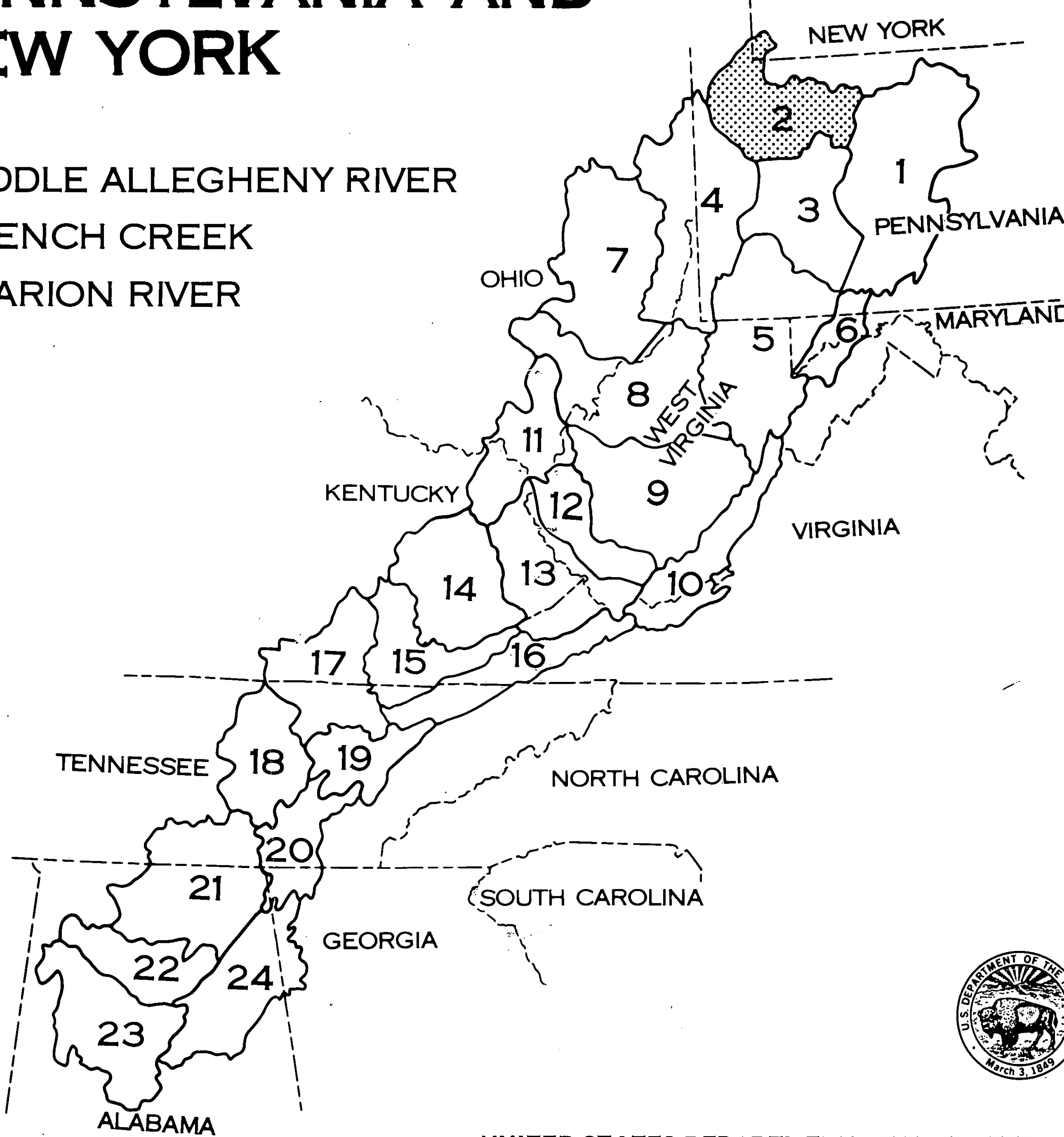
HYDROLOGY OF AREA 2, EASTERN COAL PROVINCE, PENNSYLVANIA AND NEW YORK

- MIDDLE ALLEGHENY RIVER
- FRENCH CREEK
- CLARION RIVER



UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER RESOURCES INVESTIGATIONS
OPEN FILE REPORT 82-647

HYDROLOGY OF AREA 2, EASTERN COAL PROVINCE, PENNSYLVANIA AND NEW YORK

BY
WILLIAM J. HERB, DEBORAH E. BROWN, LEWIS C. SHAW, JEFFREY D. STONER, AND JOHN K. FELBINGER

U.S. GEOLOGICAL SURVEY

WATER RESOURCES INVESTIGATIONS
OPEN FILE REPORT 82-647

HARRISBURG, PENNSYLVANIA
SEPTEMBER, 1983

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, *SECRETARY*

GEOLOGICAL SURVEY

Dallas L. Peck, *Director*

For additional information write to:

U.S. Geological Survey
Federal Building, 4th Floor
P.O. Box 1107
228 Walnut Street
Harrisburg, Pennsylvania 17108

CONTENTS

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

For convenience of readers who may want to use the International System of Units (SI), the data may be converted by using the following factors:

Multiply	By	To obtain
inches (in)	25.40	millimeters (mm)
feet (ft)	0.3048	meters (m)
feet per mile (ft/mi)	0.1894	meters per kilometer (m/km)
miles (mi)	1.609	kilometers (km)
square miles (mi^2)	2.590	square kilometers (km^2)
gallons per minute (gal/min)	0.06309	liters per second (L/s)
million gallons per day (mgal/d)	0.04381 3785.	cubic meters per second (m^3/s) cubic meters per day (m^3/d)
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)
cubic feet per second per square mile [(ft^3/s)/mi^2]	0.01093	cubic meters per second per square kilometer [(m^3/s)/km^2]
tons per square mile (tons/mi^2)	0.3503	megagrams per square kilometer (Mg/km^2)
micromhos (μmho)	1.0	microsiemens (μS)

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. NGVD of 1929 is referred to as sea level in this report.

HYDROLOGY OF AREA 2, EASTERN COAL PROVINCE, PENNSYLVANIA AND NEW YORK

BY
WILLIAM J. HERB, DEBORAH E. BROWN, LEWIS C. SHAW, JEFFREY D. STONER, AND JOHN D, FELBINGER

Abstract

Provisions of the Surface Mining Control and Reclamation Act of 1977 recognized a nationwide need for hydrologic information in mined and potentially mined areas. This report is designed to be useful to mine owners, operators, regulatory authorities, citizens groups, and others by presenting information on existing hydrologic conditions and by identifying additional sources of hydrologic information. General hydrologic information is presented in a brief text accompanied by a map, chart, graph, or other illustration for each of a series of water-resources-related topics. The summation of the topical discussions provides a description of the hydrology of the area.

The Eastern Coal Province has been divided into 24 hydrologic study areas which are shown on the cover of this report. The divisions are based on hydrologic factors, location, and size. Hydrologic units (surface drainage basins) or parts of units are combined to form each study area.

Study Area 2 covers northwestern Pennsylvania and a small part of southwestern New York. Most exposed bedrock is of Pennsylvanian, Mississippian, or Devonian ages. Glacial drift covers most of the bedrock in the northwestern part of the area. During 1979, more than 7 million tons of bituminous coal was produced from about 230 mines in Area 2 counties. Over 99 percent of the area's coal production is from surface mining.

Streamflow data are available for 18 continuous-record stations; 1 crest-stage, partial-record station; 1 low-flow, partial-record station; and 65 miscellaneous sites. Water-quality data are available for 78 locations.

Streams having the highest median specific conductance, highest median dissolved-solids concentrations, lowest median pH, highest median total-iron concentration, highest median total-manganese concentration, and highest dissolved-sulfate concentrations were found in Clarion County, the leading coal-producing county in the area.

Statistics on low flow, mean flow, peak flow, and flow duration for gaging stations can be computed from recorded mean daily flows. Similar statistics can be estimated for ungaged streams by regression and graphical techniques.

Five ground-water observation wells are being operated in Area 2. Ground-water levels fluctuate seasonally. Depth to water increases with well depth in upland areas and decreases with well depth in valleys. Well yields in the area range from less than 1 to more than 2,000 gallons per minute. Wells in unconsolidated materials usually have higher yields. Ground-water quality is adequate for most domestic purposes, except locally.

Additional water-data information are available through: (1) The National Water Data Exchange, (2) The National Water Data Storage and Retrieval System, and (3) The Office of Water Data Coordination.

1.0 INTRODUCTION

1.1 Objective

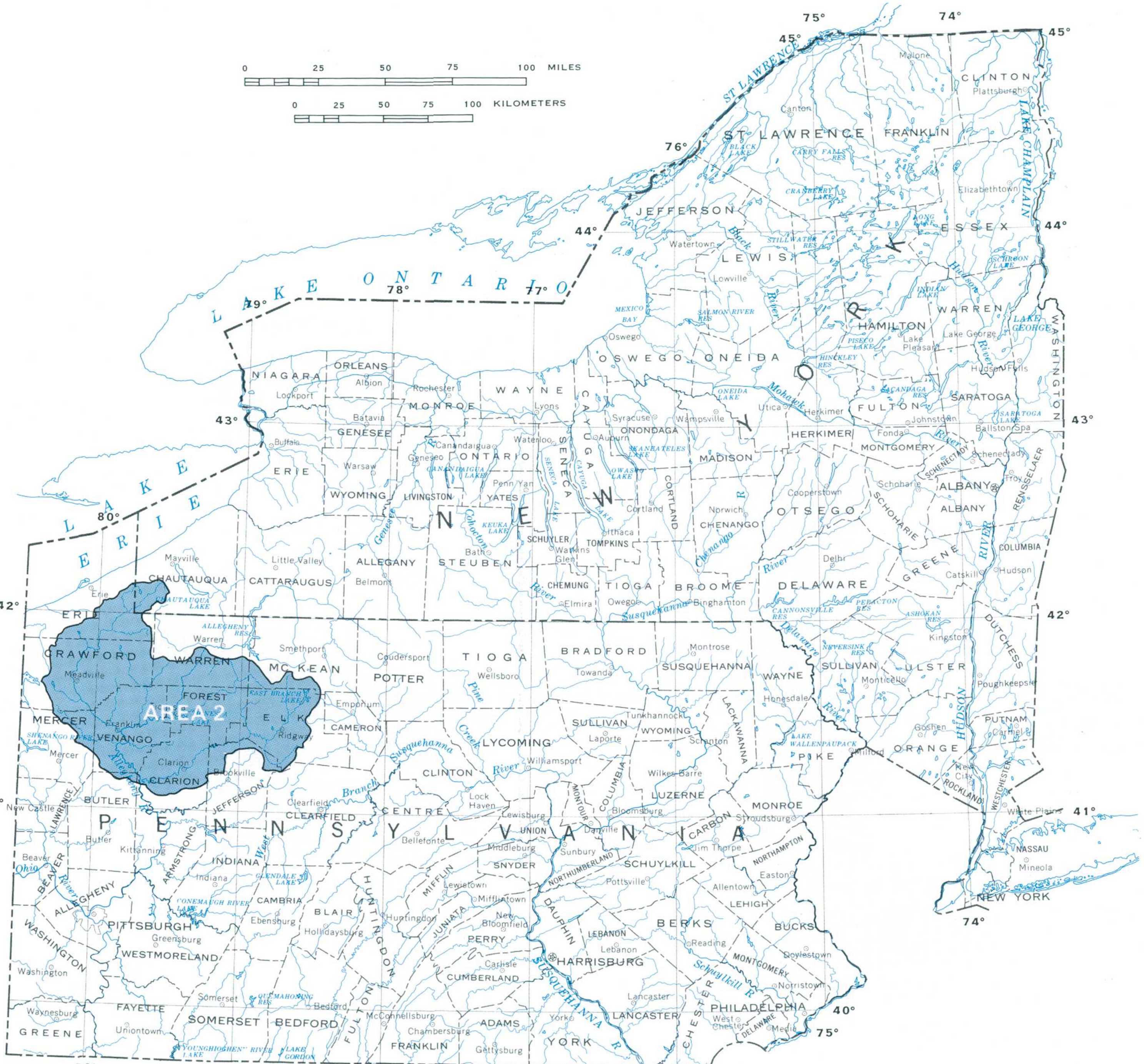
Area 2 Report to Aid Permitting

Existing hydrologic conditions and identification of sources of hydrologic information are described.

A need for hydrologic information and analysis on a scale never before required nationally was initiated when the "Surface Mining Control and Reclamation Act of 1977" was enacted as Public Law 95-87, August 3, 1977. This need is partially met by this report which broadly characterizes the hydrology of a large sub-basin in the coal area of northwestern Pennsylvania and southwestern New York (see figure 1.1-1). This report, which is for Area 2, is one of a series that covers the coal provinces nationwide. The report contains a brief text with an accompanying map, chart, graph, or other illustration for each of a number of water-resources-related topics. The summation of the topical discussions provides a description of the hydrology of the area.

The hydrologic information presented or available through sources identified in this report may be used in describing the hydrology of the "general area" of any proposed mine. Furthermore, it is expected that this hydrologic information will be supplemented by the lease applicant's specific site data as well as data from other sources to provide a more detailed picture of the hydrology in the vicinity of the mine and the anticipated hydrologic consequences of the mining operation.

The information contained herein should be useful to surface mine owners, operators, and consulting engineers in the preparation of permits and to regulatory authorities in appraising the adequacy of permit applications.



BASE FROM U.S. GEOLOGICAL SURVEY UNITED STATES BASE MAP, 1:2,500,000, 1972

BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAPS, 1:500,000, 1975

Figure 1.1-1 Location of Area 2 in Pennsylvania and New York.

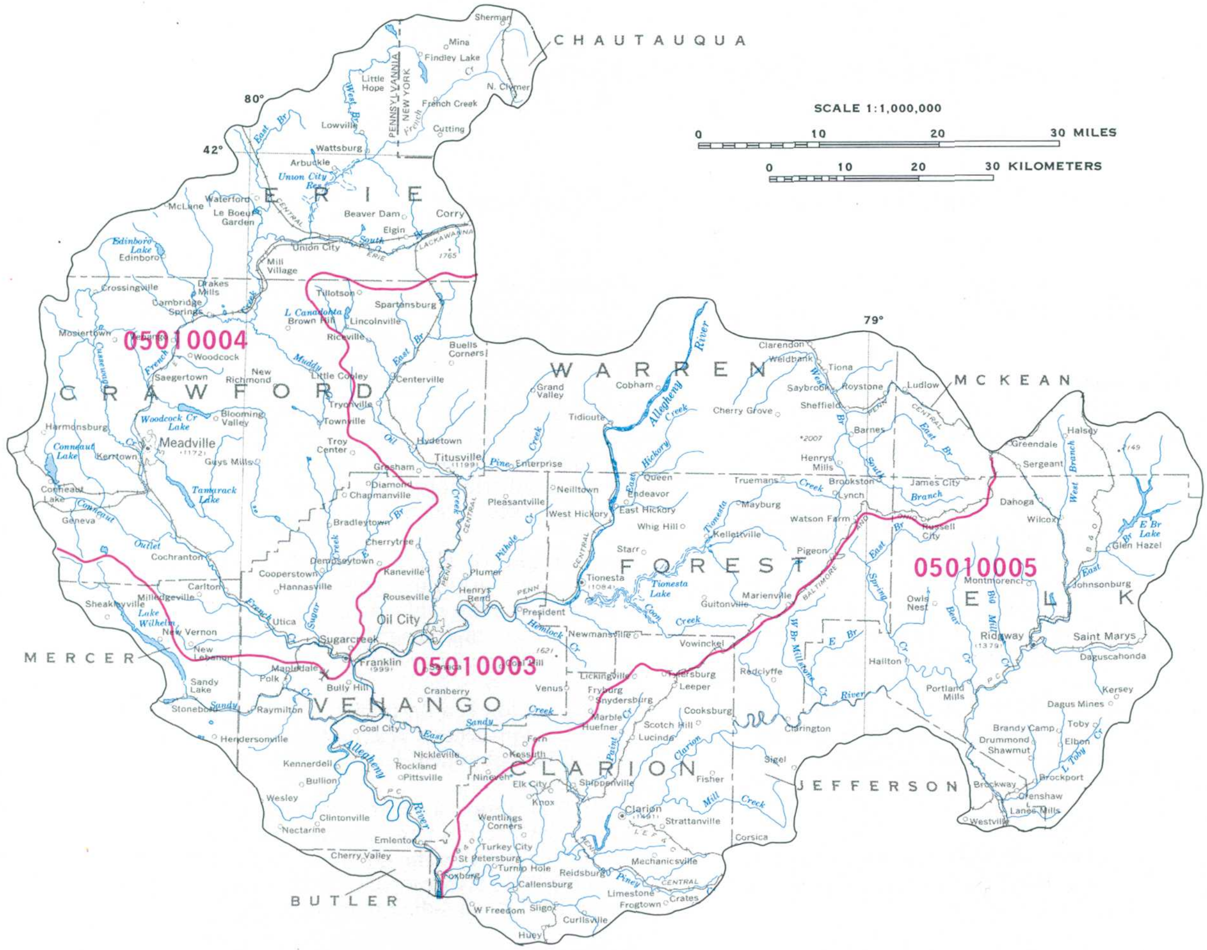
Hydrology and Water Resources Summarized for Area 2

This report summarizes the hydrology and water resources of Area 2 in the northern part of the Eastern Coal Province.

The Eastern Coal Province is divided into 24 hydrologic reporting units. The divisions are based on hydrologic factors, location, size, and mining activity (see front cover for areas in the Eastern Coal Province). Hydrologic units (drainage basins) or parts of units are combined to form each area (fig. 1.2-1).

Area 2 is in the northern part of the Eastern Coal Province in northwestern Pennsylvania and southwestern New York. The area includes all or part of Erie, Crawford, Mercer, Warren, Forest, Elk, Venango, Clarion, Butler, McKean, and Jefferson Counties, Pennsylvania; and Chautauqua County, New York.

Area 2 is comprised of the central part of the Allegheny River basin from immediately south of Warren downstream to Parker. Major tributaries in the Area include French Creek, Oil Creek, Tionesta Creek, and Clarion River. The surface area of Area 2 is 4,170 square miles.



BASE FROM U.S. GEOLOGICAL SURVEY
STATE BASE MAPS, 1:500,000, 1975

Figure 1.2-1 Hydrologic units.

2.0 DEFINITION OF TERMS

Terms Used in Hydrologic Reports Defined

Technical terms that occur in this Hydrologic Report are defined.

Bed material is the unconsolidated material of which a streambed, lake, pond, reservoir, or estuary bottom is composed.

