 0.008 mm
JAN							
04...	1325	650	--	233	409	26	36
04...	1326	612	--	233	385	26	36
FEB							
03...	1830	592	2.0	135	216	39	40
APR							
03...	1850	836	10.5	1,150	2,600	30	41
MAY							
29...	0640	566	--	42	64	66	75
AUG							
25...	1400	314	22.5	251	213	46	62
Date	Sed. susp. fall. diam. percent finer than 0.016 mm	Sed. susp. fall. diam. percent finer than 0.031 mm	Sed. susp. sieve diam. percent finer than 0.062 mm	Sed. susp. sieve diam. percent finer than 0.125 mm	Sed. susp. sieve diam. percent finer than 0.250 mm	Sed. susp. sieve diam. percent finer than 0.500 mm	Sed. susp. sieve diam. percent finer than 1.000 mm
JAN							
04...	48	67	78	88	95	99	100
04...	48	67	78	88	95	99	100
FEB							
03...	57	69	78	86	94	99	100
APR							
03...	51	61	65	74	88	96	99
MAY							
29...	81	82	86	89	92	95	98
AUG							
25...	77	86	91	95	99	100	--

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01571919 SWATARA CREEK ABOVE HIGHWAY BRIDGE 895 AT PINE GROVE, PA

TEMPERATURE (°C) OF WATER, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

ONCE-DAILY

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	---	13.0	3.0	3.5	1.5	3.0	11.5	---	17.0	22.0	---	19.0
2	---	14.0	3.0	2.5	1.0	2.5	12.0	17.0	---	---	---	23.5
3	---	12.0	4.0	2.0	1.5	2.0	10.5	---	15.0	16.0	---	21.0
4	---	11.0	5.0	4.0	2.5	1.5	5.0	17.5	15.0	---	---	17.0
5	---	11.0	4.5	4.0	3.0	2.0	6.0	---	---	22.0	---	19.5
6	---	10.5	3.0	3.5	2.5	2.5	6.0	15.0	14.0	---	---	21.0
7	---	9.0	3.5	4.0	1.0	1.5	6.5	---	16.5	21.0	---	17.0
8	---	10.0	4.5	1.5	2.0	1.5	9.0	16.0	14.0	---	---	17.0
9	---	8.5	3.0	1.0	1.5	1.0	---	---	16.0	20.5	---	20.5
10	---	7.5	2.0	.5	1.5	1.5	8.0	13.5	14.5	---	---	22.0
11	---	9.5	1.5	.5	2.0	3.0	---	---	---	22.5	21.0	21.5
12	---	7.5	2.5	.5	2.0	3.5	10.5	18.5	14.0	---	---	21.0
13	---	7.0	2.0	.5	1.5	4.0	---	---	12.5	23.0	22.0	22.5
14	---	8.0	1.0	.5	2.5	6.0	11.5	19.5	12.5	---	---	21.5
15	---	9.0	1.5	.5	2.0	4.5	---	---	19.0	20.0	---	21.5
16	---	9.0	1.5	.5	3.0	4.0	14.0	22.0	17.5	---	23.5	19.5
17	---	9.0	1.0	.5	2.5	4.0	---	---	19.0	24.5	22.0	18.5
18	---	9.0	1.0	.5	2.0	6.5	13.5	22.0	---	---	23.0	18.5
19	---	9.5	1.0	.5	2.0	6.0	---	---	19.0	21.5	23.0	17.0
20	---	9.0	1.0	.5	2.0	6.0	11.5	18.5	---	---	20.0	14.5
21	---	6.5	.5	.5	2.0	6.0	---	---	18.0	24.5	17.5	16.5
22	---	5.5	1.0	.5	2.5	7.0	13.0	16.5	16.5	---	18.5	14.5
23	12.5	5.5	1.5	.5	4.5	9.0	---	---	15.0	26.5	19.5	15.5
24	8.5	5.0	1.5	.5	4.0	8.0	16.0	12.0	---	---	23.0	17.5
25	7.0	4.0	2.0	.5	2.5	9.5	---	14.0	21.0	---	22.5	16.0
26	11.0	4.5	2.0	.5	1.5	7.0	12.5	21.5	---	---	22.0	15.5
27	13.0	6.0	2.5	.5	1.0	8.0	12.0	---	19.5	27.0	19.0	16.5
28	12.0	5.0	1.0	.5	2.0	8.0	16.0	16.5	---	---	18.5	17.0
29	10.0	5.0	2.0	.5	---	6.5	---	14.5	20.0	25.0	17.0	18.5
30	11.5	4.5	1.5	.5	---	12.0	14.5	19.0	---	---	19.0	17.0
31	10.0	---	2.0	.5	---	9.0	---	19.0	---	---	20.0	---
Mean	10.5	8.0	2.0	1.0	2.0	5.0	11.0	17.5	16.5	22.5	20.5	18.5

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01571919 SWATARA CREEK ABOVE HIGHWAY BRIDGE 895 AT PINE GROVE, PA

SEDIMENT DISCHARGE, SUSPENDED (TON/D), WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Day	Mean discharge (ft ³ /s)	Mean concentration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft ³ /s)	Mean concentration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft ³ /s)	Mean concentration (mg/L)	Sediment discharge (ton/d)
	OCTOBER			NOVEMBER			DECEMBER		
1	---	---	---	36	8	0.78	27	16	1.2
2	---	---	---	34	8	.73	68	25	4.6
3	---	---	---	28	8	.60	57	7	1.1
4	---	---	---	23	11	.68	48	5	.65
5	---	---	---	22	8	.48	41	5	.55
6	---	---	---	56	70	12	36	9	.87
7	---	---	---	45	9	1.1	31	8	.67
8	---	---	---	36	6	.58	47	26	3.3
9	---	---	---	31	12	1.0	49	13	1.7
10	---	---	---	28	14	1.1	41	6	.66
11	---	---	---	28	13	.98	38	7	.72
12	---	---	---	26	13	.91	33	6	.53
13	---	---	---	23	10	.62	32	5	.43
14	---	---	---	22	12	.71	49	13	2.5
15	---	---	---	24	10	.65	68	19	3.5
16	---	---	---	26	12	.84	41	11	1.2
17	---	---	---	26	14	.98	31	8	.67
18	---	---	---	25	16	1.1	28	6	.45
19	---	---	---	24	9	.58	25	6	.41
20	---	---	---	33	19	1.7	30	5	.41
21	---	---	---	33	8	.71	26	6	.42
22	---	---	---	29	5	.39	31	9	.75
23	---	---	---	28	5	.38	42	7	.79
24	42	16	1.8	25	4	.27	56	7	1.1
25	27	3	.22	24	5	.32	56	7	1.1
26	30	13	1.6	22	4	.24	49	6	.79
27	115	122	35	23	4	.25	48	4	.52
28	86	46	12	22	6	.36	45	12	1.5
29	59	13	2.1	21	5	.28	45	11	1.3
30	49	12	1.6	21	3	.17	41	10	1.1
31	41	12	1.3	---	---	---	36	10	.97
Total	478	---	55.62	844	---	31.49	1,295	--	36.46