Benthic invertebrate, for this study, is an animal without a backbone, living on or near the bottom of an aquatic environment, which is retained on a 210 μm mesh sieve.

Bottom material specifically includes anthropogenic matter in addition to natural solid material in bed material.

Cubic feet per second per square mile [$(ft^3/s)/mi^2$] is the average number of cubic feet of water flowing per second from each square mile of area drained, assuming that the runoff is distributed uniformly in time and area.

Cubic foot per second (ft^3/s) is the rate of discharge representing a volume of 1 cubic foot passing a given point during 1 second and is equivalent to approximately 7.48 gallons per second or 448.8 gallons per minute or 0.02832 cubic meters per second.

Discharge is the volume of water (or more broadly, volume of fluid plus suspended material) that passes a given point within a given period of time.

Mean discharge is the arithmetic mean of individual daily mean discharges during a specific period.

Instantaneous discharge is the discharge at a particular instant of time.

Dissolved refers to the amount of substance present in true chemical solution. In practice, however, the term includes all forms of substance that will pass through a 0.45-micrometer membrane filter, and thus may include some very small (colloidal) suspended particles. Analyses are performed on filtered samples.

Diversity index is a numerical expression of evenness of distribution of aquatic organisms, the formula for diversity index is:

$$\bar{d} = \sum_{i=1}^{s} \frac{n_i}{n} \log 2 \frac{n_i}{n}$$

Where n_i is the number of individuals per taxon, n is the total number of individuals, and s is the total number of taxa in the sample of the community. Diversity index values range from zero, when all the organisms in the sample are the same, to some positive number, when some or all of the organisms in the sample are different.

Drainage area of a stream at a specific location is that area, measured in a horizontal plane, enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into the river above the specified point. Figures of drainage area given herein include all closed basins, or noncontribution areas, within the area unless otherwise noted.

Drainage basin is a part of the surface of the Earth that is occupied by a drainage system, which consists of a surface stream or a body of impounded surface water together with all tributary surface streams and bodies of impounded surface water.

Gage height (G.H.) is the water-surface elevation referred to some arbitrary gage datum. Gage height is often used interchangeably with the more general term "stage", although gage height is more appropriate when used with a reading on a gage.

Gaging station is a particular site on a stream, canal, lake, or reservoir where systematic observations of hydrologic data are obtained.

Hydrologic unit is a geographic area representing part or all of a surface drainage basin or distinct hydrologic feature as delineated by the Office of Water Data Coordination on the State Hydrologic Unit Maps; each hydrologic unit is identified by an 8-digit number.

Micrograms per gram (μg/g) is a unit expressing the concentration of a chemical element as the mass (micrograms) of the element per unit mass (gram) of sediment.

Micrograms per liter (μg/L) is a unit expressing the concentration of chemical constituents in solution as mass (micrograms) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter.

Milligrams per liter (mg/L) is a unit for expressing the concentration of chemical constituents in solution. Milligrams per liter represent the mass of solute per unit volume (liter) of water. Concentration of suspended sediment also is expressed in mg/L, and is based on the mass (dry weight) of sediment per liter of water-sediment mixture.

Partial-record station is a particular site where limited streamflow and/or water-quality data are collected systematically over a period of years for use in hydrologic analyses.

Reference station is a streamflow and water-quality station operated as part of the State coal-hydrology network to monitor hydrologic characteristics in a watershed unaffected by mining.

Regression line is a line fitted to a set of data points by a least-squares statistical analysis. The same data set will always produce the same line of relation.

Sediment is solid material that originates mostly from disintegrated rocks and is transported by, suspended in, or deposited from water; it includes chemical and biochemical precipitates and decomposed organic material, such as humus. The quantity, characteristics, and cause of the occurrence of sediment in streams are influenced by environmental factors. Some major factors are degree of slope, length of slope, soil characteristics, land usage, and quantity and intensity of precipitation.

Suspended sediment is the sediment that at any given time is maintained in suspension by the upward components of turbulent currents or that exists in suspension as a colloid.

Suspended-sediment concentration is the velocity-weighted concentration of suspended sediment in the sampled zone (from the water surface to a point approximately 0.3 ft above the bed) expressed as milligrams of dry sediment per liter of water-sediment mixture (mg/L).

Specific conductance is a measure of the ability of a water to conduct an electrical current. It is expressed in micromhos per centimeter (μmho/cm) at 25°C. Specific conductance is related to the type and concentration of ions in solution and can be used for approximating the dissolved-solids concentration of the water. Commonly, the concentration of dissolved solids (in milligrams per liter) is about 65 percent of the specific conductance (in micromhos). This relation is not constant from stream to stream, and it may vary in the same stream with changes in the composition of the water.

Stage-discharge relation is the relation between gage height (stage) and volume of water per unit of time, flowing in a channel.

Streamflow is the discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than "runoff" as streamflow may be applied to discharge whether or not it is affected by diversion or regulation.

Substrate is the physical surface upon which an organism lived.

Natural substrate refers to any naturally occurring emersed or submersed solid surface, such as a rock or tree, upon which an organism lived.

Synoptic site is a station location where periodic measurements are made of streamflow and water quality. If a group of such sites is measured at about the same time, the hydrologic conditions over a wide area can be seen.

Taxonomy is the division of biology concerned with the classification and naming of organisms. The classification of organisms is based upon a hierarchical scheme beginning with Kingdom and ending with Species at the base. The higher the classification level, the fewer features the organisms have in common. For example, the taxonomy of a particular mayfly, *Hexagenia limbata* is the following:

Kingdom --- Animal

Phylum --- Arthropoda

Class --- Insecta

Order --- Ephemeroptera

Family --- Ephemeridae

Genus --- *Hexagenia*

Species --- *Hexagenia limbata*

Trend station is a streamflow and water-quality station operated as part of the State coal-hydrology network to monitor hydrologic characteristics in a watershed undergoing coal mining.

Water-year is, for this report, the 12-month period beginning October 1 of one year and ending September 30 of the following year. Water year 1979 begins on October 1, 1978, and ends on September 30, 1979.

New Regulations Set Effluent Limitations for Iron, Manganese, pH, and Suspended Solids

Standards have been set for iron, manganese, pH, and suspended solids in water discharged from areas disturbed by surface mining.

The Permanent Regulatory Program of the Office of Surface Mining Reclamation and Enforcement (1979) sets specific standards for water leaving a mine site. Section 816.42 (a) (7) of the Permanent Regulatory Program states that "discharges of water from areas disturbed by surface mining shall be made in compliance with all Federal and State laws and regulations . . . ." This same section also sets certain specific numerical effluent limitations. The specific effluent limitations are for total iron, total manganese, total suspended solids, and pH. Table 3.0-1 lists these numerical standards.

The effluent limitations for iron and manganese are considerably higher than those recommended for drinking water by the U.S. Environmental Protection Agency which sets limits of 300 $\mu g/L$ (micrograms per liter) iron and 50 $\mu g/L$ manganese.

Table 3.0-1 Mine effluent limitations.

Effluent limitations in milligrams per liter (mg/L) except for pH[1]		
Effluent characteristics	Maximum allowable	Average of daily values for 30 consecutive discharge days
Iron, total	7.0	3.5
Manganese, total[2]	4.0	2.0
Total suspended solids	70.0	35.0
pH[3]	Within range of 6.0 to 9.0	

[1]Office of Surface Mining, Reclamation, and Enforcement, 1979.
[2]Shall not apply to untreated alkaline discharges.
[3]pH may exceed 9.0, to a small extent, if needed to achieve manganese limit.

Bedrock and Unconsolidated Deposits Underlie the Area

Three principal ages of bedrock exposed in Area 2 are Pennsylvanian, Mississippian, and Devonian; most bedrock in the northwest part of the area is covered by glacial drift.

Pennsylvanian rocks crop out along the hills between major drainages in the southeastern portion of the area (fig. 4.1-1). These strata have a slight regional dip to the southwest. Superimposed on the regional structure is a series of gentle folds whose axes trend northeast. Fold heights, wavelengths, and dips along the flanks of the folds all increase southeastward. Wavelengths, measured between successive structural troughs (synclines) or ridges (anticlines), range from 6 to 9 miles. Fold dips range from 30 to 250 feet per mile.

The Pennsylvanian rocks consist of thin alternating beds of gray to white sandstone, siltstone, claystone, coal, and some limestone. Three major subdivisions of the Pennsylvanian rocks are the Pottsville, Allegheny, and Conemaugh Groups. The Conemaugh Group occurs only along the southern divide of the Clarion River basin where the Pennsylvanian rocks are about 650 feet thick. Numerous commercial coal beds exist in all three groups, but the significant coals lie within the Allegheny Group. Coal bed nomenclature is indicated in figure 4.1-2. Although many of these coal beds are not continuous throughout the area, the general column is useful in showing the relative stratigraphic position of the coal beds.

The Mississippian rocks crop out along major drainage bottoms in the southern part, and between drainages in the northwestern part of the area. The total sequence of Mississippian rocks had been extensively eroded before Pennsylvanian sediments were deposited. Therefore, only Lower Mississippian rocks remain beneath Area 2. The unit dips generally southward from 20 to 40 feet per mile. Due to the unconformable contact with the overlying Pennsylvanian rocks, the thickness of the Mississippian rocks can range from 200 feet in the north to 600 feet in the south.

The Mississippian rocks are composed mostly of shale, siltstone, sandstone, and flat-pebbled conglomerate. Due to a complex history of deposition, the rock types and thickness of units which make up the Mississippian change across the area (Schiner and Kimmel, 1972, p. A7). Consequently, the names given to major subdivisions differ from east to west (fig. 4.1-2). According to drillers logs, the Burgoon Sandstone exists only in the southern part of Clarion County.

The Devonian rocks which underlie the Mississippian rocks crop out only in the northern portion of the area. These rocks consist mostly of shale and have occasional thin layers of sandstone. The exposed thickness exceeds 900 feet. Several names have been assigned to the major subdivisions of this unit, partly as result of varied appearance, but mostly as result of changes in nomenclature given by various investigators. As it does for the Mississippian rocks, figure 4.1-2 indicates the general correlation of currently used names as well as older names that can be found in geology-related reports of the area.

Pleistocene glaciation has advanced into northwestern Pennsylvania. The southern limits of Illinoian and Wisconsin Glaciations in Area 2 are shown on figure 4.1-1. Due to the glaciation, landforms in the northwest have much less topographic relief than landforms in the rest of the area. Most bedrock northwest of the Illinoian limit of advance is covered by up to 40 feet of till (clay, silt, and boulders). In addition to this till, bedrock northwest of the Wisconsin limit of advance is also covered with local (morraine-type) deposits of alternating sand and gravel. Glacial outwash and alluvial deposits of coarse-grained sand and gravel mixed with clay and silt are found along major drainages and their tributaries northwest of the Illinoian boundary. However, outwash also occurs southeast of this limit along the Allegheny River and Tionesta Creek. The thickness of the outwash is over 100 feet locally in the major valleys.

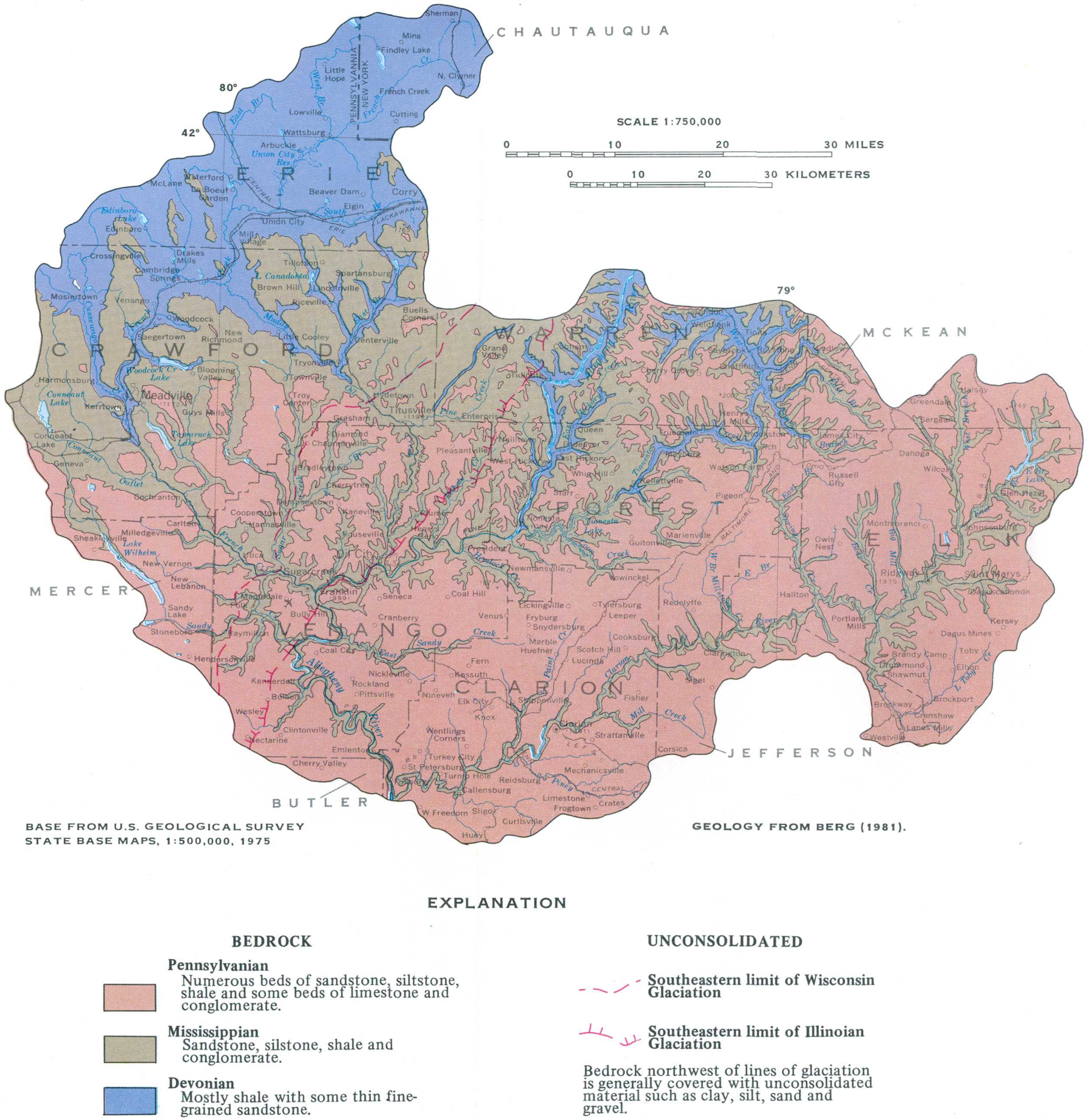


Figure 4.1-1 Geology.

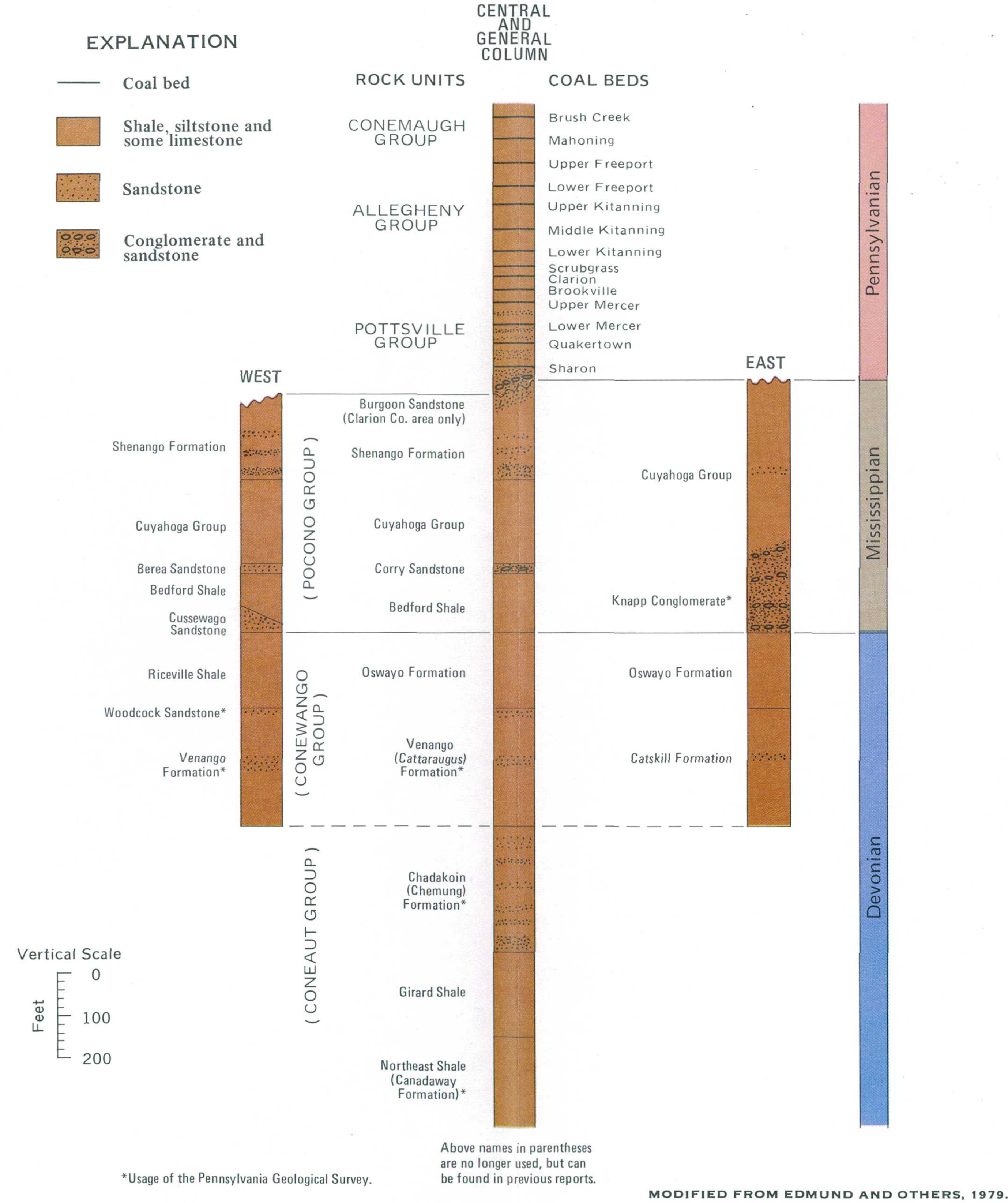


Figure 4.1-2 Generalized geologic sections.

Six Major Tributaries Drain 3,547 Square Miles of Area's 4,170 Square Miles

French Creek, Clarion River, Tionesta Creek, Oil Creek, Sandy Creek, and East Sandy Creek drain 3,547 of the 4,170 square miles in Area 2.

The Allegheny River originates in northcentral Pennsylvania near the New York border, flows northwest into New York, loops west, reenters Pennsylvania from the north, and flows south past Tidioute, Tionesta, and Foxburg (fig. 4.2-1). The entire Allegheny River basin is in the Appalachian Plateau Province (Fenneman, 1938), a highland having winding drainage divides and no definite valley and ridge pattern. Six major streams, all tributary to the Allegheny River, drain most of Area 2. Tionesta Creek, Oil Creek, French Creek, East Sandy Creek, Sandy Creek, and Clarion River drain 3,547 of Area 2's 4,170 square miles of surface area. Some characteristics of these streams are listed in table 4.2-1. The drainage area of the Allegheny River at the downstream limit of Area 2 is 7,715 square miles; 3,545 square miles are outside Area 2.

Tionesta Creek is in the Allegheny High Plateaus section of the Appalachian Plateau Province and is underlain by coal-bearing rocks of the Pottsville Group. Tionesta Creek originates in the Allegheny National Forest and enters the Allegheny River at Tionesta. The basin has very little coal production, although there is some gas and oil exploration in progress.

Oil Creek flows through the Glaciated section and Allegheny High Plateaus section. It originates north of the coal deposits, but enters the coal-bearing rocks of the Pottsville Group as it flows south. The name Oil Creek originated from the natural oil seepage on the water surface. The creek became famous on August 27, 1859, when the first drilled oil well produced.

French Creek originates in New York in the glaciated section. There is a small area of the Allegheny High Plateaus section near the mouth. French Creek flows southwest out of New York and arcs southeast to the Allegheny River at Franklin. The lower basin contains some oil and gas, and is underlain by coal-bearing rocks of the Pottsville Group.

East Sandy Creek is in the Pittsburgh Plateaus section and is underlain by coal-bearing rocks of the Allegheny and Pottsville Groups. The basin contains gas, oil, and coal. Sandy Creek is in the glaciated section and is underlain by coal-bearing rocks of the Pottsville and Allegheny Groups. The lower basin has oil and gas, while the coal beds are evenly distributed throughout the basin.

Clarion River is in the Allegheny High Plateaus and Pittsburgh Plateaus sections and is underlain by coal-bearing rocks of the Pottsville and Allegheny Groups. The upper part of the basin above Clarion has narrow steep-sided valleys with high hills. Oil and gas are limited to the lower basin, whereas the coal beds are evenly distributed throughout the basin.

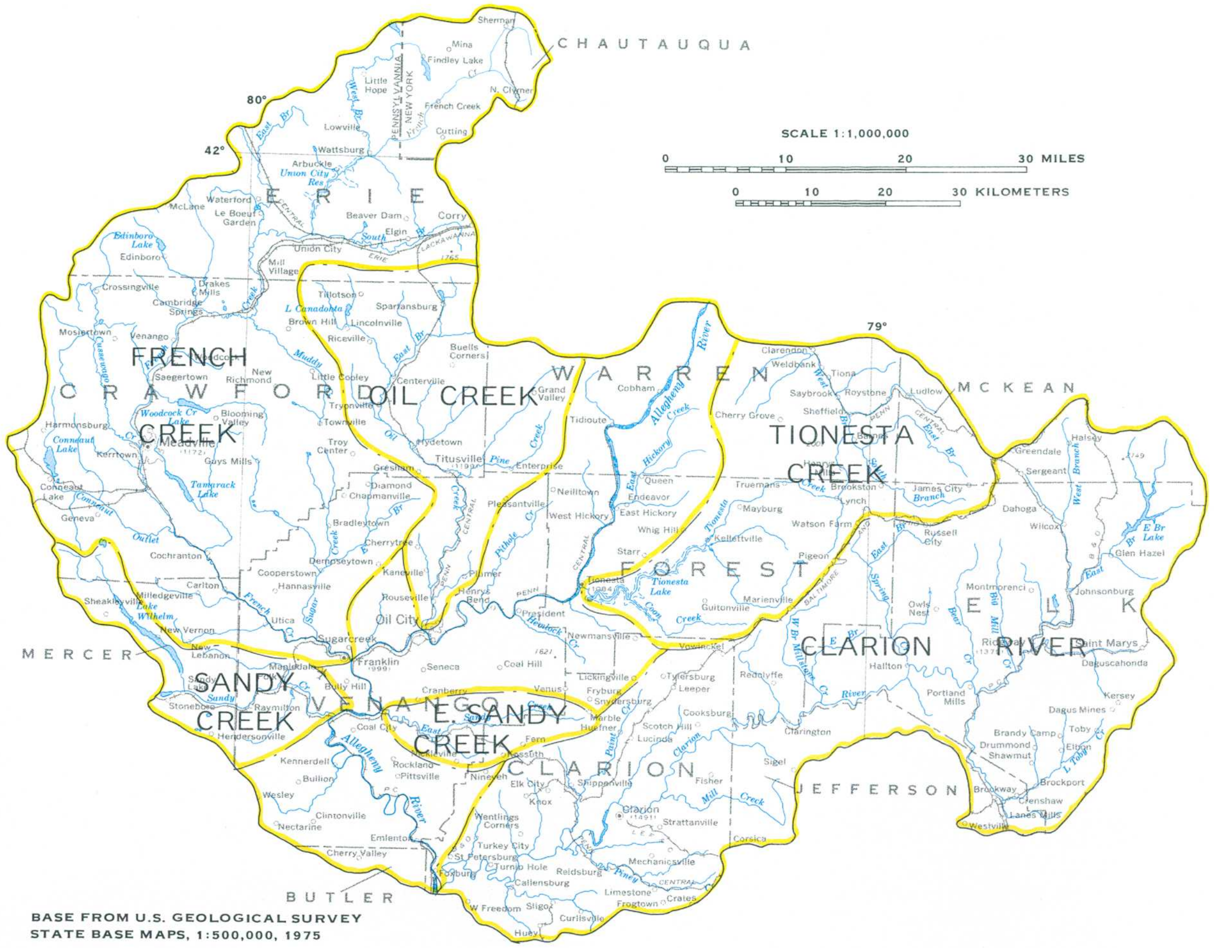


Figure 4.2-1 Major drainage basins.

Table 4.2-1 Characteristics of major drainage basins.

Basin	Drainage area (mi.^{2})	Length (mi.)	Channel slope (ft./mi.)	Drainage[1,2] pattern	Channel[3,4] pattern
Tionesta Creek	480	61.9	7.5	Dendritic	Irregular
Oil Creek	319	46.7	8.6	do.	Tortuous
French Creek	1,235	83.8[5]	4.3	Deranged	do.
East Sandy Creek	103	26.6	22.2	Dendritic	Irregular
Sandy Creek	161	41.0	6.8	do.	do.
Clarion River	1,252	99.2	5.7	do.	do..

[1]Howard (1967)
[2]See figure 4.2-2
[3]Schumm (1963)
[4]See figure 4.2-3
[5]in Pennsylvania

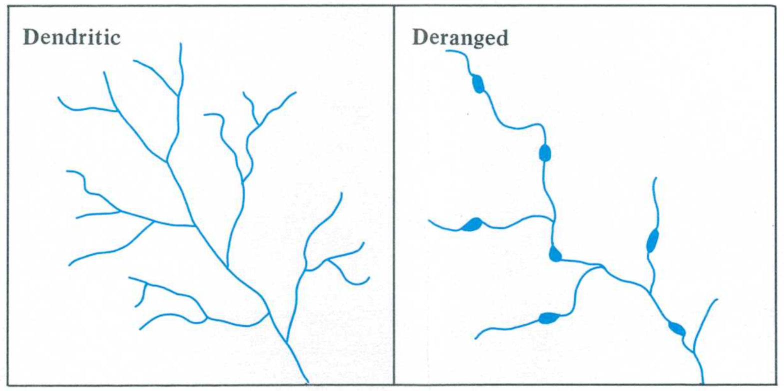


Figure 4.2-2 Morphological classifications of drainage patterns.

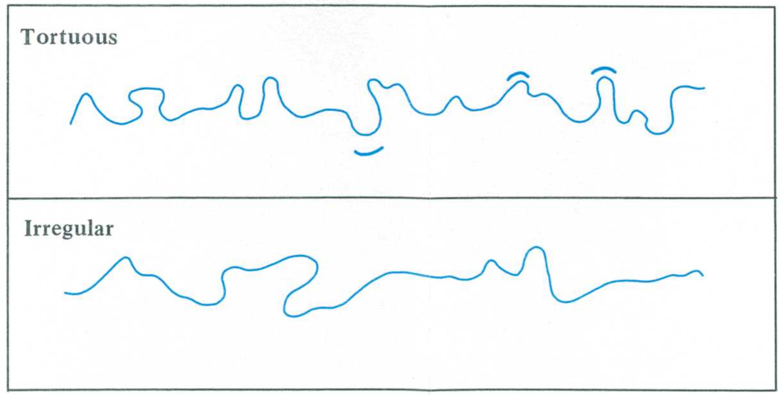


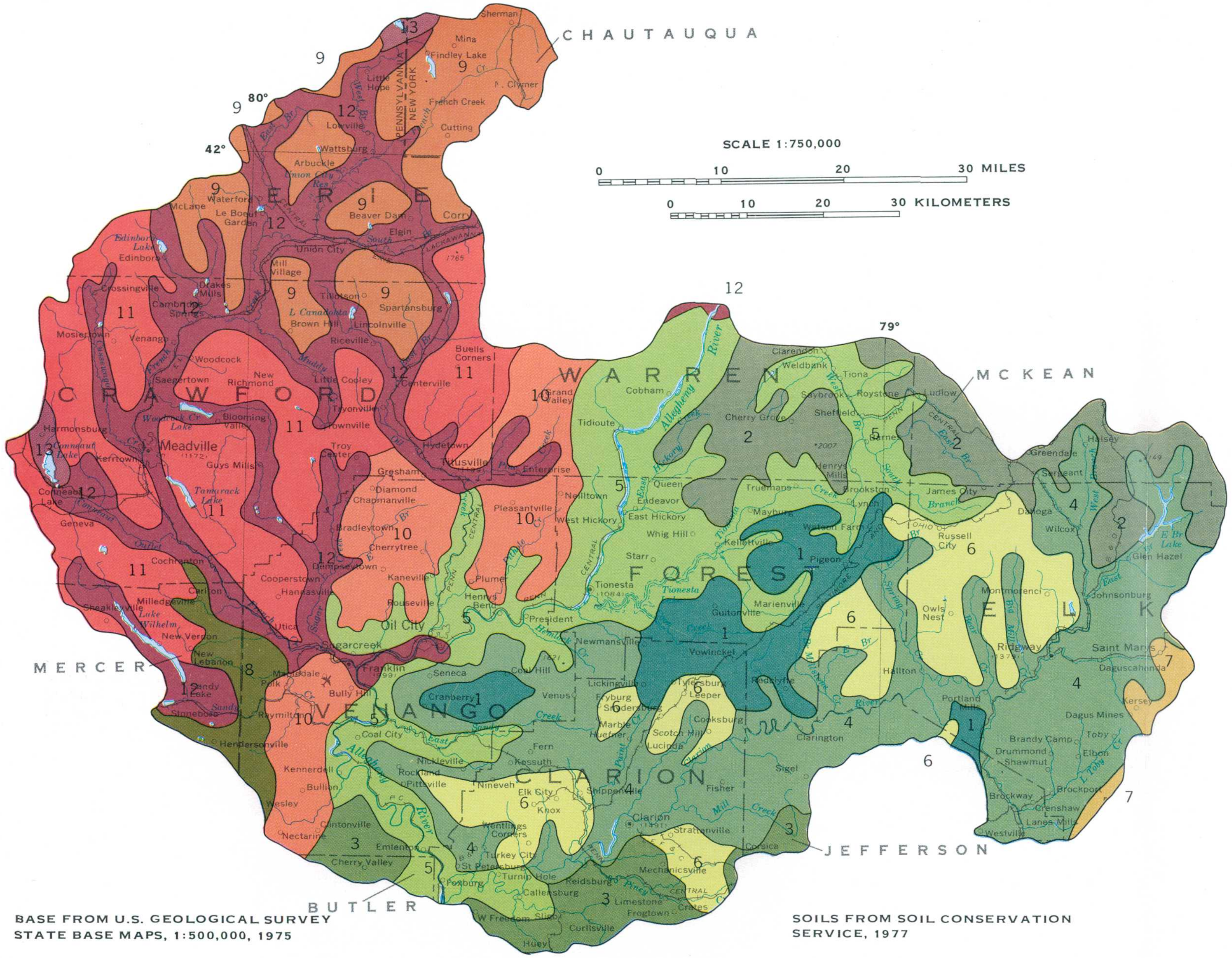
Figure 4.2-3 Channel patterns.

Residual Soils in Area Classified into Three Broad Groups

Residual soils in Area 2 are generally formed from noncarbonated sedimentary rocks, glacial till, or unconsolidated water-sorted materials.

Soils in the southeastern part of Area 2 are generally formed from noncarbonated sedimentary rocks, whereas soils in the northwestern part are formed from glacial till and unconsolidated water-sorted materials. The soils formed from the unconsolidated water-sorted materials lie in narrow bands along major streams or valley floors. The locations of the three major soil groups (Soil Conversation Service, 1972) are shown in a generalized soil map (fig. 4.3-1).

Soil depths in the southeastern part of Area 2, the Pittsburgh Plateaus and Allegheny High Plateaus Sections (Office of Resources Management, 1980), vary between 30 and 72 inches (table 4.3-1). This area is largely underlain by sandstones, conglomerates, thin shales, and coals. Slopes range from 3 to 25 percent. Most of the land is sloping except for small areas of flatlands on the valley bottoms. The northwestern part of the area, the Glaciated Section (Office of Resources Management, 1980), has soils varying in depth from 30 to 60 inches and varying in slope from 0 to 20 percent. The soils formed in unconsolidated water-sorted materials consist of silt, sand, and gravel (table 4.3-2), and overlay the remaining glacial soils, sandstones, shales, and conglomerates. The area is characterized by natural lakes, swamps, low rounded hills, and gravel deposits.



EXPLANATION

SOIL ASSOCIATIONS

Soils found in materials weathered from noncarbonate sedimentary rocks (A)

Substrata of reddish sandstone, shale, and siltstone (A2)

- 1 Cookport - Clymer - Hazelton (A2b)
- 2 Cookport - Cavode - Wharton (A2c)
- 3 Gilpin - Ernest - Wharton (A2i)
- 4 Hazelton - Cookport (A2k)
- 5 Hazelton - Gilpin - Ernest (A2l)

Substrata of reddish, yellowish, and brownish clayshale (A3)

- 6 Cavode - Wharton - Gilpin (A3a)
- 7 Upshur - Gilpin - Clarksburg (A3b)

Soils formed in glacial till (D)

Substrata grayish (D2)

- 8 Canfield - Rayenna (D2a)
- 9 Erie - Longford (D2b)
- 10 Hanover - Alvira (D2c)
- 11 Venango - Cambridge (D2h)

Soils formed in unconsolidated water-sorted materials (E)

Substrata of stratified fluvial sand, silt, and gravel (E1)

- 12 Wayland - Chenango - Braceville (E1f)

Substrata of lacustrine clay or silt (E2)

- 13 Canadice - Caneadea (E2a)

Figure 4.3-1 Generalized soil map.

Table 4.3-1 General soil characteristics

Section of Applachian Plateaus province	Soil depth (inches)	Slope range (percent)	Qualitative infiltration rate	Qualitative drainage
Pittsburgh Plateaus	30 - 72	3 - 20	Well to medium well	Good
Allegheny High Plateaus	30 - 70	3 - 25	Moderate to slow	Fair
Glaciated	30 -60	0 - 20	Slow to moderate	Poor

Table 4.3-2 Scale of particle sizes

Class name	Millimeters
Boulders	>256
Cobbles	256 - 64
Gravel	64 - 2
Very coarse sand	2.0 - 1.0
Coarse sand	1.0 - 0.50
Medium sand	0.50 - 0.25
Fine sand	0.25 - 0.125
Very fine sand	0.125 - 0.062
Coarse silt	0.062 - 0.031
Medium silt	0.031 - 0.016
Fine silt	0.016 - 0.008
Very fine silt	0.008 - 0.004
Coarse clay	0.004 - 0.0020
Medium clay	0.0020 - 0.0010
Fine clay	0.0010 - 0.0005
Very fine clay	0.0005 - 0.00024
Colloids	<0.00024

Area has Humid Continental Climate

The humid continental climate of Area 2 is dominated by the west and southwest winds that influence most of the weather disturbances in the area.

Area 2 is located in the upper and central Allegheny River basin. A number of storm tracks cross the area from the north, west, and south. The Gulf of Mexico and Great Lakes are the primary sources of moisture. Winters are partly controlled by dry air masses that originate in Canada and travel south from Hudson Bay or east from the Rocky Mountains. Cold Hudson Bay air can carry moisture from the Great Lakes, which may produce heavy local snowfalls and sub-zero weather. At other times, moist air from the southwest causes rain and snow. Winter weather can change every few days and extended periods of extreme cold or warmth are rare.

Summer weather usually originates from the southwest. Warm, moist air brings thunderstorms that can occur anytime from May to September. Temperatures peak during July. Hurricanes and tropical storms follow a northeasterly track and may produce heavy rains in the area, generally from June to November.

Mean annual precipitation is shown by the isohyets on figure 4.4-1 for the base period 1941-70. The monthly normals and extremes at weather stations in Franklin and Warren (immediately north of Area 2) are shown in figure 4.4-2. Monthly extremes of snowfall and ice pellets are illustrated in figure 4.4-3.

Temperatures as high as 105°F have been recorded during July and as low as -32°F in February. Because of the differences in topography, the mean annual frost-free period in Area 2 ranges from 130 days to 175 days. The recorded monthly temperature normals and extremes at the Franklin and Warren weather stations are shown in figure 4.4-4.

Daily precipitation data are published monthly as "Local Climatological Data for Pennsylvania" by the National Oceanic and Atmospheric Administration, National Climatic Center, Ashville, N.C. Statistical information concerning analysis and data are presented by the U.S. Department of Commerce (1973).