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01571919 SWATARA CREEK ABOVE HIGHWAY BRIDGE 895 AT PINE GROVE, PA

SEDIMENT DISCHARGE, SUSPENDED (TON/D), WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Day	Mean discharge (ft ³ /s)	Mean concentration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft ³ /s)	Mean concentration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft ³ /s)	Mean concentration (mg/L)	Sediment discharge (ton/d)
	JANUARY			FEBRUARY			MARCH		
1	72	23	4.5	360	54	52	92	12	3.0
2	86	28	6.5	180	48	23	97	12	3.1
3	68	21	3.9	339	111	145	99	13	3.5
4	458	288	416	424	46	53	90	15	3.6
5	403	46	50	239	25	16	103	21	5.8
6	246	25	17	177	18	8.6	106	16	4.6
7	171	15	6.9	140	20	7.6	144	29	11
8	136	11	4.0	110	16	4.8	174	27	13
9	111	11	3.3	100	16	4.3	126	25	8.5
10	88	9	2.1	97	15	3.9	103	26	7.2
11	72	20	3.9	86	15	3.5	113	44	13
12	66	20	3.6	78	16	3.4	262	224	172
13	62	11	1.8	72	22	4.3	275	177	139
14	60	18	2.9	66	12	2.1	288	69	54
15	59	17	2.7	70	13	2.5	268	35	25
16	58	16	2.5	133	30	11	236	24	15
17	57	21	3.2	153	19	7.8	246	19	13
18	57	13	2.0	108	19	5.5	236	33	21
19	58	13	2.0	99	18	4.8	243	31	20
20	60	23	3.7	88	16	3.8	239	17	11
21	59	17	2.7	108	19	5.5	262	47	33
22	58	16	2.5	136	20	7.3	249	33	22
23	57	20	3.1	159	19	8.2	220	23	14
24	56	20	3.0	168	19	8.6	202	16	8.7
25	55	15	2.2	123	13	4.3	189	23	12
26	54	15	2.2	101	19	5.2	214	36	21
27	53	16	2.3	97	14	3.7	186	22	11
28	52	18	2.5	94	10	2.5	162	22	9.6
29	51	18	2.5	---	---	---	142	14	5.4
30	50	25	3.4	---	---	---	131	16	5.7
31	60	27	4.4	---	---	---	165	139	76
TOTAL	3,053	---	573.3	4,105	---	412.2	5,662	---	764.7

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01571919 SWATARA CREEK ABOVE HIGHWAY BRIDGE 895 AT PINE GROVE, PA

SEDIMENT DISCHARGE, SUSPENDED (TON/D), WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Day	Mean discharge (ft ³ /s)	Mean concentration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft ³ /s)	Mean concentration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft ³ /s)	Mean concentration (mg/L)	Sediment discharge (ton/d)	
		APRIL			MAY			JUNE		
1	196	88	47	217	11	6.4	177	82	71	
2	147	24	9.5	202	10	5.5	473	84	112	
3	476	838	1,770	177	10	4.8	375	75	81	
4	764	200	413	162	11	4.8	379	28	29	
5	477	51	66	147	12	4.8	488	250	529	
6	403	33	36	131	12	4.2	884	114	274	
7	333	25	22	123	12	4.0	613	56	93	
8	294	18	14	120	12	3.9	428	34	39	
9	278	19	14	118	11	3.5	339	22	20	
10	265	17	12	106	10	2.9	285	20	15	
11	285	15	12	94	12	3.0	262	18	13	
12	285	14	11	92	15	3.7	227	16	9.8	
13	278	16	12	92	12	3.0	362	64	77	
14	262	18	13	84	8	1.8	389	23	24	
15	233	21	13	77	10	2.1	291	19	15	
16	211	22	13	75	13	2.6	252	29	21	
17	214	69	50	72	11	2.1	307	28	23	
18	301	101	83	66	9	1.6	233	29	18	
19	217	35	21	64	8	1.4	199	20	11	
20	199	13	7.0	66	8	1.4	174	25	12	
21	177	8	3.8	62	8	1.3	150	16	6.5	
22	165	8	3.6	77	10	2.1	126	19	6.5	
23	165	8	3.6	99	8	2.1	133	14	5.0	
24	156	9	3.8	88	7	1.7	113	18	5.5	
25	150	9	3.6	75	7	1.4	101	13	3.5	
26	214	58	44	62	2	.33	94	16	4.1	
27	281	34	26	53	1	.14	90	11	2.7	
28	310	43	36	90	136	66	84	17	3.9	
29	259	14	9.8	443	151	220	249	947	860	
30	233	13	8.2	233	14	8.8	211	66	42	
31	---	---	---	193	25	13	---	---	---	
TOTAL	8,228	---	2,780.9	3,760	---	384.37	8,488	---	2,426.5	

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01571919 SWATARA CREEK ABOVE HIGHWAY BRIDGE 895 AT PINE GROVE, PA

SEDIMENT DISCHARGE, SUSPENDED (TON/D), WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Day	Mean discharge (ft ³ /s)	Mean concentration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft ³ /s)	Mean concentration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft ³ /s)	Mean Concentration (mg/L)	Sediment discharge (ton/d)
	JULY			AUGUST			SEPTEMBER		
1	118	26	8.3	45	11	1.3	42	11	1.2
2	97	24	6.3	41	13	1.4	49	20	2.6
3	144	168	101	41	13	1.4	53	12	1.7
4	208	64	43	38	10	1.0	38	7	.72
5	128	16	5.5	37	7	.70	35	6	.57
6	106	11	3.1	33	6	.53	33	8	.71
7	90	10	2.4	34	6	.55	33	8	.71
8	84	11	2.5	421	787	2,620	33	9	.80
9	74	12	2.4	528	94	156	31	9	.75
10	66	10	1.8	291	38	30	30	7	.57
11	66	15	2.7	174	21	9.9	29	10	.78
12	128	116	49	131	20	7.1	29	17	1.3
13	79	18	3.8	88	6	1.4	29	8	.63
14	62	15	2.5	72	6	1.2	29	6	.47
15	57	11	1.7	62	8	1.3	28	4	.30
16	54	13	1.9	57	10	1.5	28	3	.23
17	51	10	1.4	54	8	1.2	26	8	.56
18	56	18	2.7	54	9	1.3	26	5	.35
19	54	13	1.9	46	8	.99	26	5	.35
20	59	16	2.5	48	15	1.9	27	6	.44
21	57	15	2.3	53	7	1.0	28	3	.23
22	48	10	1.3	41	10	1.1	42	24	2.7
23	43	4	.46	41	15	1.7	72	29	5.6
24	41	3	.33	38	10	1.0	38	8	.82
25	38	5	.51	233	607	572	32	8	.69
26	38	7	.72	111	27	8.1	28	5	.38
27	37	10	1.0	72	14	2.7	126	141	60
28	90	257	93	61	11	1.8	68	22	4.0
29	62	18	3.0	53	11	1.6	48	11	1.4
30	48	11	1.4	43	10	1.2	38	8	.82
31	48	12	1.6	41	9	1.0	---	---	---
TOTAL	2,331	---	352.02	3,082	---	3,433.87	1174	---	92.38
YEAR	42,500		11,343.81						

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

DATE	Time	Stream-flow, instantaneous (ft ³ /s)	Specific conductance (μS/cm)	pH (Units)	Temperature (°C)	Turbidity (FTU)	Oxygen, dissolved (mg/L)	Oxygen demand, chemical (high level) (mg/L)	Coliform, fecal, 0.7 UM-MF (Cols./100 mL)	Strep-tococci, fecal, KF Agar (Cols. per 100 mL)	Hardness (mg/L as CaCO ₃)
DEC											
15...	1115	24	88	7.0	0.5	4.0	14.0	24	25	100	20
JAN											
18...	1015	--	85	7.6	.0	--	10.0	<10	17	73	18
20...	1500	21	68	6.3	.5	5.0	13.6	--	16	84	27
FEB											
03...	1830	666	72	6.2	.5	120	10.4	26	--	--	16
04...	0150	452	72	6.3	.5	78	13.0	19	--	--	18
04...	1245	244	78	6.2	1.0	30	13.0	<10	--	--	21
05...	1110	123	83	6.5	1.0	13	13.6	<10	K260	2,000	22
16...	0915	55	86	6.7	2.0	17	13.0	--	800	>240	24
MAR											
23...	1130	78	59	6.7	4.5	5.0	13.2	<10	100	K61	<20
APR											
20...	1345	80	65	6.9	11.0	6.0	10.2	<10	K32	170	20
26...	1430	68	61	7.0	13.0	8.0	10.0	--	--	--	16
26...	2000	228	64	6.9	12.0	35	10.0	--	--	--	17
27...	0100	198	62	6.6	12.0	24	10.0	--	--	--	18
27...	1215	116	63	7.1	13.5	9.0	10.8	--	--	--	18
MAY											
25...	1330	21	63	7.3	14.5	4.0	8.8	<10	400	200	<20
JUN											
22...	1200	57	63	7.8	17.5	--	10.2	32	260	280	43
JUL											
27...	1300	6.0	59	7.4	23.5	--	8.4	13	160	270	20
AUG											
25...	0430	17	81	7.1	18.0	28	7.6	15	--	--	9
25...	1110	90	76	7.2	18.5	33	7.2	32	--	--	5
25...	1635	53	9	7.2	20.0	23	7.0	28	--	--	25
26...	1145	25	88	7.5	18.0	11	8.6	56	--	--	26
SEP											
14...	1130	5.7	75	8.4	18.0	2.5	9.4	<10	120	67	30

K = Results based on non-ideal colony count.

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Acidity (mg/L as CaCO ₃)	Calcium dis- solved (mg/L as Ca)	Magne- sium, dis- solved (mg/L as Mg)	Sodium, dis- solved (mg/L as Na)	Percent sodium	Sodium ad- sorp- tion ratio	Potas- sium, dis- solved (mg/L as K)	Alka- linity field (mg/L as CaCO ₃)	Sulfate dis- solved (mg/L as SO ₄)	Chlo- ride, dis- solved (mg/L as CL)	Silica, dis- solved (mg/L as SiO ₂)
DEC											
15...	0.0	6.1	2.8	4.5	26	0.4	1.1	11	5.0	8.0	5.1
JAN											
18...	1.0	3.8	2.0	3.3	28	.3	.9	7	25	7.0	6.2
20...	.0	2.5	5.1	3.0	19	.3	.9	5	5.0	6.0	.5
FEB											
03...	10	3.8	1.6	3.8	28	.4	3.8	2	10	7.0	2.1
04...	4.0	4.2	1.8	3.8	27	.4	3.2	4	10	7.0	2.6
04...	2.0	4.8	2.2	4.2	27	.4	2.5	4	10	8.0	3.9
05...	.0	5.2	2.3	4.3	27	.4	2.1	3	5.0	8.0	3.9
16...	.0	5.3	2.5	4.7	27	.4	2.7	8	10	8.0	4.4
MAR											
23...	.0	--	--	--	--	--	--	3	6.0	6.0	--
APR											
20...	3.0	4.3	1.9	2.6	23	.3	.7	7	10	6.0	4.6
26...	.0	3.8	1.7	2.4	23	.3	.8	1	<5.0	5.0	4.3
26...	4.0	4.1	1.6	2.7	25	.3	1.0	7	<5.0	6.0	4.4
27...	2.0	4.4	1.7	2.3	21	.2	1.1	6	5.0	5.0	4.6
27...	.0	3.9	1.9	3.0	26	.3	.9	7	5.0	6.0	5.0
MAY											
25...	2.0	4.3	2.1	3.1	25	.3	.7	10	5.0	6.0	5.4
JUN											
22...	.0	4.7	2.3	3.1	23	.3	.7	11	10	5.0	5.4
JUL											
27...	.0	4.0	1.8	3.1	27	.3	.9	12	15	6.0	4.3
AUG											
25...	3.0	5.4	2.4	2.5	18	.2	1.4	5	5.0	7.0	4.6
25...	2.0	5.3	2.2	2.4	18	.2	1.5	13	5.0	7.0	5.4
25...	2.0	5.9	2.5	2.9	19	.3	1.8	12	5.0	8.0	6.2
26...	2.0	6.0	2.7	2.6	17	.2	1.7	15	10	7.0	5.9
SEP											
14...	.0	5.2	2.5	3.8	23	.3	2.9	10	5.0	6.0	4.2

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Nitro- gen, nitrate total (mg/L as N)	Nitro- gen, nitrate dis- solved (mg/L as N)	Nitro- gen, nitrite total (mg/L as N)	Nitro- gen, nitrite dis- solved (mg/L as N)	Nitro- gen, ammonia total (mg/L as N)	Nitro- gen, ammonia dis- solved (mg/L as N)	Nitro- gen, organic total (mg/L as N)	Nitro- gen, organic dis- solved (mg/L as N)	Nitro- gen,am- monia + organic total (mg/L as N)	Nitro- gen,am- monia + organic dis. (mg/L as N)	Nitro- gen, total (mg/L as N)
DEC											
15...	2.2	2.00	0.010	0.010	0.030	0.020	0.58	0.58	0.61	0.60	2.8
JAN											
18...	2.6	1.80	<.010	<.010	.110	.110	.49	.48	.60	.59	--
20...	2.6	--	.010	--	.030	.030	.80	.80	.83	.83	3.5
FEB											
03...	1.4	1.40	.030	.010	.300	.260	.40	.19	.70	.45	2.1
04...	1.7	1.70	.020	.010	.220	.180	.89	.27	1.10	.45	2.9
04...	2.6	2.60	.010	.010	.140	.130	.56	.56	.70	.69	3.3
05...	2.3	1.80	.010	.010	.080	.080	.62	.53	.70	.61	3.0
16...	1.9	1.90	.020	.010	.180	.150	.75	.75	.93	.90	2.8
MAR											
23...	1.7	1.70	<.010	<.010	.060	.010	.29	.29	.35	.30	2.0
APR											
20...	1.6	1.60	.010	.010	.030	.030	.87	.87	.90	.90	2.5
26...	1.2	1.20	.010	.010	.060	.050	.75	.75	.81	.80	2.0
26...	1.0	1.00	.010	.010	.080	.070	.92	.83	1.00	.90	2.0
27...	1.1	1.10	.020	.010	.100	.090	.86	.86	.96	.95	2.1
27...	1.2	1.20	.010	.010	.030	.030	.80	.80	.83	.83	2.0
MAY											
25...	.91	.91	.010	.010	.030	.030	1.3	1.2	1.30	1.2	2.2
JUN											
22...	1.9	1.90	<.010	<.010	.040	.040	.96	.86	1.00	.90	--
JUL											
27...	.53	.53	.010	.010	.020	.020	.38	.38	.40	.40	.94
AUG											
25...	1.4	1.40	.010	.010	.070	.070	1.4	1.2	1.50	1.3	2.9
25...	1.3	1.30	.020	.010	.020	.020	.78	.68	.80	.70	2.1
25...	1.4	1.40	.030	.020	.040	.010	.99	.99	1.00	1.0	2.4
26...	1.6	1.60	.010	.010	.020	.010	.99	.99	1.00	1.0	2.6
SEP											
14...	.87	.87	.010	.010	.020	.020	.40	.40	.42	.42	1.3