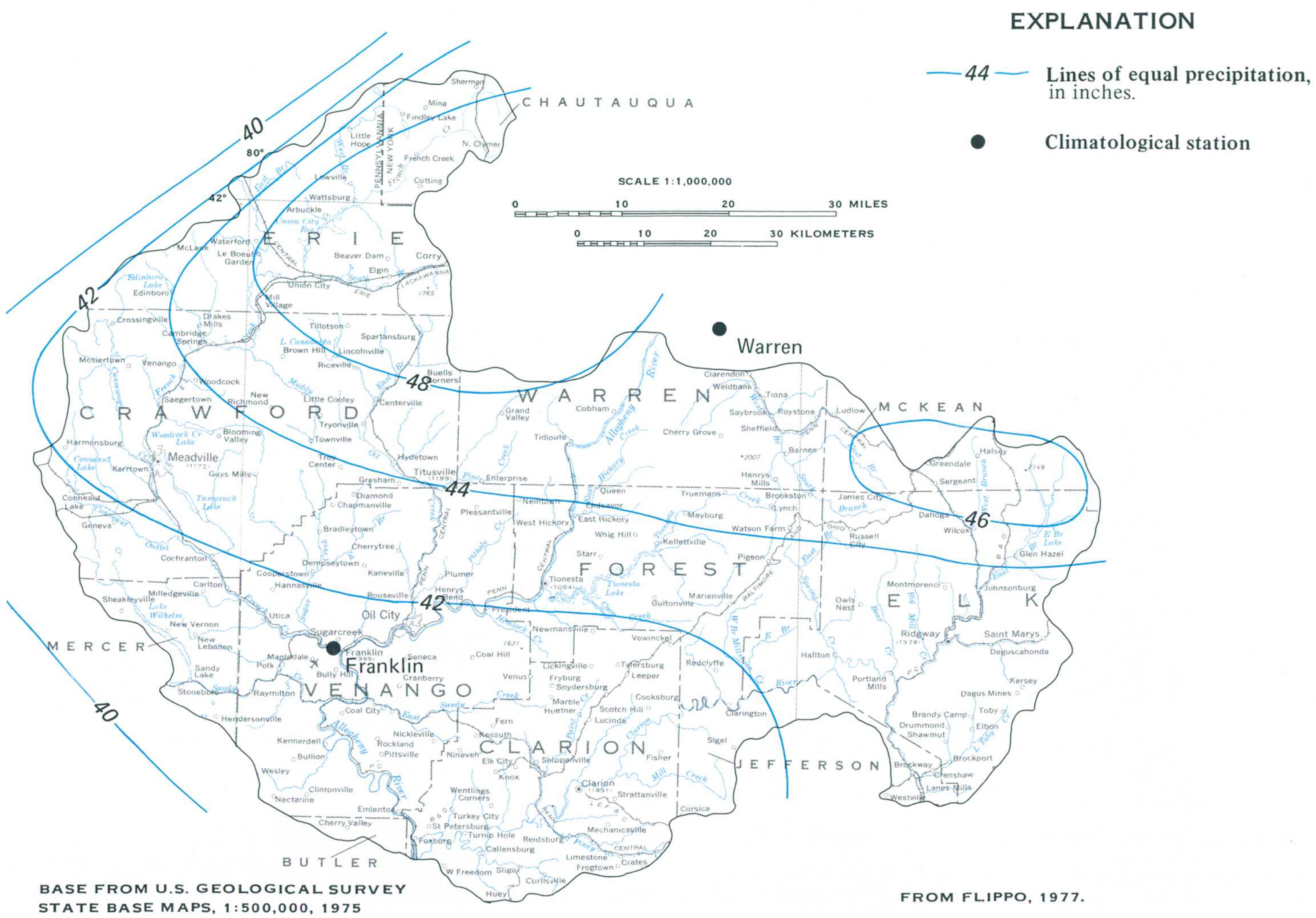
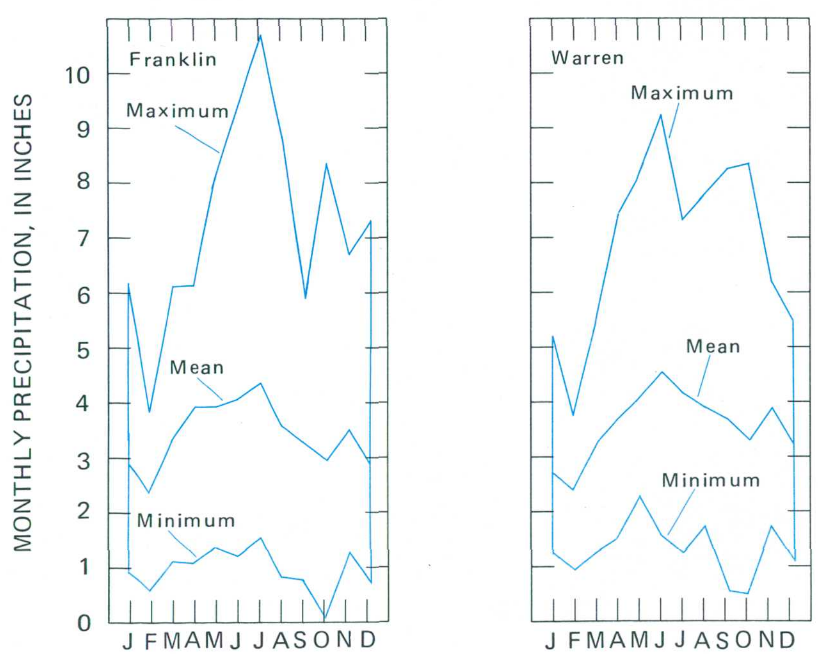


Figure 4.4-1 Mean annual precipitation from 1941-70.



CLIMATOLOGICAL DATA FROM NATIONAL CLIMATIC CENTER, 1977

Figure 4.4-2 Monthly precipitation.

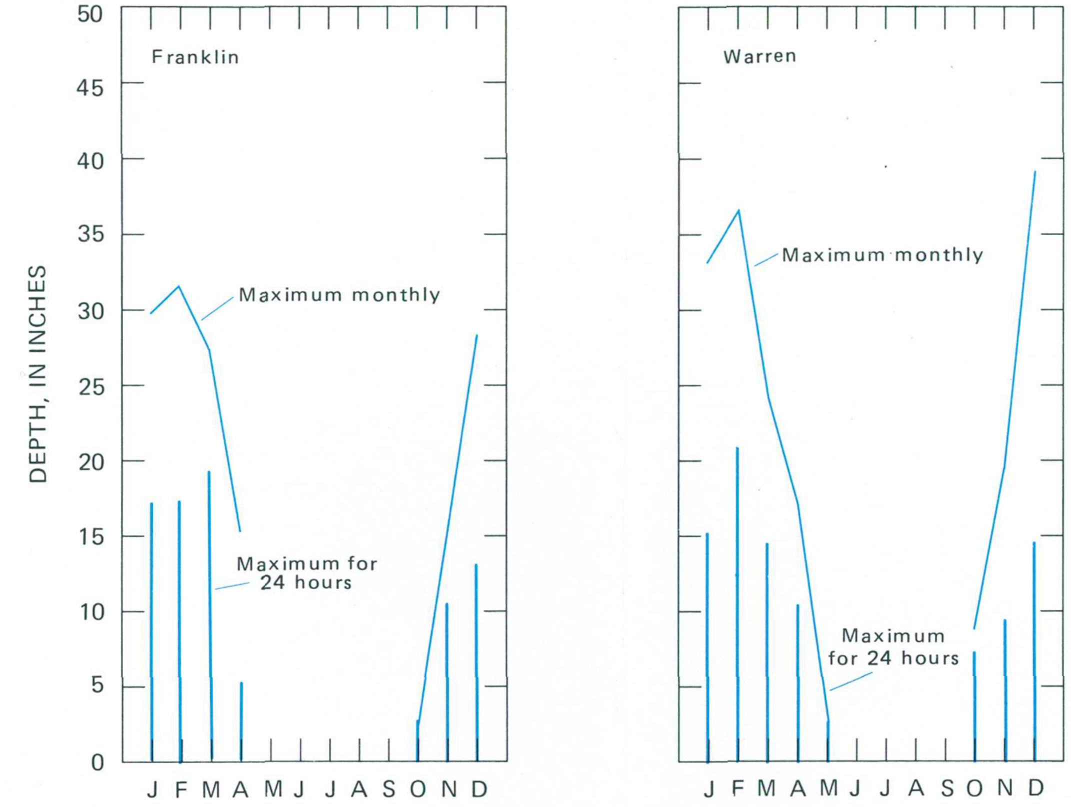


Figure 4.4-3 Depth of snowfall and ice pellets.

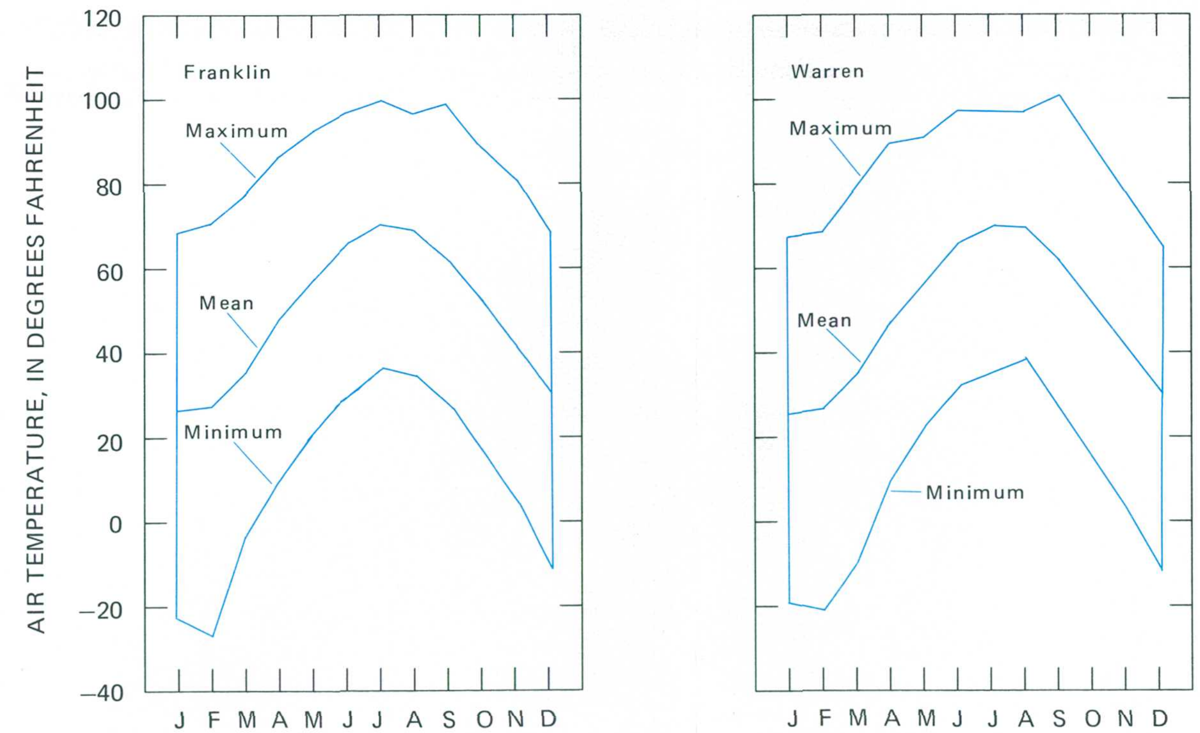


Figure 4.4-4 Air temperature.

5.0 COAL

Clarion County Leading Coal Producer in Area

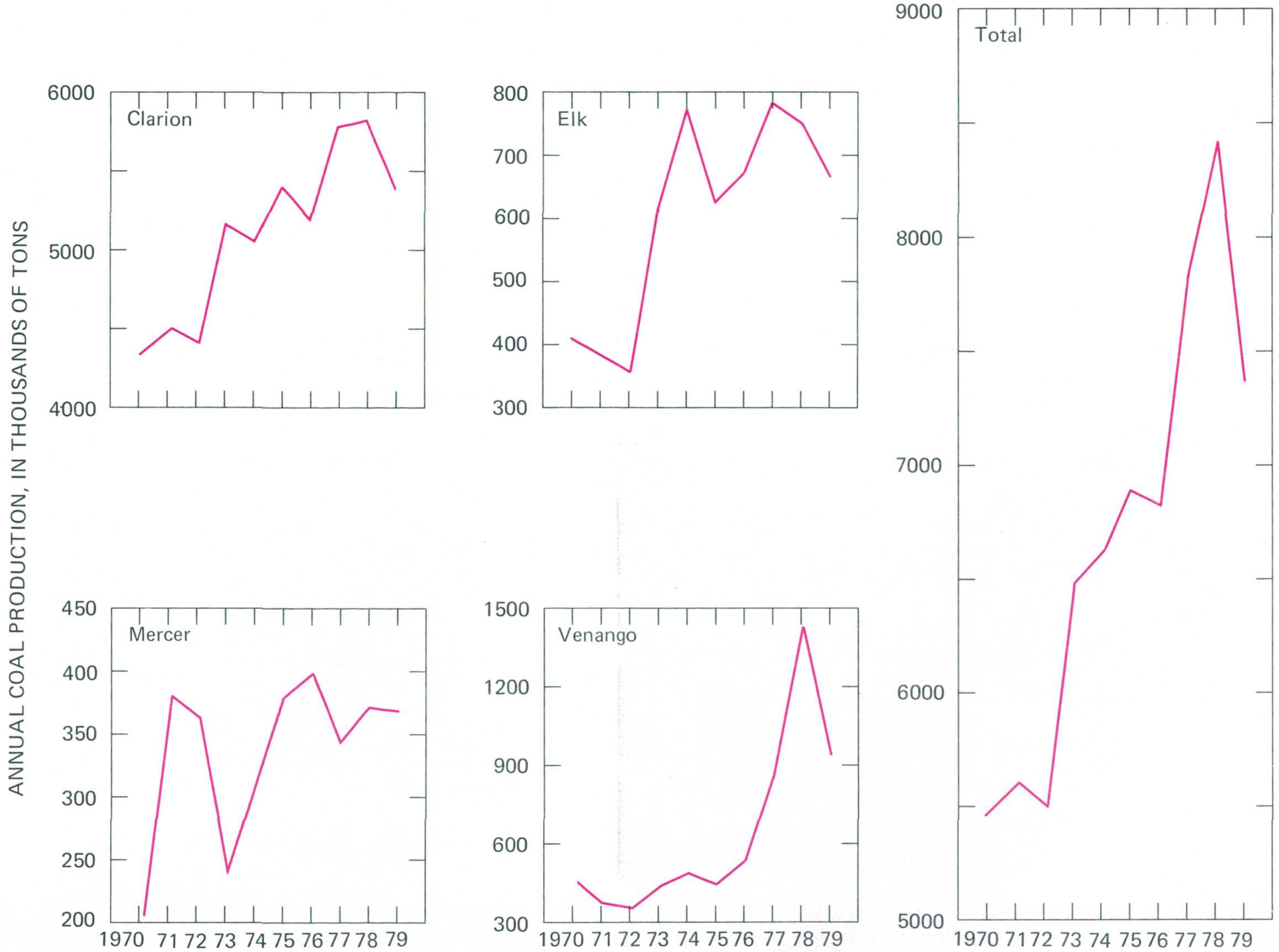
Clarion County produced 5.4 million of the area's 7.4 million tons of coal during 1979.

During 1979, 229 coal mines in Area 2 counties produced 7,370,040 tons (table 5.0-1) of bituminous coal. Clarion County mines produced 5,392,189 tons or 73 percent of the total (Commonwealth of Pennsylvania, 1980). More than 99 percent of Area 2's production was from strip mining; less than 1 percent was from auger mining. Area 2 counties produced about 8 percent of the State's bituminous coal during 1979. Coal production for parts of Butler and Jefferson Counties was included with Areas 4 and 3, respectively.

During the early to mid-1970's coal production in Area 2 counties generally showed an increasing trend (fig. 5.0-1), but during 1979, production dropped to about 7.4 million tons or to about 88 percent of the 8.4 million tons produced in 1978. This drop in production was found in all four coal-producing counties in the area.

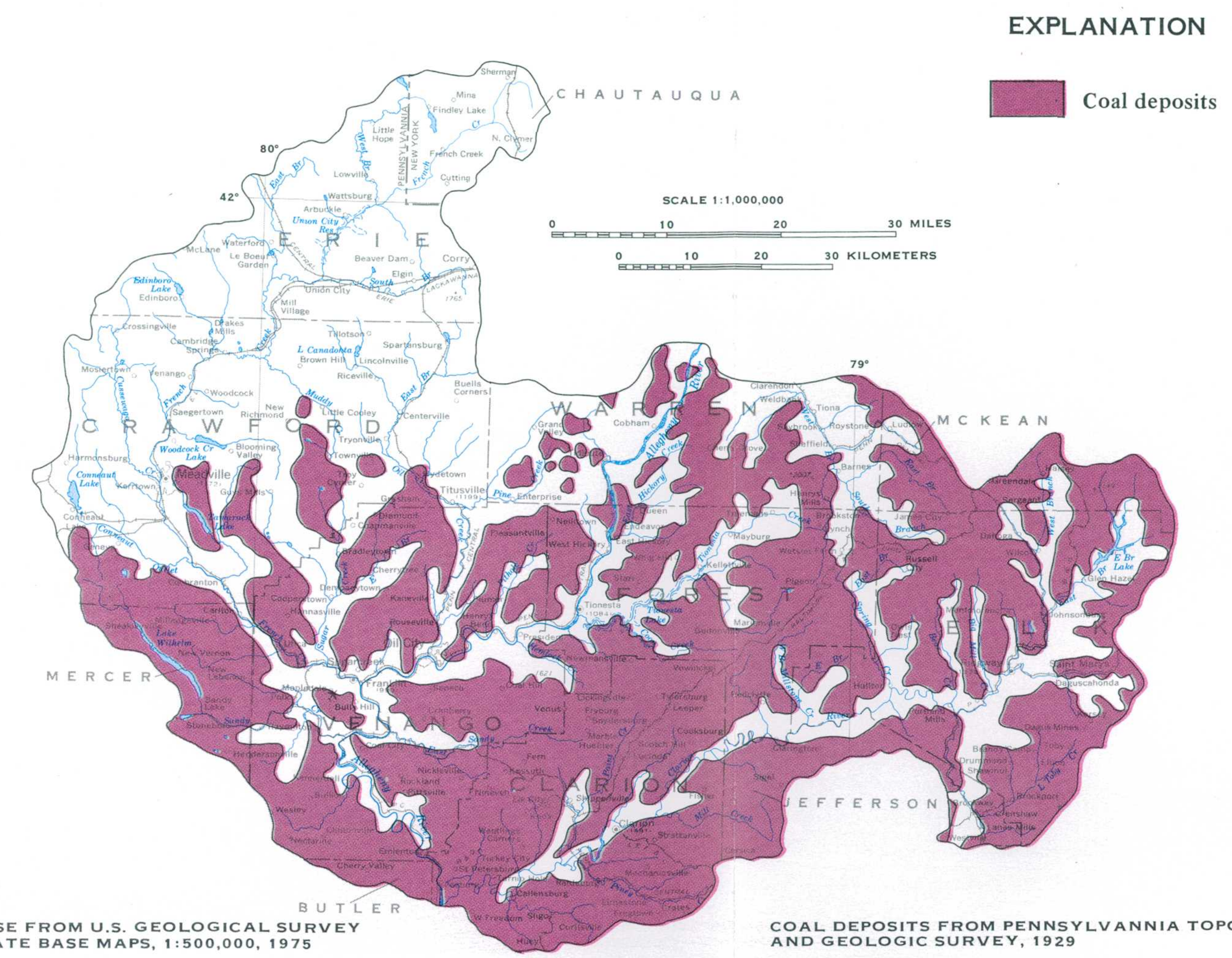
The State of Pennsylvania has about 300,000 acres (468 square miles) of disturbed coal land in need of reclamation, but only 60,000 acres have a legal requirement for reclamation (U.S. Department of Agriculture, 1977). Area 2 counties have about 18,800 acres (29 square miles) of coal land in need of reclamation, but only about 2,400 acres have a legal requirement for reclamation (table 5.0-2).