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Nitro- gen dis- solved (mg/L as N)	Phos- phorus, total (mg/L as P)	Phos- phorus, dis- solved (mg/L as P)	Phos- phorus, ortho, total (mg/L as P)	Phos- phorus, ortho, dis- solved (mg/L as P)	Alum- inum, total recov- erable (µg/L as AL)	Alum- inum, dis- solved (µg/L as AL)	Chro- mium, total recov- erable (µg/L as Cr)	Copper, total recov- erable (µg/L as Cu)	Iron, total recov- erable (µg/L as Fe)	Iron, dis- solved (µg/L AS Fe)
DEC											
15...	2.6	0.050	0.040	<0.010	<0.010	410	110	--	--	850	210
JAN											
18...	--	.030	.010	<.010	<.010	90	30	--	--	120	40
20...	--	.030	.030	.010	<.010	70	30	--	--	100	50
FEB											
03...	1.9	.310	.100	.050	.020	3,400	90	50	30	7,900	100
04...	2.2	.220	.080	.040	.040	2,200	70	30	30	4,300	50
04...	3.3	.110	.040	.020	.020	1,900	30	30	20	1,900	50
05...	2.4	.070	.030	.030	--	760	80	--	30	990	80
16...	2.8	.100	.060	.050	.040	990	60	--	--	980	80
MAR											
23...	2.0	.020	.010	<.010	<.010	80	--	--	--	170	--
APR											
20...	2.5	.070	.020	--	<.010	140	110	--	--	790	40
26...	2.0	.040	.020	<.010	<.010	670	140	<10	10	250	80
26...	1.9	.100	.030	.010	.010	3,100	200	<10	20	2,200	150
27...	2.1	.080	.040	.010	.010	1600	--	40	30	1,700	170
27...	2.0	.040	.030	--	<.010	490	160	10	10	470	80
MAY											
25...	2.1	.030	.020	<.010	<.010	400	160	--	--	200	110
JUN											
22...	--	.030	.020	<.010	<.010	160	<10	--	--	400	90
JUL											
27...	.94	.050	.020	<.010	<.010	380	70	--	--	310	100
AUG											
25...	2.7	.090	.040	<.010	<.010	1,000	90	10	30	1,000	80
25...	2.0	.120	.030	.010	<.010	1,200	320	10	20	1,400	150
25...	2.4	.080	.040	.010	.010	710	330	<10	10	940	180
26...	1.0	.050	.040	.010	.010	420	160	<10	20	450	60
SEP											
14...	1.3	.030	.030	.010	.010	240	160	--	--	130	90

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Lead, total recov- erable (µg/L as Pb)	Manga- nese, total recov- erable (µg/L as Mn)	Manga- nese, dis- solved (µg/L as Mn)	Mercury total recov- erable (µg/L as Hg)	Zinc, total recov- erable (µg/L as Zn)	Carbon, organic total (mg/L as C)	Carbon, organic dis- solved (mg/L as C)	Sedi- ment, sus- pended (mg/L)	Sedi- ment, dis- charge, sus- pended (ton/d)	Sed. susp. sieve diam. percent finer than 0.062 mm
DEC										
15...	--	80	10	--	--	1.5	1.1	1	0.06	--
JAN										
18...	--	30	30	--	--	<1.0	<1.0	--	--	--
20...	--	30	20	--	--	1.8	1.8	3	.17	--
FEB										
03...	11	310	150	<2.0	40	8.8	7.0	201	361	91
04...	10	200	100	<2.0	30	5.9	5.0	149	182	87
04...	<5	140	80	<2.0	30	4.6	3.7	89	59	91
05...	7	70	40	<2.0	--	3.3	2.6	40	13	82
16...	--	40	10	--	--	5.7	5.2	27	4.0	--
MAR										
23...	--	30	--	--	--	--	--	5	1.1	--
APR										
20...	--	30	10	--	--	2.1	1.7	11	2.4	--
26...	5	50	50	<2.0	<10	--	2.2	13	2.4	77
26...	40	120	90	<2.0	<10	--	3.9	96	59	82
27...	25	100	50	<2.0	20	--	4.3	51	27	84
27...	<5	40	30	<2.0	20	1.5	1.5	13	4.1	86
MAY										
25...	--	30	20	--	--	1.1	1.1	5	.28	--
JUN										
22...	--	670	20	--	--	1.1	--	9	1.4	--
JUL										
27...	--	40	20	--	--	<1.0	--	22	.36	--
AUG										
25...	<5	70	30	<2.0	50	2.6	--	91	4.2	52
25...	20	80	20	<2.0	20	3.3	--	58	14	93
25...	<5	50	20	<2.0	20	--	4.4	33	4.7	89
26...	<5	40	10	<2.0	30	--	4.0	11	.74	85
SEP										
14...	--	40	20	--	--	1.4	1.4	5	.08	--

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

PARTICLE-SIZE DISTRIBUTION OF SUSPENDED-SEDIMENT, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Time	Stream- flow, instan- taneous (ft ³ /s)	Temper- ature (°C)	Sedi- ment, sus- pended (mg/L)	Sedi- ment, dis- charge, sus- pended (ton/d)	Sed. susp. fall diam. percent finer than 0.004 mm	Sed. susp. fall diam. percent finer than 0.008 mm	
JAN								
04...	1315	536	4.5	364	527	37	52	
FEB								
03...	1900	984	--	218	579	43	56	
APR								
03...	1820	824	10.0	1,360	3,030	41	55	
MAY								
29...	0615	335	--	67	61	60	72	
AUG								
25...	1330	77	--	40	8.3	74	--	
Date		Sed. susp. fall diam. percent finer than 0.016 mm	Sed. susp. fall diam. percent finer than 0.031 mm	Sed. susp. seive diam. percent finer than 0.062 mm	Sed. susp. seive diam. percent finer than 0.125 mm	Sed. susp. seive diam. percent finer than 0.250 mm	Sed. susp. seive diam. percent finer than 0.500 mm	Sed. susp. seive diam. percent finer than 1.00 mm
JAN								
04...	68	80	89	96	99	100	--	
FEB								
03...	65	73	93	95	97	99	100	
APR								
03...	72	82	92	97	99	100	--	
MAY								
29...	84	92	96	97	99	100	--	
AUG								
25...	--	--	95	--	--	--	100	

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

SPECIFIC CONDUCTANCE (MICROSIEMENS/CM at 25°C), WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981

ONCE-DAILY

Day	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1										---	58	123
2										---	57	77
3										---	59	70
4										---	60	67
5										---	58	63
6										---	59	64
7										---	56	64
8										---	56	64
9										---	61	69
10										75	57	85
11										---	55	72
12										---	55	71
13										68	56	70
14										66	58	67
15										66	56	71
16										66	58	68
17										63	58	70
18										63	59	76
19										61	56	72
20										65	55	73
21										75	53	75
22										66	56	73
23										66	53	75
24										65	52	71
25										64	52	71
26										63	54	72
27										62	58	71
28										62	60	68
29										62	81	68
30										64	65	67
31										60	60	---
MEAN										65	58	72

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

SPECIFIC CONDUCTANCE (MICROSIEMENS/CM AT 25°C), WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982
ONCE-DAILY

Day	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	68	102	78									
2	66	98	85									
3	67	98	96									
4	74	96	94									
5	74	93	95									
6	72	98	94									
7	70	101	90									
8	73	101	90									
9	72	98	89									
10	---	97	90									
11	74	94	91									
12	72	93	90									
13	72	92	90									
14	70	89	90									
15	70	87	82									
16	71	91	112									
17	72	90	81									
18	72	94	111									
19	70	93	113									
20	75	90	107									
21	79	90	113									
22	83	91	---									
23	82	91	112									
24	78	90	107									
25	94	90	112									
26	90	90	115									
27	87	85	107									
28	116	84	---									
29	118	83	---									
30	111	83	---									
31	106	---	---									
MEAN	80	92	97									

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

TEMPERATURE (°C) OF WATER, WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981

ONCE-DAILY

Day	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1										---	24.0	22.0
2										---	24.5	21.0
3										---	21.5	21.0
4										---	24.0	20.5
5										---	23.5	21.0
6										---	22.0	22.0
7										---	23.5	21.0
8										---	20.5	20.5
9										---	24.0	19.5
10										25.5	26.0	18.5
11										---	26.0	21.0
12										---	25.0	22.0
13										25.0	24.5	21.0
14										25.0	24.5	23.5
15										23.5	22.0	21.0
16										22.0	23.5	18.0
17										24.0	22.0	19.0
18										24.5	21.5	18.0
19										26.0	22.0	16.5
20										24.5	21.5	17.5
21										24.0	21.5	17.0
22										21.5	20.5	17.5
23										21.5	17.5	15.0
24										20.0	21.0	15.0
25										20.5	21.0	15.5
26										21.0	21.5	16.5
27										24.0	23.0	17.0
28										21.5	23.0	16.5
29										21.5	23.0	14.0
30										22.5	21.0	13.0
31										23.0	22.5	---
MEAN										23.0	22.5	18.5

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

TEMPERATURE (°C) OF WATER, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

ONCE-DAILY

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	12.5	11.5	2.0	3.0	0.5	2.0	11.0	---	17.5	21.0	---	20.5
2	12.5	13.0	2.0	2.0	.5	2.0	10.5	17.5	16.0	---	---	24.0
3	11.5	11.5	3.5	2.0	1.0	1.0	10.0	---	15.5	17.0	---	22.5
4	12.0	10.5	4.5	4.5	2.0	1.0	5.5	17.0	15.0	---	---	18.0
5	15.0	10.0	4.5	3.5	2.0	1.0	7.0	---	---	22.5	---	19.5
6	14.5	10.0	2.5	3.0	2.0	1.5	6.0	16.0	14.5	---	---	20.5
7	12.5	9.0	3.0	4.5	1.0	1.5	4.0	---	17.0	19.5	---	18.0
8	12.5	8.0	4.0	1.5	1.0	1.0	6.0	16.0	14.0	---	---	17.0
9	11.0	7.5	2.5	1.0	1.0	1.0	---	---	16.0	23.0	---	20.0
10	---	6.5	1.5	.5	1.0	1.0	5.5	15.5	15.0	---	---	21.0
11	9.5	8.5	1.0	.5	1.0	2.5	---	---	---	23.5	20.5	20.0
12	11.0	6.5	1.5	.5	1.0	2.5	10.0	19.0	15.0	---	---	21.5
13	10.0	5.5	1.0	.5	1.0	3.0	---	---	13.0	24.5	21.0	22.5
14	10.0	6.5	1.0	.5	1.5	5.0	10.5	20.0	13.0	---	---	22.0
15	10.5	8.0	1.0	.5	1.5	4.0	---	---	18.0	22.0	---	21.0
16	11.0	8.0	1.0	.5	2.0	4.0	13.0	21.5	17.5	---	22.0	20.0
17	11.0	8.0	1.0	.0	2.0	4.5	---	---	19.0	26.0	22.0	19.0
18	10.0	8.0	1.0	.0	1.5	5.0	12.0	22.0	---	---	21.5	18.5
19	9.0	8.5	.5	.0	1.5	6.0	---	---	18.0	24.5	22.0	17.5
20	9.0	8.5	.5	.0	1.5	5.5	10.0	20.0	---	---	20.5	15.0
21	9.5	6.5	1.0	.0	1.5	6.0	---	---	17.5	25.0	18.5	17.0
22	12.0	5.0	1.0	.0	2.0	6.5	13.0	19.0	17.5	---	20.5	15.0
23	12.0	4.5	1.5	.0	3.0	8.0	---	---	16.5	26.0	19.5	15.5
24	9.0	4.0	2.0	.0	3.0	6.0	15.5	13.0	---	---	22.0	16.5
25	7.0	3.0	2.0	.0	1.5	9.5	---	14.5	20.0	---	21.0	16.5
26	9.5	3.0	1.5	.0	1.0	7.5	13.5	21.0	---	---	21.5	16.0
27	13.0	4.5	1.5	.0	1.0	5.5	13.0	---	20.5	26.5	19.0	17.0
28	13.0	4.5	1.5	.0	1.5	5.0	15.5	17.0	---	---	19.5	17.0
29	10.0	4.5	1.5	.0	---	4.0	---	15.5	21.0	24.0	17.0	18.0
30	10.5	3.5	1.0	.0	---	9.0	15.0	19.0	---	---	19.5	18.0
31	9.5	---	1.5	.5	---	9.5	---	18.0	---	---	20.5	---
MEAN	11.0	7.0	2.0	1.0	1.5	4.0	10.5	18.0	16.5	23.0	20.5	19.0

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

SEDIMENT DISCHARGE, SUSPENDED (TON/D), WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981