The Eastern Coal Province extends from southwest Alabama to northcentral Pennsylvania. Area 2 contains the most northern coal fields in the Ohio River basin. There are eight coal seams in Area 2: Upper and Lower Freeport; Upper, Middle, and Lower Kittanning; Clarion; Brookville; and Lower Mercer. The Clarion-Brookville complex is the major source of strippable coal, and it also contains the largest deep coal reserves. These deep reserves may become more important as the strippable coal is depleted. All Area 2 counties except Erie and Chautauqua contain coal deposits (fig. 5.0-2).



COAL PRODUCTION FROM COMMONWEALTH OF PENNSYLVANIA, 1980

Figure 5.0-1 Coal production 1970-79.



BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAPS, 1:500,000, 1975

COAL DEPOSITS FROM PENNSYLVANIA TOPOGRAPHIC AND GEOLOGIC SURVEY, 1929

Figure 5.0-2 Coal deposits.

Table 5.0-1 Bituminous coal production, in tons, in Area 2 counties* during 1979**.

County	Production by method: Strip	Deep	Auger	Total
Clarion	5,392,189	-----	10,489	5,402,678
Crawford	-----	-----	-----	-----
Elk	658,061	-----	11,434	669,495
Erie	-----	-----	-----	-----
Forest	-----	-----	-----	-----
McKean	-----	-----	-----	-----
Mercer	370,489	-----	-----	370,489
Venango	949,301	-----	-----	949,301
Warren	-----	-----	-----	-----
Area total	7,370,040	-----	21,923	7,391,963
State total	45,116,917	43,350,852	351,333	88,819,102

*Jefferson County production included with Area 3; Butler County production included with Area 4.
**Commonwealth of Pennsylvania (1980).

Table 5.0-2 Disturbed coal land, in acres, in Area 2 counties* in need of reclamation as of July 1977**.

County	Reclamation required by law	Reclamation not required by law	Total
Clarion	1,000	10,000	11,000
Crawford	-----	-----	-----
Elk	500	2,000	2,500
Erie	-----	-----	-----
Forest	-----	-----	-----
McKean	-----	-----	-----
Mercer	400	1,400	1,800
Venango	500	3,000	3,500
Warren	-----	-----	-----
Area total*	2,400	16,400	18,800
State total	60,000	240,000	300,000

*Jefferson County figures included with Area 3; Butler County figures with Area 4.
**U.S. Department of Agriculture (1977).

Streamflow Data Collected at 85 Locations

Streamflow data have been collected at 18 continuous-record gaging stations, 1 crest-stage low-flow partial-record station, 1 low-flow partial-record station, and 65 miscellaneous sites in area.

Systematic collection of streamflow data at an established network of stations is a key ingredient in the assessment of the hydrology of any area. If streamflow-data are collected over a period of time, it is possible to make estimates of certain streamflow characteristics at the stations, such as peak discharge, low flow, mean flow, and flow duration.

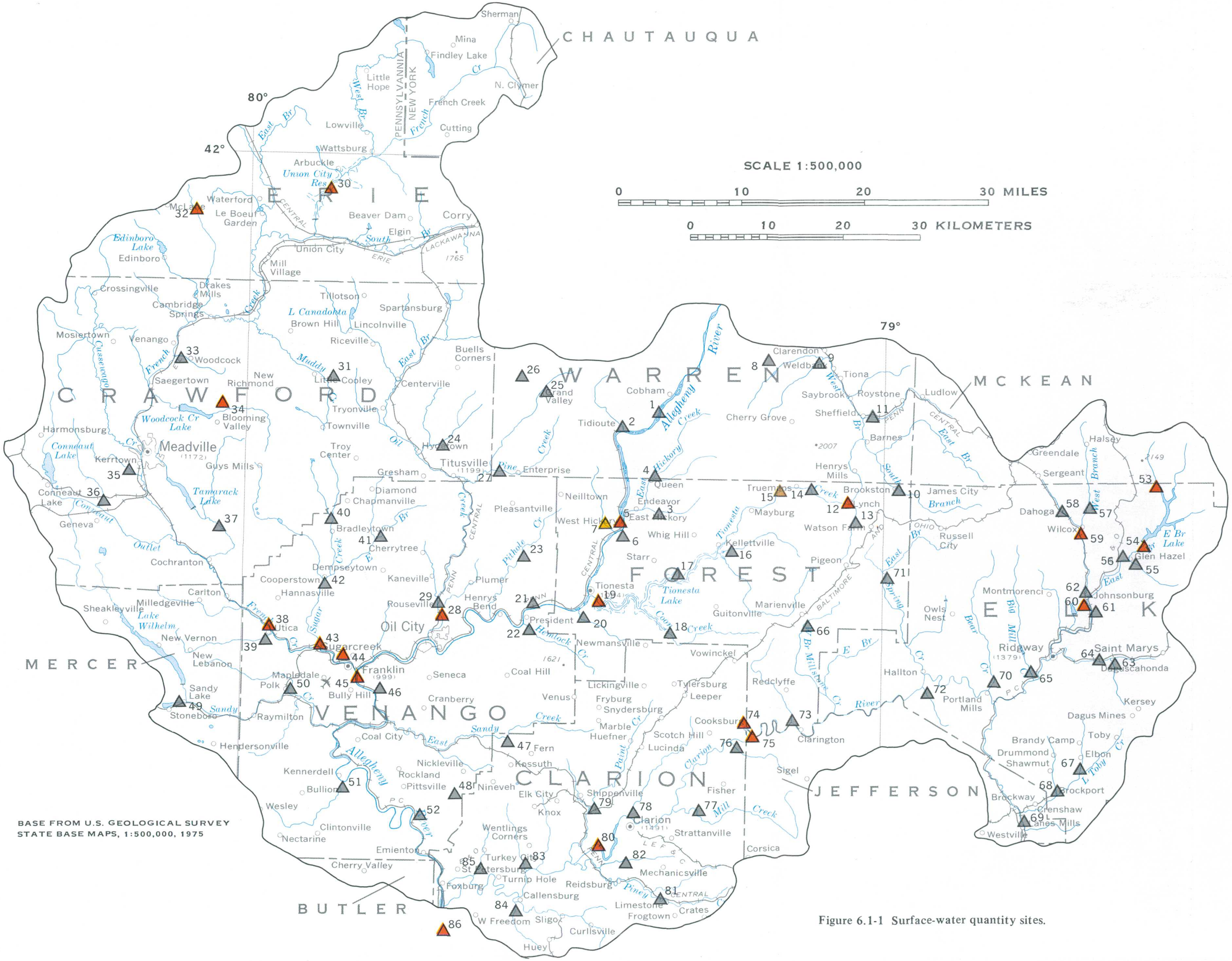
Systematic data collection also provides hydrologists with the necessary information to make estimates of streamflow characteristics for sites where data are not collected. Section 12.1 lists 18 continuous-record gaging stations; 1 crest-stage, partial-record station; 1 low-flow partial-record station and 65 miscellaneous sites where surface-water data have been collected, and figure 6.1-1 shows their locations.

Continuous-record stations are locations where a continuous record of stream gage height (stage) is collected. The gage height information is generally collected and recorded by a variety of automatic recorders. Periodic measurements of actual streamflow and indirect determinations of flood flow relate specific gage heights to specific discharges. The continuous record of gage height, combined with the stage-discharge relation, provides a continuous record of streamflow. Such continuous streamflow data are usually presented as mean discharges on a daily and yearly basis, although instantaneous discharges at specific times during the period of record can also be determined. Continuous-record stations provide the most detailed streamflow data.

Partial-record stations provide less detailed data at a much lower cost than those provided by a continuous-record station. Low-flow partial-record stations have no recording devices, but provide data when measured during low flow. Data from concurrent flows at partial-record and continuous-record stations may be used indirectly to supplement the data available at the low-flow partial-record sites. Crest-stage partial-record stations utilize a simple gage to record the peak gage height reached by a stream during a storm. A stage-discharge relation is then used to compute the peak flow during the storm. Such peak-flow data can be analyzed to determine the flood-flow frequency of a stream.

Miscellaneous sites are locations at which occasional discharge measurements are made, usually when water-quality samples are collected. Discharge data at miscellaneous sites can be combined with water-quality data to compute instantaneous loads of various dissolved or suspended constituents.

The U.S. Geological Survey publishes water-quality data for Area 2 annually in the report "Water Resources Data for Pennsylvania, Volume 3, Ohio and St. Lawrence River Basins."



BASE FROM U.S. GEOLOGICAL SURVEY
STATE BASE MAPS, 1:500,000, 1975

Figure 6.1-1 Surface-water quantity sites.

EXPLANATION

WATER QUANTITY SITES

See section 12.1 for detailed site description.

- Continuous-record
- Crest-stage partial-record and low-flow partial-record
- Low-flow partial-record
- Miscellaneous
- 43 Site number

Water-Quality Data Available for 78 Sites in Area

Water-quality data have recently been collected at 71 synoptic sites, 1 partial-record coal hydrology site and 6 partial-record sites.

The locations of 78 sites where recent water-quality data have been collected are shown in figure 6.2-1. The sites are identified by reference number, downstream order number, and name in section 12.1.

The 71 sites designated as synoptic sites had water quality data routinely collected in the spring and summer. Station 28, the partial-record coal hydrology site, was sampled more frequently because historic water quality data already existed for it. The 6 other partial-record sites were sampled as part of other programs, but provided data useful in the coal hydrology program. Typical data collected during water years 1979 and 1980 included specific conductance, pH, temperature, turbidity, dissolved oxygen, suspended sediment, acidity, alkalinity, dissolved sulfate, dissolved iron, and taxonomic identification of benthic invertebrates.

Seasonal variations in streamflow can concentrate or dilute contaminants in the water. Changes in water quality are more readily detected with frequent, long-term sampling, but a general overview can be obtained through synoptic sampling.

All first order streams in coal-bearing sections of Area 2 were initally considered for a synoptic site. First order streams were defined as those unbranched streams appearing on a 1:500,000 scale Hydrologic Unit map. A subset of these first order streams was selected for actual synoptic site location. The final site selection was designed to provide broad areal coverage.

The 71 synoptic sites had drainage areas ranging from 1.46 to 62.5 mi^2 (square miles). The median drainage area for all streams was about 14.4 mi^2. Almost 68 percent of the streams have drainage areas less than 20 mi^2.

The U.S. Geological Survey publishes water-quality data for Area 2 annually in the report "Water Resources Data for Pennsylvania, Volume 3, Ohio and St. Lawrence River Basins."

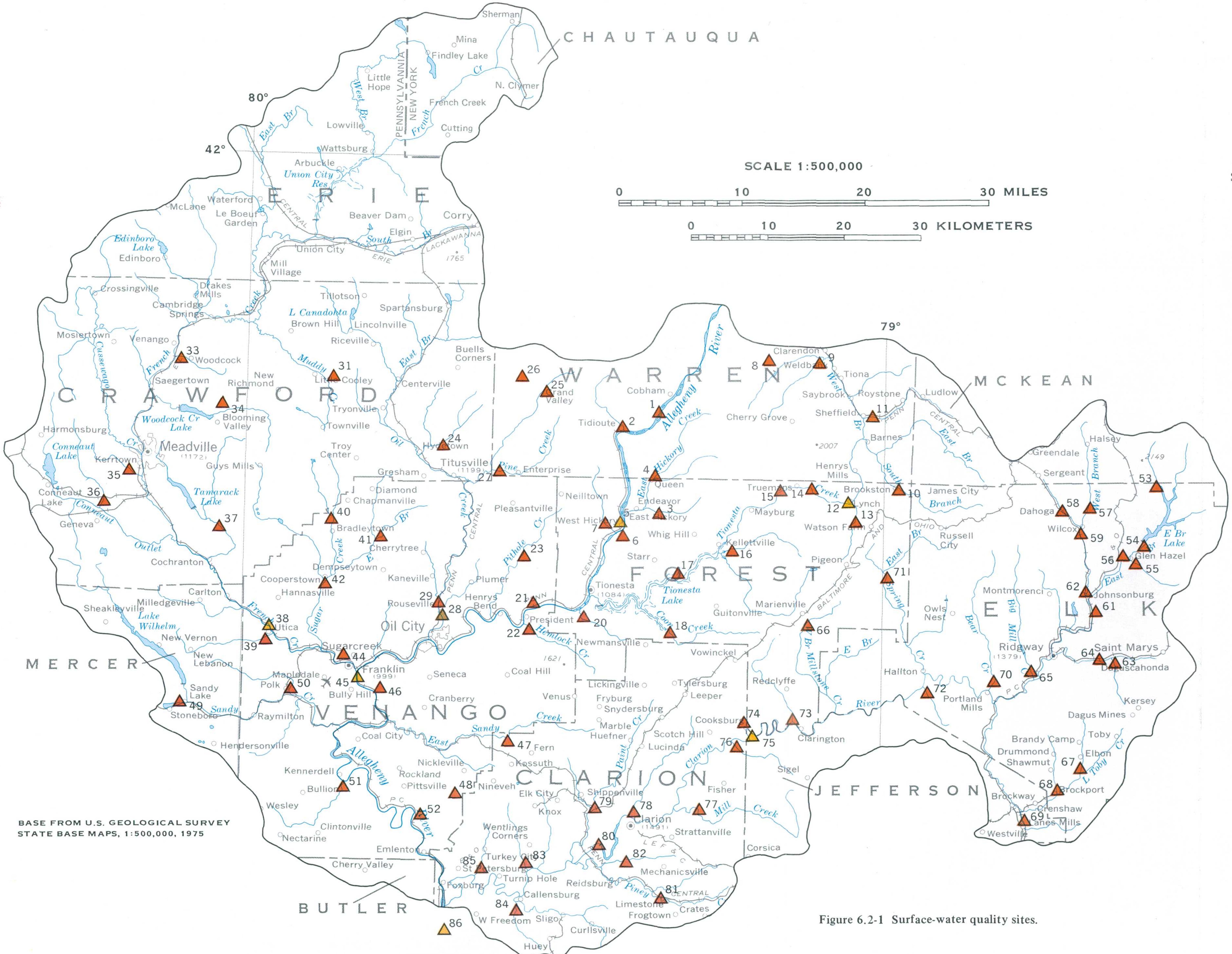


Figure 6.2-1 Surface-water quality sites.

EXPLANATION

WATER QUALITY SITES

See section 12.1 for detailed site description.

- Synoptic
- Partial-record (coal hydrology)
- Partial-record (non-coal hydrology)
- 37 Site number

Sampling Network Designed to Define Coal-Related Water-Quality in Area

A network of 71 synoptic sites and 1 continuous-record station is being sampled to collect water-quality data which may be related to the presence of coal or coal mining. The sampling schedule is designed to collect data over a range of flow conditions.

The present sampling program of the coal hydrology network utilizes two types of sampling stations, each having a distinct purpose. A large network of synoptic sites is designed to provide broad areal coverage, while a smaller network of continuous-record stations is designed to provide more detailed information on changes in water quality over time. Water-quality and stream discharge data have been collected under low, medium, and high baseflow conditions.

Table 6.3-1 lists the types and frequencies of data collection at the 71 synoptic sites. These data were selected to concentrate on information which may be useful in coal-bearing areas. Many of the water-quality constituents listed in table 6.3-1 are specifically mentioned in the surface mining regulations. These water-quality data have been published by U.S. Geological Survey (1980, 1981).

Similar data are being collected at the single continuous-record station in Area 2's coal hydrology network; however, samples are being collected more frequently than at the synoptic sites and additional samples are being collected. Table 6.3-2 lists the types and frequencies of sampling at the continuous-record station. The data collected at this site has been published by U.S. Geological Survey (1980, 1981).

Table 6.3-1 Types and frequency of water-data collection at synoptic sites.

Each visit (low, medium, and high flows)

Discharge	Dissolved iron
Temperature	Total manganese
Specific conductance	Dissolved manganese
pH	Sulfate
Alkalinity	Residue, dissolved
Acidity	Suspended sediment
Total iron	

Annually (low flow)

Identification of benthic invertebrates

One time only (low flow)
Bottom materials

Arsenic	Manganese
Cadium	Mercury
Chromium	Selenium
Cobalt	Zinc
Copper	Organic carbon
Iron	Inorganic carbon
Lead	Coal

Storm events (high flow)
selected sites

Suspended sediment and discharge

Table 6.3-2 Types and frequency of water-data collection at the continuous-record station.

Each visit (6 - 9, times annually)

Discharge	Dissolved iron
Temperature	Total manganese
Specific conductance	Dissolved manganese
pH	Sulfate
Alkalinity	Residue, dissolved
Acidity	Suspended sediment

Annually (low flow)

Identification of benthic invertebrates

One time only (low flow)
Bottom materials

Arsenic	Manganese
Cadium	Mercury
Chromium	Selenium
Cobalt	Zinc
Copper	Organic carbon
Iron	Inorganic carbon
Lead	Coal

Common constituents

Sodium absorption ratio	Dissolved fluoride
Sodium percent	Residue, dissolved
Dissolved calcium	Dissolved silica
Dissolved manganese	Dissolved sulfate
Dissolved potassium	Nitrite plus nitrate
Dissolved sodium	Total phosphorus
Dissolved chloride	Total alkalinity

Minor elements

Total barium	Total manganese
Total cadium	Total silver
Total chromium	Total zinc
Total copper	Total arsenic
Total iron	Total selenium
Total lead	Cyanide
	Total mercury

Specific Conductances High in Streams of Leading Coal-Producing County

Streams in Clarion County, which produces three-fourths of the coal mined in Area 2, had a median specific conductance twice as great as the median for any other county in the area.

Table 7.1-1 shows coal production and median stream specific conductances for six counties in Area 2. Although there is no predictive relation between coal production and median specific conductance, a general trend does exist. Streams in Clarion County, which produces about 72 percent of the coal mined in the seven counties, had a median specific conductance of 390 μmho/cm (micromhos per centimeter) at 25°C. This is almost twice the median specific conductance of 200 μmho/cm for streams in Crawford County, where no coal is produced. Median stream specific conductances for the coal-producing counties ranged from 76 to 390 μmho/cm, whereas median specific conductances for the non-coal-producing counties ranged from 55 to 200 μmho/cm.

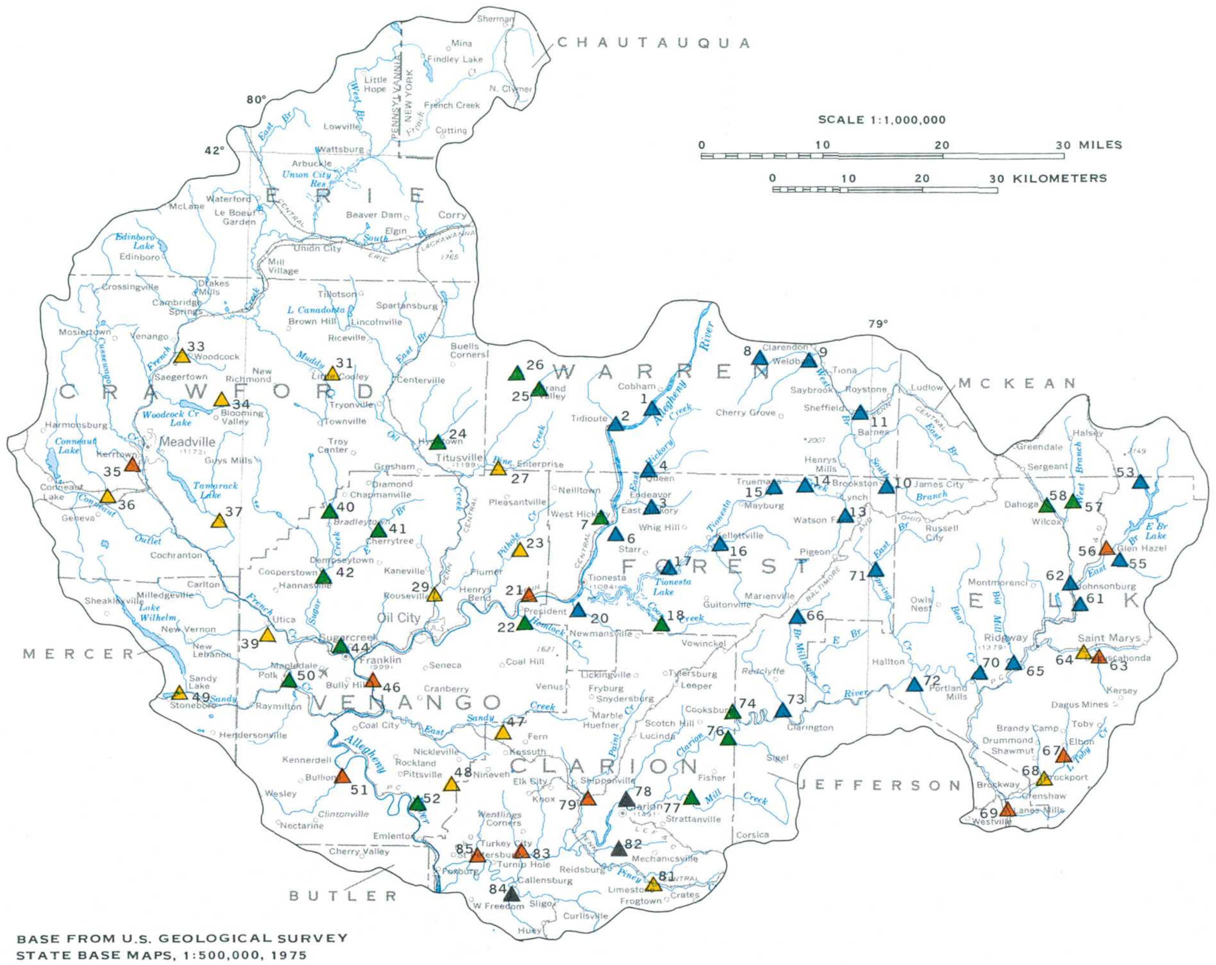
Most streams in Area 2 having maximum specific conductances (highest observed during sample period) of 400 μmho/cm or greater were in the south-central part of the area in Venango and Clarion Counties (fig. 7.1-1). High specific conductances were also common near the eastern border of Area 2 in Elk County. Several streams in Clarion County had maximum specific conductances in excess of 1,000 μmho/cm (fig. 7.1-1).

The remaining sections of the area are characterized by maximum specific conductances less than 400 μmho/cm. Streams in Warren, Forest, and western Elk Counties generally have maximum specific conductances less than 100 μmho/cm. Venango and northern Crawford County streams usually have maximum specific conductances in the range of 100 to 400 μmho/cm.

Maximum specific conductances measured at Area 2 streams ranged from 50 to 1,800 μmho/cm. The mean and median maximum specific conductances were 269 and 170 μmho/cm, respectively. The difference between the mean and median values is a result of the effect of several high specific conductances on the mean. Only 8 of 71 streams (11 percent) had a maximum specific conductance greater than 500 μmho/cm (fig. 7.1-2). Figure 7.1-2 also shows that 25 streams (35 percent) had maximum specific conductances of 100 μmho/cm or less, and that 49 streams (69 percent) had maximum specific conductances of 300 μmho/cm or less.

Specific conductances (section 12.2) were measured in the field according to procedures described by Skougstad and others (1979). Samples were generally collected four times during the 1979 and 1980 water years during periods of low, medium, and high base flow. Specific-conductance data for the 1979 and 1980 water years are published by the U.S. Geological Survey (1980, 1981).

Specific conductances vary over time within individual streams (fig. 7.1-3). During the 1976-78 water years, the maximum specific conductance observed at four selected stations was 2 to 6 times the minimum observed during the same period. The mean specific conductances for all the stations illustrated in figure 7.1-3 are significantly different (95-percent level) from one another, except when comparing station 12 with stations 59 and 75. All four streams exhibit a negative correlation between specific conductance and the log (base 10) of discharge. The correlation is significant (95-percent level) for stations 59 and 75 (Snedecor, 1957). Such a negative correlation indicates a relatively stable source of dissolved material which is diluted to a greater or lesser extent as streamflow increases or decreases.



EXPLANATION

MAXIMUM SPECIFIC CONDUCTANCE RANGES,
In micromhos per centimeter at 25° Celsius

- ▲ 0 - 100
- ▲ 100 - 200
- ▲ 200 - 400
- ▲ 400 - 1000
- ▲ Greater than 1000
- △[57] **Site number** See section 12.1 for detailed site description and section 12.2 for water-quality analysis.

Figure 7.1-1 Maximum specific conductances for selected sites.

Table 7.1-1 Average coal production, 1976-80, and median stream specific conductances, 1979-80, for selected counties.

County	Number of streams sampled	Median specific conductance (μmho)	Average annual coal production (tons)
Clarion	11	390	5,218,414
Venango	14	177	913,009
Elk	13	76	732,923
Mercer	1	*	413,368
Crawford	8	200	0
Forest	12	60	0
Warren	10	55	0

*Data insufficient for median computation.

See adjacent map for site locations.

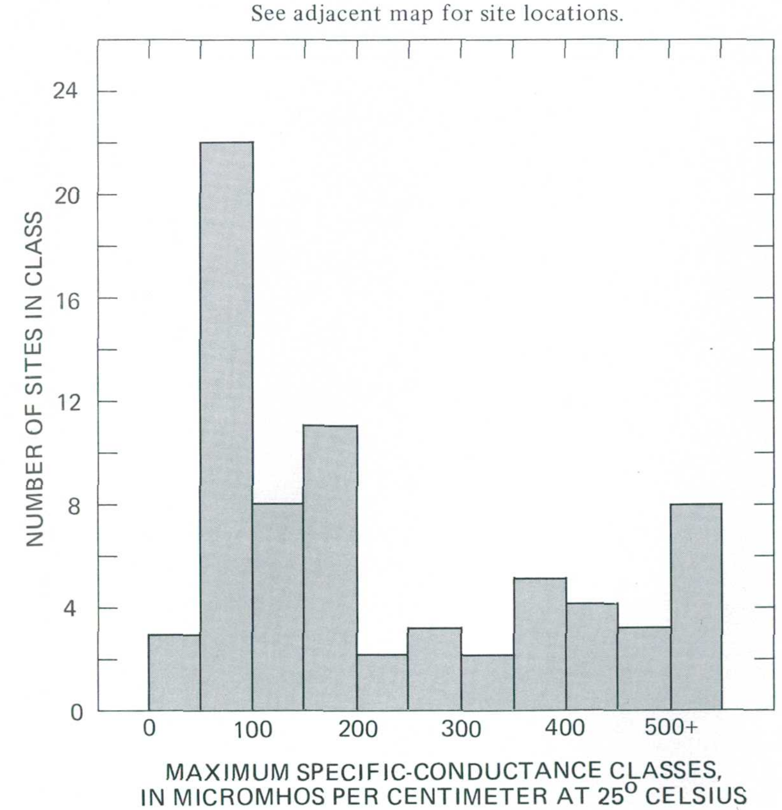


Figure 7.1-2 Maximum specific conductance for selected streams.

See section 12.1 for detailed site description.

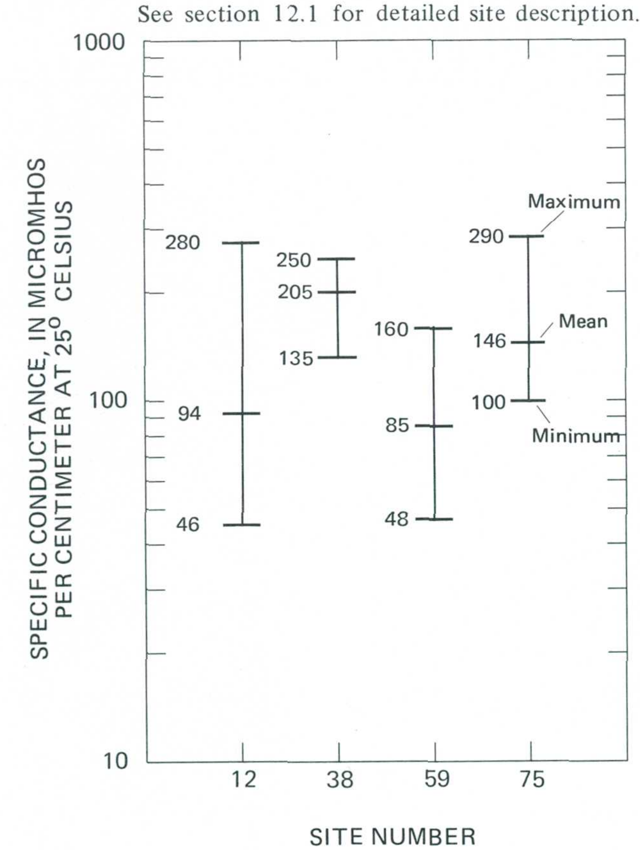


Figure 7.1-3 Variation in specific conductance of selected streams for water years 1979-80.

Coal Production and Dissolved Solids Both High in Clarion County

The median dissolved-solids concentration for streams sampled in Clarion County was 70 percent greater than the median concentration for streams in any of Area 2's other counties. About three-fourths of the coal produced in the area is mined in Clarion County.

Median dissolved-solids concentrations for streams in Area 2 counties and average coal production figures (by county) are presented in table 7.2-1. The median concentration for the area's leading coal-producing county was 224 mg/L (milligrams per liter) or about 72 percent greater than the median concentration of 126 mg/L for Crawford County, which produces no coal. Clarion County's median concentration was also about 5 times higher than the medians for the other non-coal-producing counties in the area. However, there is no predictive relation between average coal production and median dissolved-solids concentration.

Nine of the eleven streams sampled in Clarion County had maximum dissolved-solids concentrations (highest observed during sample period) of 200 mg/L or greater (fig. 7.2-1). The highest dissolved-solids concentrations in Area 2, 500 mg/L or greater, were found at 3 sites in Clarion County. Streams in eastern Warren, northeastern Forest, and northeastern Elk Counties generally had maximum dissolved-solids concentrations less than 50 mg/L. Streams in areas adjacent to the above area generally had concentrations in the 50-100 mg/L range, while streams in the western part of Area 2 generally had maximum dissolved-solids concentrations of 100-200 mg/L.

Maximum dissolved-solids concentrations in Area 2 ranged from 28 to 1,800 mg/L. The mean and median maximum dissolved-solids concentrations were 174 and 105 mg/L, respectively. The difference between the mean and median concentrations was a result of the effect of several high concentrations on the mean.

Fifteen Area 2 streams had maximum dissolved-solids concentrations of 50 mg/L or less (fig. 7.2-2). Fifty streams in the area had maximum concentrations of 150 mg/L or less, and only 7 streams had maximum concentrations in excess of 300 mg/L (fig. 7.2-2).

Dissolved-solids concentration and specific conductance are closely related as shown in figure 7.2-3, based on 207 concurrent pairs of samples for specific conductance and dissolved solids. The relation between the two water-quality measures has a slope of 0.81. The slope of 0.81 is well within the range of 0.54 to 0.96 for natural waters as reported by Hem (1970). Hem indicated that a slope greater than 0.75 is generally associated with water high in sulfate content. Figure 7.2-4 shows the relation between dissolved solids and dissolved sulfate based on 207 concurrent pairs of samples from Area 2 streams. For the 207 concurrent samples, the mean dissolved-solids concentration was 136 mg/L and the mean dissolved-sulfate concentration was 53 mg/L. Dissolved sulfate; therefore, contributed about 40 percent of the dissolved-solids for the 207 samples collected to date.

Water samples for dissolved-solids determinations (section 12.2) were collected four times at each site during the 1979 and 1980 water years. Samples were collected during low, medium, and high base flow. Laboratory analyses for dissolved solids were done according to procedures described by Skougstad and others (1979). Dissolved-solids data for the 1979 and 1980 water years are published by the U.S. Geological Survey (1980, 1981).

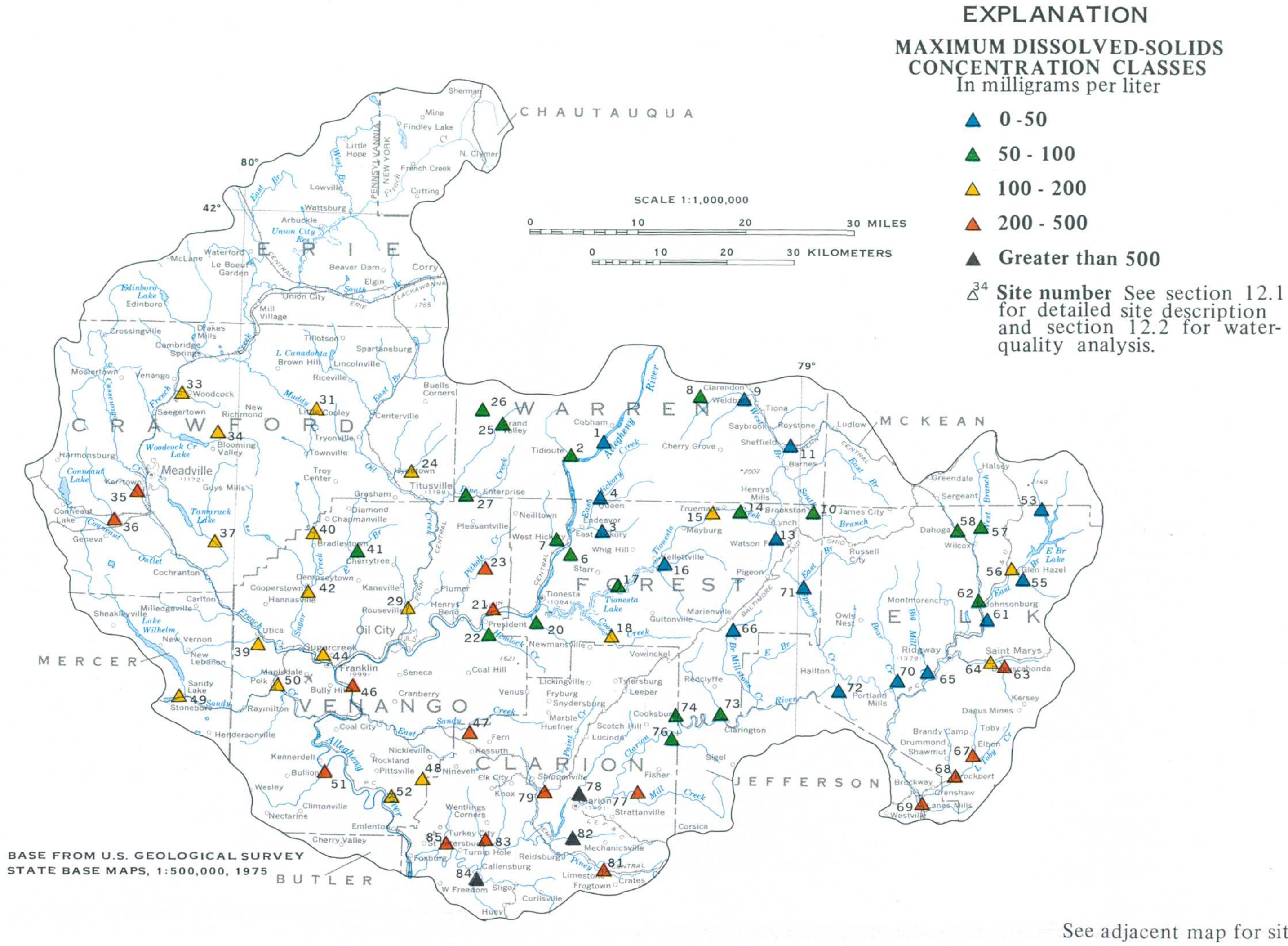


Figure 7.2-1 Maximum dissolved-solids concentrations for selected sites.

Table 7.2-1 Average coal production, 1976-80, and median stream dissolved-solids concentrations, 1979-80, for selected counties.