Day	Mean discharge (ft ³ /s)	Mean concentration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft ³ /s)	Mean concentration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft ³ /s)	Mean concentration (mg/L)	Sediment discharge (ton/d)
JULY			AUGUST			SEPTEMBER			
1	---	---	---	11	7	0.21	6.9	7	0.13
2	---	---	---	9.8	8	.21	6.0	5	.08
3	---	---	---	9.8	9	.24	5.4	4	.06
4	---	---	---	11	10	.30	4.9	5	.07
5	---	---	---	9.8	7	.19	4.9	5	.07
6	---	---	---	8.6	6	.14	4.9	5	.07
7	---	---	---	8.0	8	.17	4.4	6	.07
8	---	---	---	11	10	.30	6.5	17	.30
9	---	---	---	9.8	8	.21	11	12	.36
10	---	---	---	8.0	5	.11	5.4	6	.09
11	---	---	---	7.4	6	.12	4.4	5	.06
12	---	---	---	7.4	7	.14	3.9	6	.06
13	---	---	---	6.9	6	.11	3.9	4	.04
14	---	---	---	6.5	5	.09	3.9	4	.04
15	---	---	---	6.9	5	.09	4.9	9	.12
16	17	---	---	7.4	5	.10	9.2	10	.25
17	15	---	---	6.0	4	.06	7.4	7	.14
18	14	---	---	4.9	8	.11	6.5	5	.09
19	13	---	---	4.9	8	.11	11	7	.21
20	50	---	---	4.4	5	.06	7.4	6	.12
21	96	---	---	3.9	4	.04	5.4	5	.07
22	61	---	---	3.9	5	.05	4.9	8	.11
23	32	---	---	4.4	5	.06	4.9	9	.12
24	23	9	0.56	4.4	5	.06	3.9	9	.09
25	21	11	.62	4.4	5	.06	3.5	10	.09
26	20	8	.43	4.4	5	.06	3.5	8	.08
27	19	8	.41	4.4	5	.06	3.5	7	.07
28	15	7	.28	3.9	5	.05	3.5	9	.09
29	16	7	.30	3.5	6	.06	3.2	8	.07
30	13	9	.32	3.5	5	.05	3.2	7	.06
31	12	9	.29	8.6	7	.16	---	---	---
TOTAL	437	---	3.21	208.8	---	3.78	162.3	---	3.28

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

SEDIMENT DISCHARGE, SUSPENDED (TON/D), WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Day	Mean discharge (ft ³ /s)	Mean concentration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft ³ /s)	Mean concentration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft ³ /s)	Mean concentration (mg/L)	Sediment discharge (ton/d)
	OCTOBER			NOVEMBER			DECEMBER		
1	3.9	10	.11	9.8	2	0.05	8.6	1	0.02
2	7.4	15	.30	8.6	1	.02	45	6	.73
3	4.9	6	.08	8.0	3	.06	29	2	.16
4	3.9	6	.06	7.4	1	.02	24	3	.19
5	3.5	6	.06	7.4	2	.04	22	3	.18
6	3.9	7	.07	29	15	1.2	19	2	.10
7	6.0	9	.15	17	4	.18	17	3	.14
8	4.9	10	.13	13	3	.11	26	5	.35
9	3.9	8	.08	11	2	.06	24	7	.45
10	3.1	6	.05	11	2	.06	19	5	.26
11	3.1	7	.06	9.8	2	.05	17	3	.14
12	3.1	7	.06	8.6	1	.02	16	3	.13
13	3.1	6	.05	7.4	2	.04	16	5	.22
14	3.1	7	.06	7.4	1	.02	17	4	.18
15	3.5	8	.08	7.4	1	.02	22	3	.18
16	3.5	8	.08	8.6	1	.02	18	8	.39
17	3.9	7	.07	8.0	4	.09	17	6	.28
18	4.9	8	.11	7.4	4	.08	16	7	.30
19	9.2	7	.17	7.4	2	.04	15	6	.24
20	4.9	7	.09	11	2	.06	15	4	.16
21	3.9	7	.07	11	1	.03	14	5	.19
22	3.5	7	.07	8.6	1	.02	18	6	.29
23	6.5	9	.16	7.4	1	.02	30	6	.49
24	12	10	.32	7.4	1	.02	67	5	.90
25	4.9	5	.07	7.4	1	.02	64	6	1.0
26	4.9	8	.11	7.4	1	.02	58	6	.94
27	34	20	1.8	6.9	1	.02	55	3	.45
28	34	12	1.1	6.9	1	.02	51	6	.83
29	19	4	.21	6.5	1	.02	37	8	.80
30	13	3	.11	6.5	1	.02	29	8	.63
31	11	2	.06	---	---	---	41	10	1.1
TOTAL	234.4	---	6.00	281.2	---	2.45	866.6	---	12.42

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

SEDIMENT DISCHARGE, SUSPENDED (TON/D), WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Day	Mean discharge (ft ³ /s)	Mean concentration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft ³ /s)	Mean concentration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft ³ /s)	Mean concentration (mg/L)	Sediment discharge (ton/d)
	JANUARY			FEBRUARY			MARCH		
1	79	26	5.5	280	67	51	39	2	0.21
2	81	25	5.5	140	29	11	39	3	.32
3	66	15	2.7	260	180	126	36	3	.29
4	362	221	280	300	118	96	51	7	.96
5	267	55	46	94	48	12	47	7	.89
6	153	15	6.2	82	13	2.9	39	9	.95
7	111	9	2.7	72	11	2.1	99	108	48
8	79	7	1.5	62	18	3.0	77	26	5.4
9	70	5	.95	52	3	.42	57	7	1.1
10	60	8	1.3	48	4	.52	52	26	3.7
11	52	12	1.7	45	8	.97	80	70	22
12	46	7	.87	43	20	2.3	196	133	76
13	42	4	.45	41	8	.89	163	58	28
14	37	6	.60	39	8	.84	159	29	12
15	33	4	.36	46	15	1.9	132	9	3.2
16	29	4	.31	78	43	10	115	7	2.2
17	26	4	.28	71	14	2.7	121	7	2.3
18	24	5	.32	50	1	.14	111	7	2.1
19	23	4	.25	47	2	.25	109	6	1.8
20	22	3	.18	44	2	.24	101	5	1.4
21	21	1	.06	57	6	.92	98	6	1.6
22	20	1	.05	87	12	2.8	89	4	.96
23	20	1	.05	87	13	3.1	77	5	1.0
24	20	4	.22	83	10	2.2	68	3	.55
25	19	5	.26	60	3	.49	63	1	.17
26	19	2	.10	60	10	1.6	75	7	1.4
27	19	1	.05	63	4	.68	59	3	.48
28	19	1	.05	43	2	.23	50	2	.27
29	18	5	.24	---	---	---	47	2	.25
30	18	2	.10	---	---	---	44	2	.24
31	20	2	.11	---	---	---	56	7	1.3
TOTAL	1,875	---	358.96	2,434	---	337.19	2,549	---	221.04

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

SEDIMENT DISCHARGE, SUSPENDED (TON/D), WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Day	Mean discharge (ft ³ /s)	Mean concentration (mg/L)	Sediment discharge (ton/d)	mean discharge (ft ³ /s)	Mean Concentration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft ³ /s)	Mean Concentration (mg/L)	Sediment discharge (ton/d)
	APRIL			MAY			JUNE		
1	68	22	4.0	94	5	1.3	102	57	50
2	56	6	.91	80	5	1.1	358	153	179
3	316	614	1,260	69	5	.93	242	44	29
4	370	244	289	58	5	.78	215	23	13
5	189	35	18	54	5	.73	288	71	80
6	163	16	7.0	49	6	.79	526	73	109
7	130	10	3.5	45	7	.85	326	31	27
8	110	8	2.4	44	9	1.1	213	22	13
9	106	8	2.3	40	8	.86	150	14	5.7
10	107	11	3.2	35	6	.57	115	11	3.4
11	131	12	4.2	31	5	.42	109	16	4.7
12	136	10	3.7	30	5	.41	86	9	2.1
13	142	8	3.1	30	5	.41	192	54	43
14	130	7	2.5	26	5	.35	223	25	15
15	105	6	1.7	23	6	.37	153	13	5.4
16	90	6	1.5	22	7	.42	118	15	4.8
17	85	13	3.0	20	6	.32	178	56	33
18	123	23	9.4	19	5	.26	110	12	3.6
19	84	6	1.4	18	6	.29	90	10	2.4
20	78	11	2.3	19	6	.31	75	8	1.6
21	72	9	1.7	19	6	.31	65	5	.88
22	63	6	1.0	26	9	.63	55	5	.74
23	57	4	.62	30	12	.97	62	21	3.5
24	53	6	.86	25	7	.47	46	7	.87
25	49	5	.66	21	4	.23	40	4	.43
26	109	34	18	17	1	.05	36	4	.39
27	145	26	12	15	3	.12	33	4	.36
28	208	38	23	39	88	18	30	4	.32
29	144	14	5.4	242	139	120	50	38	9.8
30	113	7	2.1	118	31	10	53	53	9.0
31	---	---	---	107	31	10	---	---	---
TOTAL	3,732	---	1,688.45	1,465	---	173.35	4,339	---	650.99