County	Number of streams sampled	Median dissolved-solids concentration (mg/L)	Average annual coal production (tons)
Clarion	11	224	5,218,414
Venango	14	106	913,009
Elk	13	48	732,923
Mercer	1	*	413,368
Crawford	8	126	0
Forest	12	42	0
Warren	10	44	0

*Data insufficient for median computation.

See adjacent map for site locations.

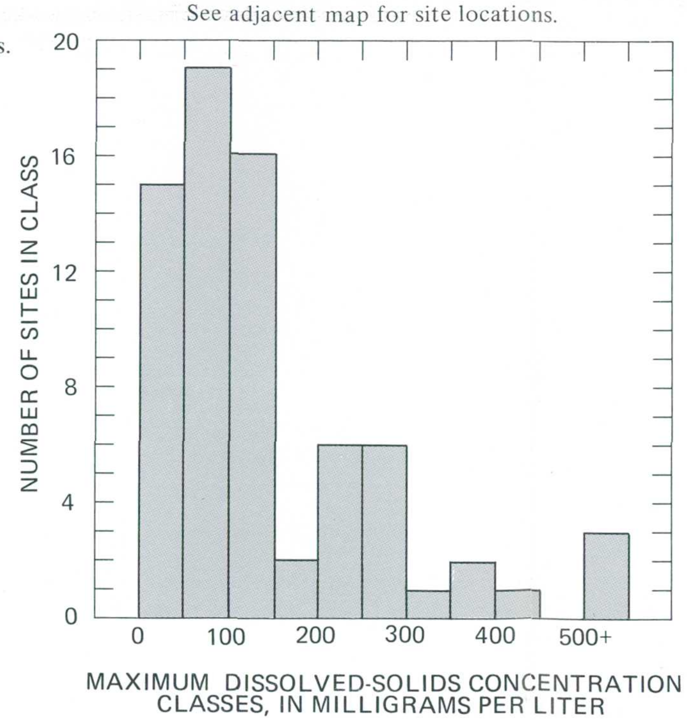


Figure 7:2-2 Maximum dissolved-solids concentration.

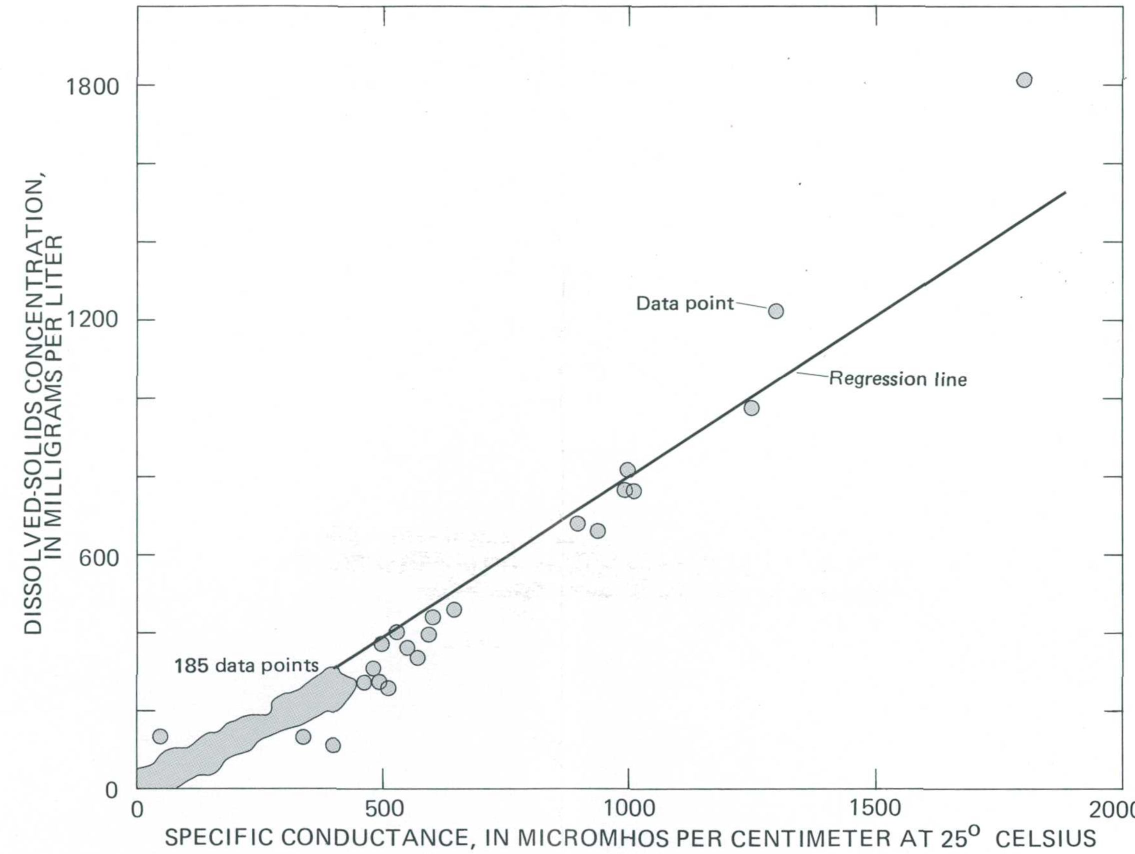


Figure 7.2-3 Relation between dissolved-solids concentration and specific conductance.

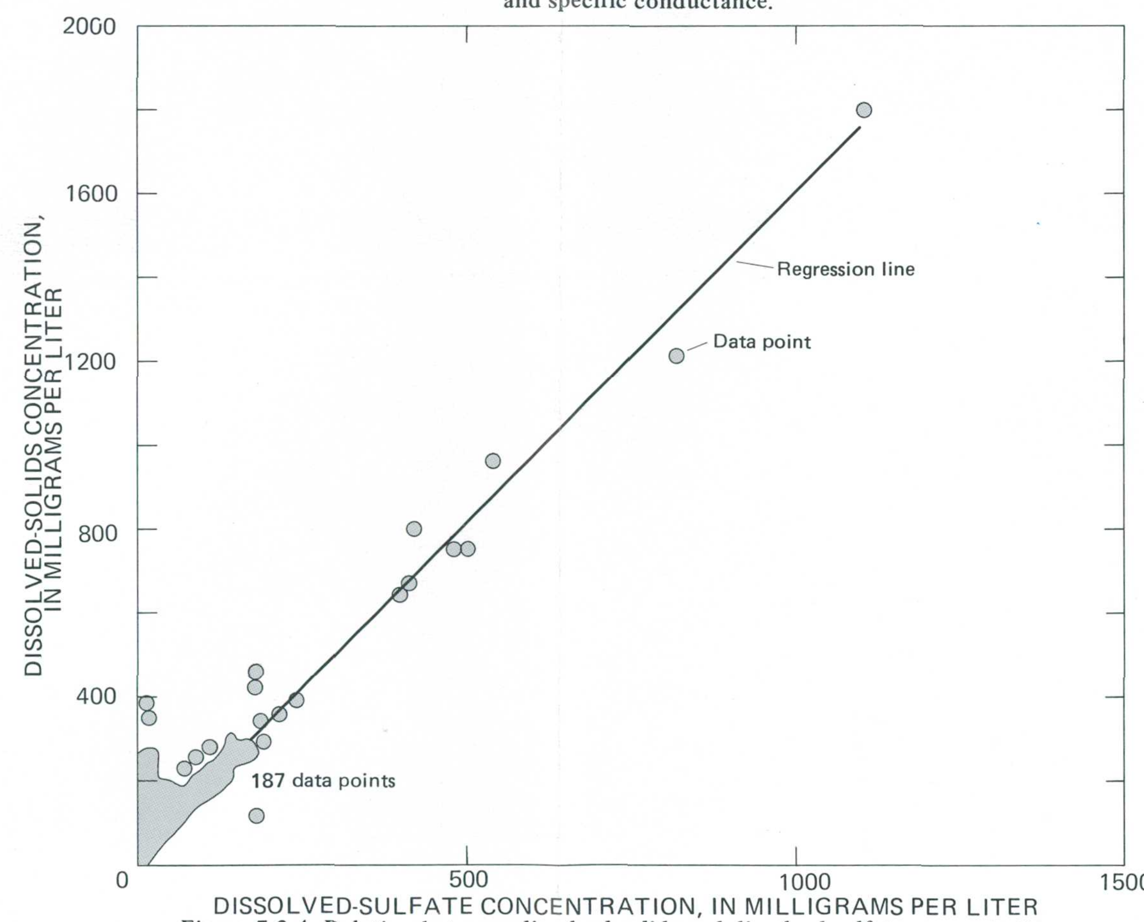


Figure 7.2-4 Relation between dissolved-solids and dissolved-sulfate concentrations.

Streams in Top Coal-Producing County Exhibit Low pH Values

Streams in Clarion County, the leading coal-producing county in the area, have a median pH value almost 1 unit less than that of streams in other area counties.

Water samples collected from 11 Clarion County streams during the 1979 and 1980 water years had a median pH value of 6.2. Median pH values for streams in Area 2's other counties ranged from 6.9 to 7.5 (table 7.3-1). Clarion County is the leading coal-producing county in the area, accounting for over 70 percent of the annual production. The four streams in Area 2 which had a minimum pH (lowest pH observed) less than 3.5 were in Clarion County in the vicinity of Clarion (fig. 7.3-1).

Minimum pH values found in selected Area 2 streams ranged from 3.1 to 7.4. The mean and median minimum pH values were 6.1 and 6.4, respectively. The minimum pH values for 48 of 71 streams (68 percent) were within 1 pH unit of neutral (fig. 7.3-2). Eight streams (11 percent) had a minimum pH value of 4.5 or less (fig. 7.3-2).

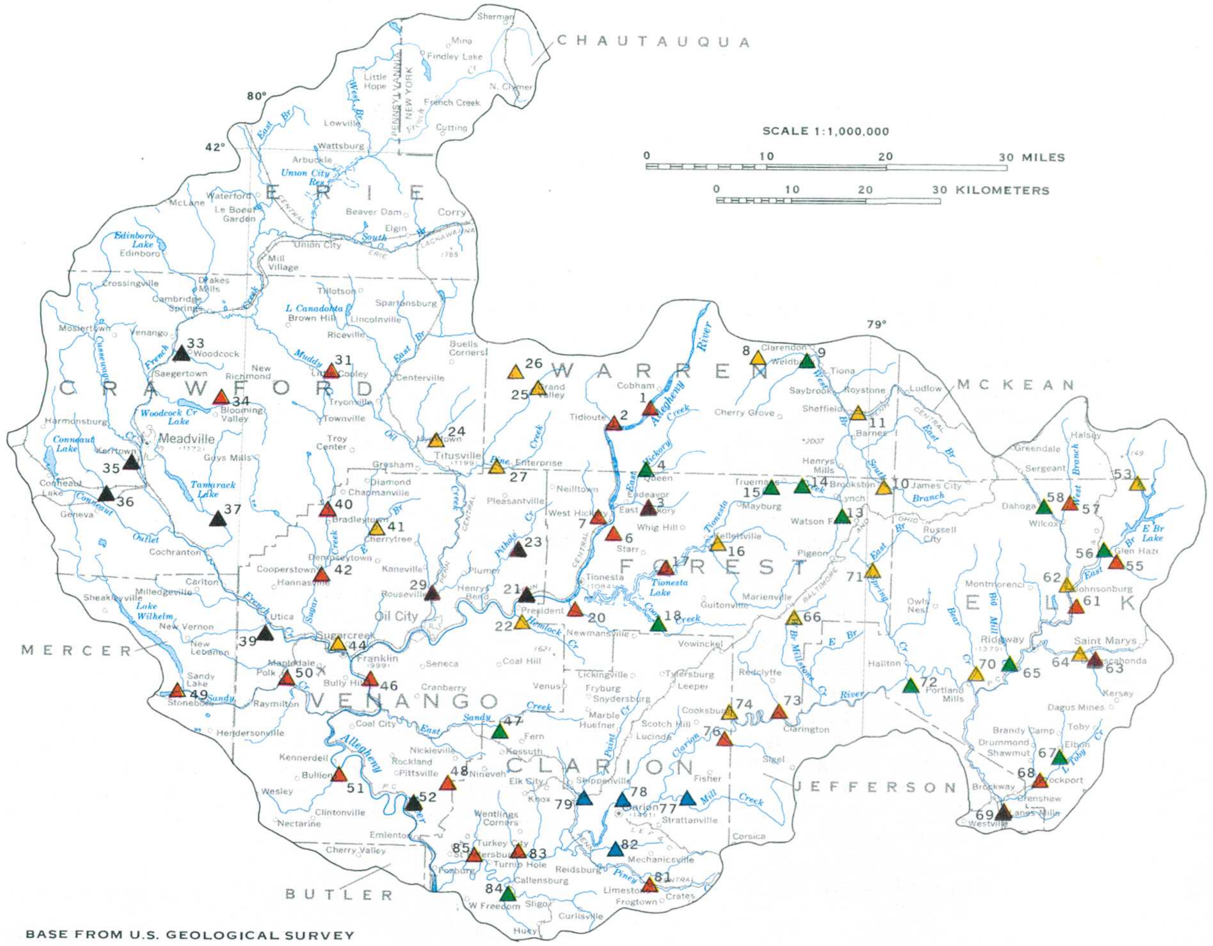
Streamside pH values (section 12.2) were determined at 71 sites in Area 2 according to procedures described by Skougstad and others (1979). Determinations were generally made four times at each site during low, medium, and high base-flow conditions during the 1979 and 1980 water years. These pH data are published by the U.S. Geological Survey (1980, 1981).

Data collected at four gaging stations during the 1976-78 water years indicate that pH values vary over time in a single stream (fig. 7.3-3). Data collected from four selected streams show a difference between the maximum and minimum observed pH values ranging from 1.7 to 3.0 pH units. Because of the logarithmic nature of the pH scale, these differences represent changes in hydrogen-ion activity ranging from a factor of 50 to a factor of 1,000. The mean pH values for all four streams were significantly different at the 95-percent level except when comparing station 38 with station 59 (fig. 7.3-3). None of the four stations showed a significant correlation (Snedecor, 1957) between pH and the log (base 10) of discharge. Discharge and pH data for the 1976-78 water years are published by the U.S. Geological Survey (1977, 1978, 1979).

Table 7.3-1 Average coal production, 1976-80, and median stream pH, 1979-80, for selected counties.

County	Number of streams sampled	Median pH (units)	Average annual coal production (tons)
Clarion	11	6.2	5,218,414
Venango	14	7.2	913,009
Elk	13	6.9	732,923
Mercer	1	*	413,368
Crawford	8	7.5	0
Forest	12	6.9	0
Warren	10	7.0	0

*Data insufficient for median computation.



BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAPS, 1:500,000, 1975

EXPLANATION

MINIMUM pH-VALUE CLASSES
In units

- ▲ Greater than 7.0
- ▲ 6.5 - 7.0
- ▲ 6.0 - 6.5
- ▲ 3.5 - 6.0
- ▲ Less than 3.5
- △16 **Site number** See section 12.1 for detailed site description and section 12.2 for water-quality analysis.

Figure 7.3-1 Minimum pH values for selected sites

See adjacent map for site locations.

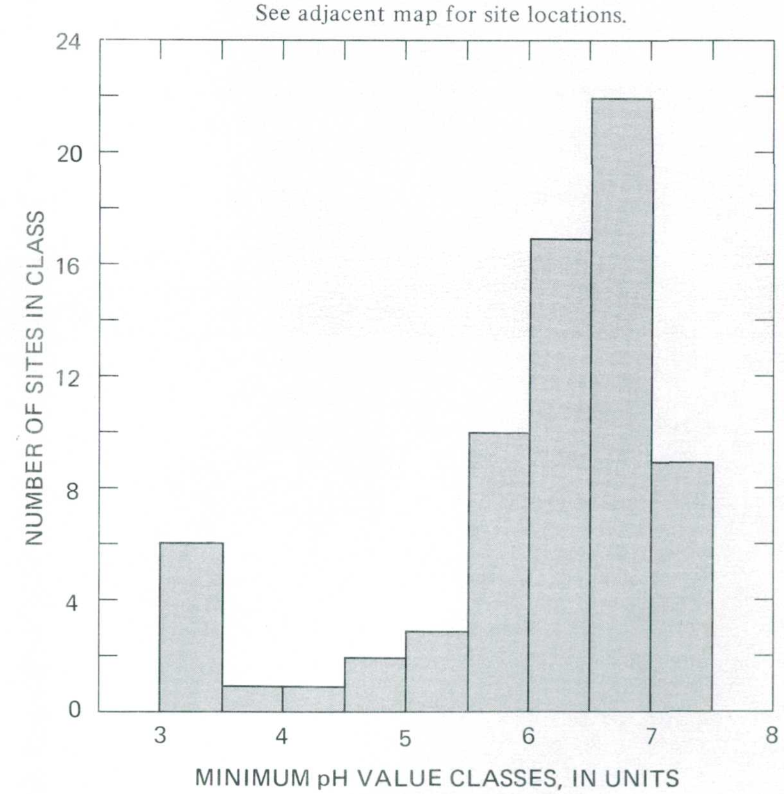


Figure 7.3-2 Minimum pH values.

See section 12.1 for detailed site description.

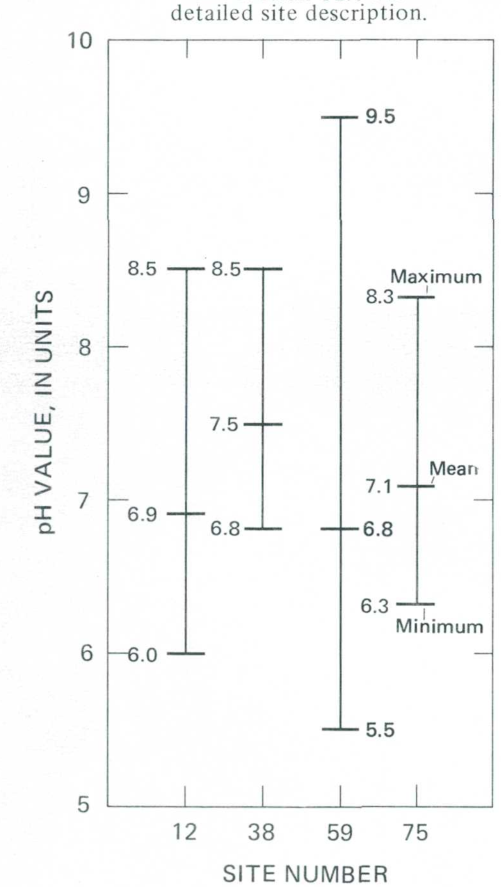


Figure 7.3-3 Variation in pH for water years 1976-78.