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572000 LOWER LITTLE SWATARA CREEK AT PINE GROVE, PA

SEDIMENT DISCHARGE, SUSPENDED (TON/D), WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Day	Mean discharge (ft ³ /s)	Mean concentration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft ³ /s)	Mean concentration (mg/L)	Sediment discharge (ton/d)	Mean discharge (ft ³ /s)	Mean concentration (mg/L)	Sediment discharge (ton/d)
	JULY			AUGUST			SEPTEMBER		
1	33	8	0.71	6.9	6	0.11	11	1	0.03
2	27	7	.51	6.2	5	.08	15	8	.68
3	48	31	6.0	6.3	5	.09	26	22	1.9
4	56	32	5.6	5.8	4	.06	12	4	.13
5	34	23	2.1	5.2	4	.06	9.2	2	.05
6	29	16	1.3	4.6	4	.05	8.2	3	.07
7	25	6	.41	4.3	5	.06	7.7	6	.12
8	23	6	.37	217	190	552	8.3	3	.07
9	20	6	.32	441	137	261	8.0	5	.11
10	18	7	.34	225	48	37	7.4	4	.08
11	17	8	.37	111	20	6.0	6.8	7	.13
12	22	8	.48	73	14	2.8	6.0	4	.06
13	16	14	.60	48	8	1.0	5.5	3	.04
14	14	13	.49	37	7	.70	5.4	4	.06
15	12	4	.13	30	7	.57	5.4	2	.03
16	11	9	.27	24	8	.52	5.7	3	.05
17	11	8	.24	23	7	.43	4.7	3	.04
18	11	12	.36	21	8	.45	4.4	3	.04
19	11	11	.33	17	7	.32	4.8	2	.03
20	18	22	1.5	17	11	.50	5.2	6	.08
21	14	13	.49	22	7	.42	6.3	5	.09
22	9.0	6	.15	14	6	.23	13	11	.39
23	7.9	10	.21	12	6	.19	22	12	.71
24	7.5	8	.16	12	6	.19	11	6	.18
25	6.5	5	.09	49	45	7.0	7.9	4	.09
26	6.2	3	.05	24	13	.84	7.1	3	.06
27	5.9	10	.16	19	3	.15	62	81	17
28	18	15	.72	16	4	.17	31	16	1.3
29	11	10	.30	12	3	.10	22	6	.36
30	7.7	8	.17	11	2	.06	17	3	.14
31	7.5	7	.15	11	2	.06	---	---	---
TOTAL	557.6	---	25.08	1,525.3	---	873.21	366.0	---	24.12
YEAR	2,022.51		4,721.26						

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572200 SWATARA CREEK AT INWOOD, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Time	Stream- flow, instan- taneous (ft ³ /s)	Spe- cific con- duct- ance (μS/cm)	pH (Units)	Temper- ature (°C)	Tur- bid- ity (FTU)	Oxygen, dis- solved (mg/L)	Oxygen demand, chem- ical (high leve) (mg/L)	Coli- form, fecal, 0.7 UM-MF (Cols./ 100 mL)	Strep- tococci fecal, KF Agar (Cols. per 100 mL)	Hard- ness (mg/L as CaCO ₃)
DEC											
15...	1330	75	166	6.9	0.5	3.0	13.6	10	K6	18	66
JAN											
20...	1000	114	159	6.8	.5	5.0	12.8	--	<2	K6	55
FEB											
04...	0745	1,280	98	6.4	.5	40	11.2	50	--	--	25
05...	1615	538	110	6.3	1.0	14	13.4	10	K130	42	30
16...	1435	236	jgd	b\$1	x\$d	jv	jv\$o	vv	†v1	fvxd	go
+> ^m											
vg\$\$\$	jx11	lgr	jdb	b\$g	b\$1	b\$d	jv\$v	nn	w4	K4	28
APR											
20...	0745	169	115	6.5	10.0	8.0	10.4	<10	K9	160	34
26...	1830	436	94	6.7	12.5	10	10.4	--	--	--	33
27...	1500	568	93	6.8	13.0	9.0	10.2	--	--	--	30
MAY											
25...	0845	145	149	6.6	14.0	5.0	8.8	<10	180	110	46
JUN											
22...	1400	274	130	6.4	19.0	--	9.2	44	--	94	40
JUL											
27...	1445	62	205	6.5	24.5	1.4	8.0	<10	39	200	71
AUG											
25...	0745	169	162	6.8	18.5	27	7.6	<10	--	--	52
25...	1430	644	146	6.5	20.0	230	7.6	556	--	--	44
26...	1645	202	134	6.9	20.0	11	7.2	68	--	--	41
SEP											
14...	1445	54	190	6.8	19.5	1.6	9.2	<10	K67	62	70

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572200 SWATARA CREEK AT INWOOD, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Acidity (mg/L as CaCO ₃)	Calcium dis- solved (mg/L as Ca)	Magne- sium, dis- solved (mg/L as Mg)	Sodium, dis- solved (mg/L as Na)	Percent sodium	Sodium ad- sorp- tion ratio	Potas- sium, dis- solved (mg/L as K)	Alka- linity field as CaCO ₃)	Sulfate dis- solved (mg/L as SO ₄)	Chlo- ride, dis- solved (mg/L as Cl)	Silica, dis- solved (mg/L as SiO ₂)
DEC											
15...	0.0	12	6.8	6.2	19	0.4	1.1	9	45	10	2.4
JAN											
20...	12	6.9	12	6.9	18	.4	.8	9	40	9.0	5.4
FEB											
04...	3.0	5.7	2.7	6.1	32	.5	2.6	4	15	10	3.6
05...	2.0	6.6	3.4	6.0	28	.5	2.0	4	20	9.0	4.0
16...	.0	8.1	4.4	8.3	31	.6	2.0	6	25	12	5.5
MAR											
23...	6.0	6.8	4.0	3.9	20	.3	.8	2	26	6.0	5.6
APR											
20...	4.0	8.3	5.0	4.0	17	.3	.8	1	30	7.0	5.3
26...	2.0	6.7	3.9	3.8	20	.3	.8	4	25	6.0	5.5
27...	3.0	6.5	3.3	3.4	19	.3	.8	5	15	6.0	5.1
MAY											
25...	2.0	9.9	6.3	5.5	19	.3	.8	4	35	6.0	5.8
JUN											
22...	12	9.7	5.7	5.1	18	.3	1.0	6	35	6.0	6.9
JUL											
27...	2.0	14	8.7	6.8	17	.4	1.2	6	60	8.0	5.8
AUG											
25...	3.0	11	6.7	4.9	16	.3	1.3	8	35	7.0	6.3
25...	8.0	10	5.1	4.0	15	.3	1.5	6	30	8.0	5.4
26...	2.0	8.8	4.6	3.5	15	.2	1.2	8	25	6.0	6.2
SEP											
14...	3.0	14	8.4	5.6	14	.3	2.8	7	40	8.0	5.8

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572200 SWATARA CREEK AT INWOOD, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Nitro- gen, nitrate total (mg/L as N)	Nitro- gen, nitrate dis- solved (mg/L as N)	Nitro- gen, nitrite total (mg/L as N)	Nitro- gen, nitrite dis- solved (mg/L as N)	Nitro- gen, ammonia total (mg/L as N)	Nitro- gen, ammonia dis- solved (mg/L as N)	Nitro- gen, organic total (mg/L as N)	Nitro- gen, organic dis- solved (mg/L as N)	Nitro- gen,am- monia = organic total (mg/L as N)	Nitro- gen,am- monia = organic dis. (mg/L as N)	Nitro- gen, total (mg/L as N)
DEC											
15...	1.2	1.20	0.010	0.010	0.080	0.080	0.72	0.62	0.80	0.70	2.0
JAN											
20...	1.2	1.20	.010	.010	.120	.120	.55	.55	.67	.67	1.9
FEB											
04...	1.6	1.60	.020	.010	.200	.180	.93	.93	1.10	1.1	2.7
05...	1.4	1.30	.010	.010	.080	.080	.58	.52	.66	.60	2.0
16...	1.3	1.20	.010	.010	.140	.130	.77	.77	.90	.90	2.2
MAR											
23...	1.7	1.70	.010	.010	.070	.070	.23	.23	.30	.30	2.0
APR											
20...	.84	.80	<.010	<.010	.090	.090	--	.86	--	.95	--
26...	.61	.59	.010	.010	.090	.080	.71	.62	.80	.70	1.4
27...	.72	.72	.010	<.010	.030	.030	.87	.77	.90	.80	--
MAY											
25...	.50	.50	<.010	<.010	.150	.150	1.0	1.0	1.20	1.2	--
JUN											
22...	1.2	1.20	<.010	<.010	.110	.110	1.0	1.0	1.10	1.1	--
JUL											
27...	.47	.47	.010	<.010	.050	.050	.45	.30	.50	.35	--
AUG											
25...	.89	.89	.010	.010	.080	.070	1.0	.01	1.10	1.1	--
25...	.69	.69	.010	.010	.170	.090	2.4	.56	2.60	.65	--
26...	.90	.90	.010	<.010	.100	.100	1.3	.55	1.40	.65	--
SEP											
14...	.60	.60	<.010	<.010	.010	.010	.59	.59	.60	.60	--

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572200 SWATARA CREEK AT INWOOD, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Nitrogen dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Aluminum, total recoverable (µg/L as Al)	Aluminum, dissolved (µg/L as Al)	Chromium, total recoverable (µg/L as Cr)	Copper, total recoverable (µg/L as Cu)	Iron, total recoverable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)
DEC											
15...	1.9	0.040	0.040	<0.010	<0.010	170	170	--	--	220	40
JAN											
20...	1.9	.030	.030	.010	<.010	90	30	--	--	400	270
FEB											
04...	2.7	.160	.030	.010	<.010	2,200	110	20	20	3,000	70
05...	1.8	.070	.020	.030	.010	800	560	10	20	1,500	90
16...	2.1	.060	.010	.020	<.010	610	100	--	--	1,200	180
MAR											
23...	2.0	.020	.020	<.010	<.010	490	70	--	--	880	260
APR											
20...	--	.040	.020	<.010	<.010	410	70	--	--	740	30
26...	1.3	.030	.010	<.010	<.010	710	140	<10	10	780	80
27...	--	.040	.020	--	<.010	610	210	10	10	840	90
MAY											
25...	--	.020	.010	<.010	<.010	270	90	--	--	280	70
JUN											
22...	--	.030	.010	<.010	<.010	290	20	--	--	500	30
JUL											
27...	--	.030	.010	<.010	<.010	210	40	--	--	200	60
AUG											
25...	--	.090	.020	.010	<.010	1100	410	<10	20	1900	60
25...	--	.250	.020	.010	<.010	13,000	220	<10	60	21,000	70
26...	--	.030	.030	.010	<.010	400	90	20	30	620	60
SEP											
14...	--	.030	.030	<.010	<.010	180	100	--	--	70	50

Table 9.--Surface-water and water-quality data, July 1981 through September 1982--Continued

01572200 SWATARA CREEK AT INWOOD, PA

WATER-QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

Date	Lead, total recoverable (µg/L as Pb)	Manga- nese, total recoverable (µg/L as Mn)	Manga- nese, dis- solved (µg/L as Mn)	Mercury total recoverable (µg/L as Hg)	Zinc, total recoverable (µg/L as Zn)	Carbon, organic total (mg/L as C)	Carbon, organic dis- solved (mg/L as C)	Sedi- ment, sus- pended (mg/L)	Sedi- ment, dis- charge, sus- pended (ton/d)	Sed. susp. sieve diam. percent finer than 0.062 mm
DEC										
15...	--	650	610	--	--	1.0	1.0	2	0.40	--
JAN										
20...	--	560	550	--	--	1.3	1.3	6	1.8	--
FEB										
04...	9	370	210	<2.0	110	4.9	4.4	143	494	63
05...	5	290	280	<2.0	50	3.7	2.8	34	49	81
16...	--	340	320	--	--	3.7	2.7	16	10	--
MAR										
23...	--	310	310	--	--	--	--	11	16	--
APR										
20...	--	330	310	--	--	2.0	2.0	12	5.5	--
26...	30	350	350	<2.0	<10	--	2.0	21	25	69
27...	<5	230	220	<2.0	40	--	1.5	23	35	68
MAY										
25...	--	470	470	--	--	1.1	1.1	4	1.6	--
JUN										
22...	--	340	320	--	--	<1.0	--	10	7.4	--
JUL										
27...	--	350	340	--	--	<1.0	--	4	.67	--
AUG										
25...	52	500	430	<2.0	90	2.0	--	51	23	93
25...	46	710	350	<2.0	120	<1.0	--	652	1,130	97
26...	5	300	270	<2.0	60	--	2.4	16	8.7	88
SEP										
14...	--	370	370	--	--	--	1.5	5	.73	--

PARTICLE-SIZE DISTRIBUTION OF SUSPENDED SEDIMENT, DECEMBER 1981 to SEPTEMBER 1982

Date	Time	Stream- flow, instan- taneous (ft ³ /s)	sedi- ment, sus- pended (mg/L)	Sedi- ment, Dis- charge, sus- pended (ton/d)	Sed. susp. fall diam. percent finer than 0.004 mm	Sed. susp. fall diam. percent finer than 0.008 mm	Sed. susp. fall diam. percent finer than 0.016 mm	Sed. susp. fall diam. percent finer than 0.031 mm	Sed. susp. sieve diam. percent finer than 0.062 mm	Sed. susp. sieve diam. percent finer than 0.125 mm
AUG										
25...	1520	629	586	995	51	68	86	95	99	100