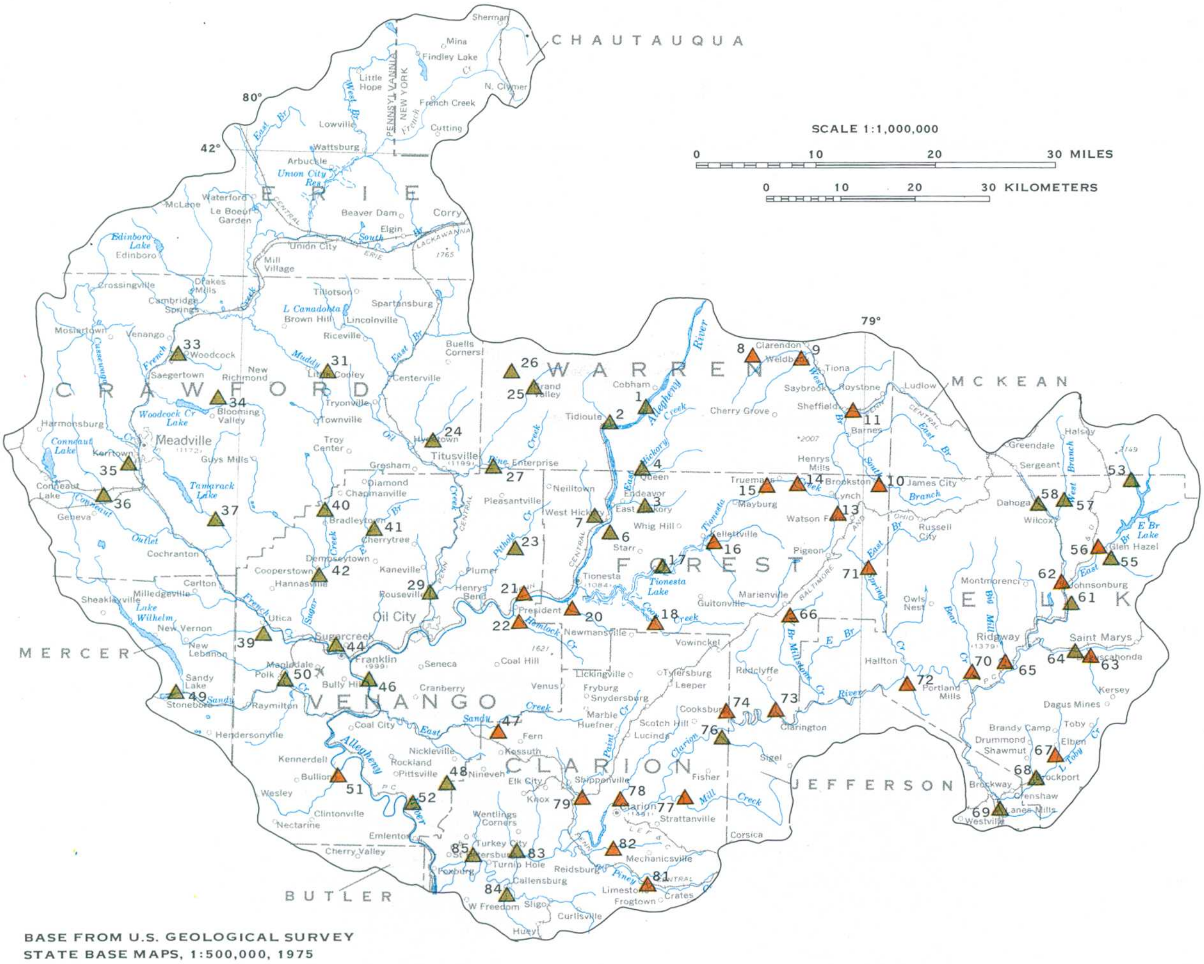
Acidity in Excess of Alkalinity Most Common in Streams in Eastern Part of Area

Streams in the eastern part of Area 2 are more likely to have acidity in excess of alkaliny than are streams in the western part.

Acidity and alkalinity are expressed as milligrams per liter of calcium carbonate. Streams in the eastern part of Area 2 are more likely to have acidity in excess of alkalinity than are streams elsewhere in the area (fig. 7.4-1). Of the 71 streams sampled in the area, 30 streams (42 percent) have acidity in excess of alkalinity. If acidity exceeded alkalinity during any visit, the stream was considered to have excess acidity.

Samples for acidity and alkalinity determinations (section 12.2) were generally collected four times under base-flow conditions during the 1979 and 1980 water years. The determinations were conducted according to procedures described by Skougstad and others (1979). All alkalinity titrations were conducted in the field, but acidity determinations were done in the laboratory prior to July 1980. After July 1980, acidity titrations were also done in the field. The acidity data in section 12.2 after July 1980 is probably more representative of in-stream conditions than earlier samples. Acidity and alkalinity data for the 1979 and 1980 water years are published by the U.S. Geological Survey (1980, 1981).

Hem (1970) defines acidity as "the quantitative capacity of aqueous media to react with hydroxyl ions," and alkalinity as "the quantitative capacity of aqueous media to react with hydrogen ions." Acidity and alkalinity are measures of a solution's buffering capacity, or ability to resist a pH change upon the addition of a base (acidity) or an acid (alkalinity). The concentration of hydrogen ions in a stream's water is measured by its pH. The acidity of a stream is dependent upon pH and the concentration of dissolved metals, mostly iron and aluminum. The alkalinity of a stream is dependent upon pH and the concentration of salts of weak acids and bases. Acidity can be measured by titrating a water sample to a pH of 8.3 with sodium hydroxide. Alkalinity can be measured by titrating a water sample to a pH of 4.5. If the pH of a stream is between 4.5 and 8.3, the stream will have both acidity and alkalinity. If the acidity is greater than the alkalinity, the stream is said to be acid; whereas, if alkalinity exceeds acidity, the stream is said to be alkaline.



EXPLANATION

▲ Acidity is greater than alkalinity

▲ Acidity is less than or equal to alkalinity

△53 **Site number** See section 12.1 for detailed site description and section 12.2 for water-quality analysis.

Figure 7.4-1 Acidity and alkalinity for selected sites.

Total-Iron Concentrations are High in Area's Leading Coal-Producing County

Streams in Clarion County, the leading coal producer in Area 2, had a median total-iron concentration about 3 times greater than those of the other counties in the area.

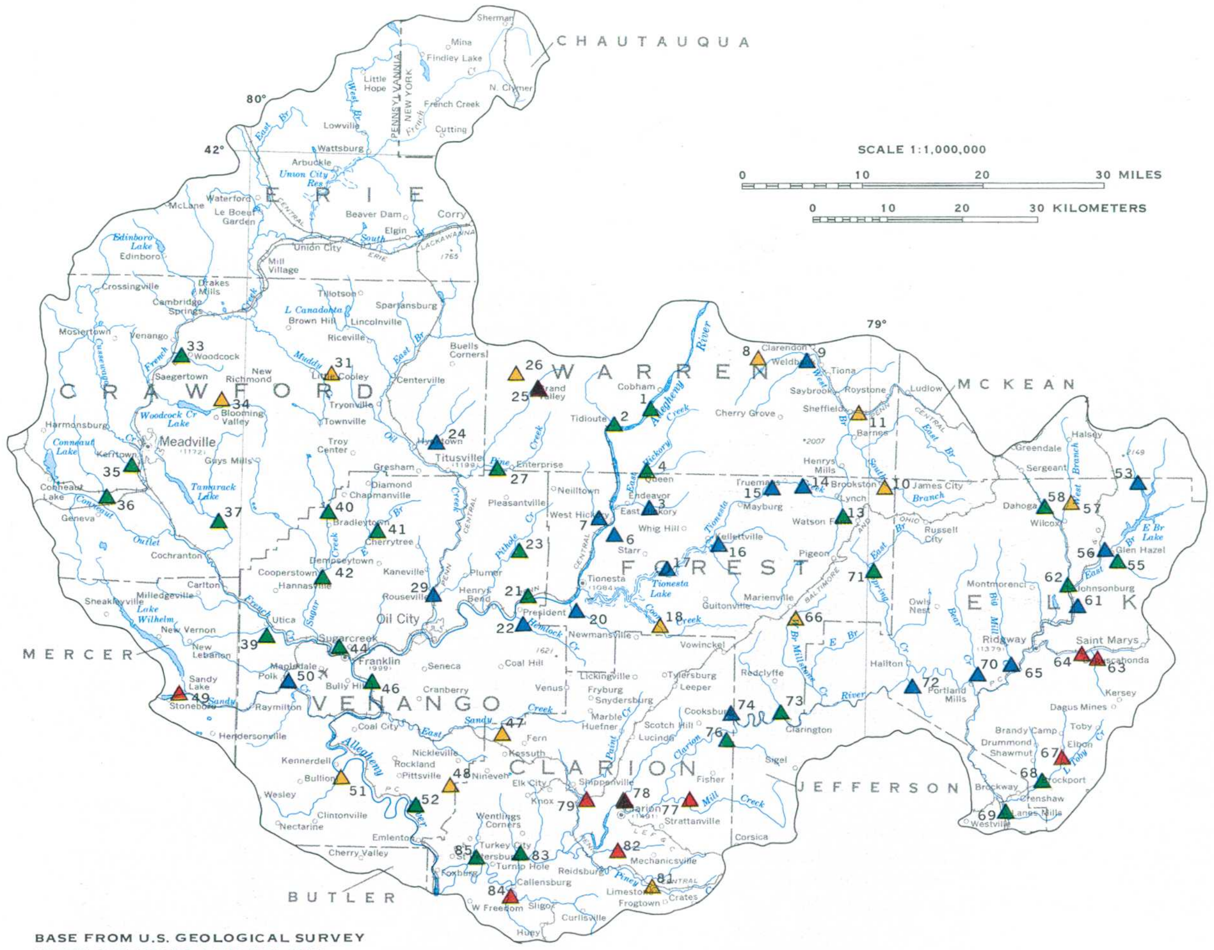
Clarion County produces about 72 percent of the coal mined in Area 2. The median concentration of dissolved iron in 11 Clarion County streams was 1,040 μg/L (micrograms per liter), whereas streams in the other area counties had median total-iron concentrations ranging from 330 to 470 μg/L (table 7.5-1).

Of 11 streams sampled in Clarion County, 5 had maximum total-iron concentrations (highest observed during sample period) of 3,000 μg/L or greater (fig. 7.5-1). Similarly high iron concentrations were found in only 5 of the remaining 60 streams sampled in Area 2. Maximum total-iron concentrations less than 500 μg/L were common in the north-central and northeastern parts of the area.

Maximum total-iron concentrations in Area 2 streams ranged from 180 to 28,000 μg/L. The mean and median maximum concentrations were 1,865 and 780 μg/L, respectively. The nearly 200-percent difference between the mean and median was the result of the effect of several high concentrations on the mean. Maximum dissolved-iron concentrations ranged from 20 to 26,000 μg/L, and had a mean and median of 1,050 and 180 μg/L, respectively. The maximum total-iron concentration at 24 of 71 sites sampled (34 percent) was 600 μg/L or less (fig. 7.5-2), whereas the maximum dissolved-iron concentration was 600 μg/L or less at 60 of 71 stations (85 percent). Eleven of 71 stations had maximum total-iron concentrations greater than 3,000 μg/L (fig. 7.5-2), whereas 11 stations had maximum dissolved-iron concentrations of 600 μg/L or greater.

In spite of the distribution differences between total and dissolved iron, the two constituents are closely related as shown in figure 7.5-3, which is based on 263 concurrent samples for dissolved and total iron. These data pairs had a mean total-iron concentration of 1,030 μg/L and a mean dissolved-iron concentration of 555 μg/L.

Samples for dissolved- and total-iron determinations (section 12.2) were collected at 71 sites in Area 2 and analyzed according to procedures detailed by Skougstad and others (1979). Samples were generally collected four times under base-flow conditions during the 1979 and 1980 water years. Dissolved- and total-iron data for the 1979 and 1980 water years are published by the U.S. Geological Survey (1980, 1981).



EXPLANATION

MAXIMUM TOTAL-IRON CONCENTRATION CLASSES
In micrograms per liter

△

- ▲ **0 -500**
- ▲ **500 - 1000**
- ▲ **1000 - 3000**
- ▲ **3000 - 10,000**
- ▲ **Greater than 10,000**
- △[17] **Site number** See section 12.1 for detailed site description and section 12.2 for water-quality analysis.

Figure 7.5-1 Maximum total-iron concentrations for selected sites.

Table 7.5-1 Average coal production, 1976-80, and median stream total-iron concentrations, 1979-80, for selected counties.

County	Number of streams sampled	Median total-iron concentration (μg/L)	Average annual coal production (tons)
Clarion	11	1,040	5,218,414
Venango	14	345	913,009
Elk	13	330	732,923
Mercer	1	*	413,368
Crawford	8	470	0
Forest	12	330	0
Warren	10	435	0

*Data insufficient for median computation.

See adjacent map for site locations.

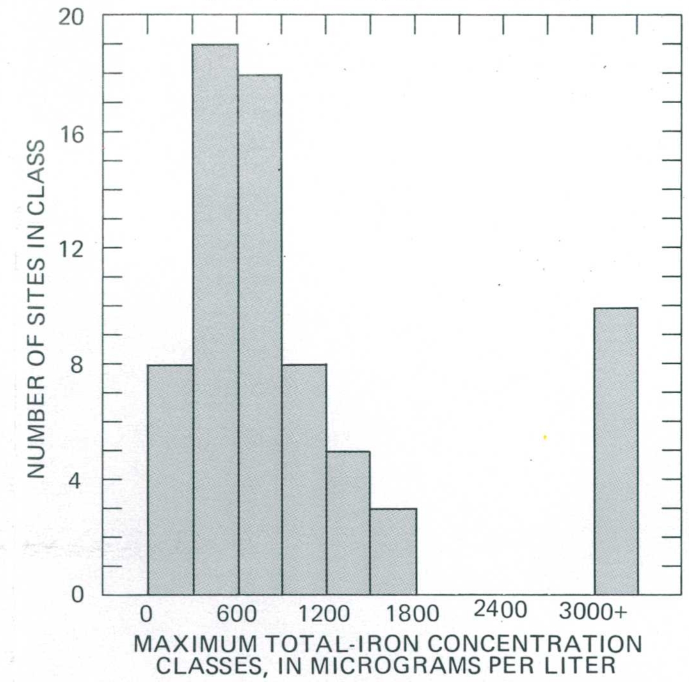


Figure 7.5-2 Maximum total-iron concentration.

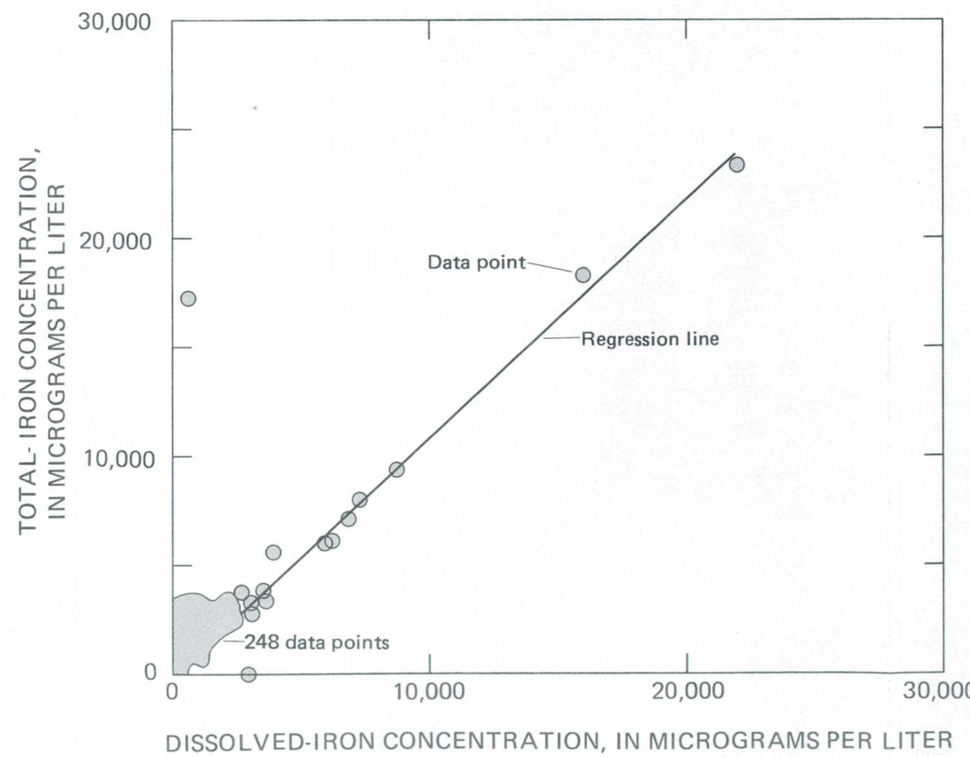


Figure 7.5-3 Relation between total- and dissolved-iron concentration.

See section 12.1 for detailed site description.

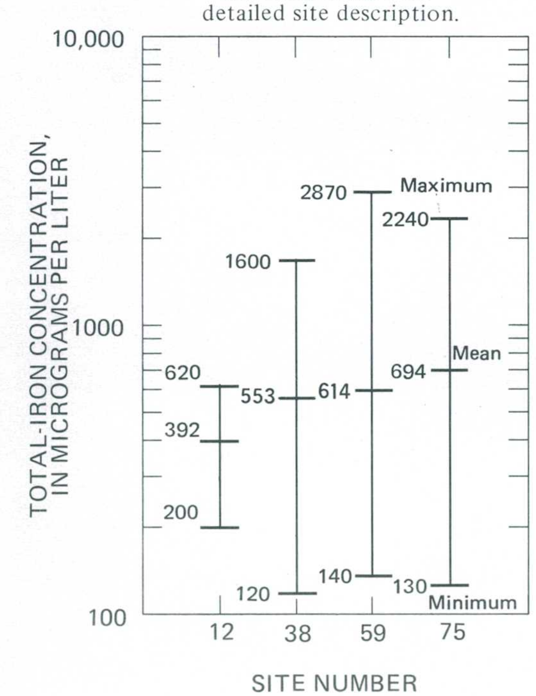


Figure 7.5-4 Variation in total-iron concentrations for water years 1976-1978.

Streams in Area's Top Coal-Producing County have High Total-Manganese Concentrations

Streams sampled in Clarion County, Area 2's top coal producer, had median total-manganese concentrations 18 to 78 times greater than the medians for the other counties in the area.

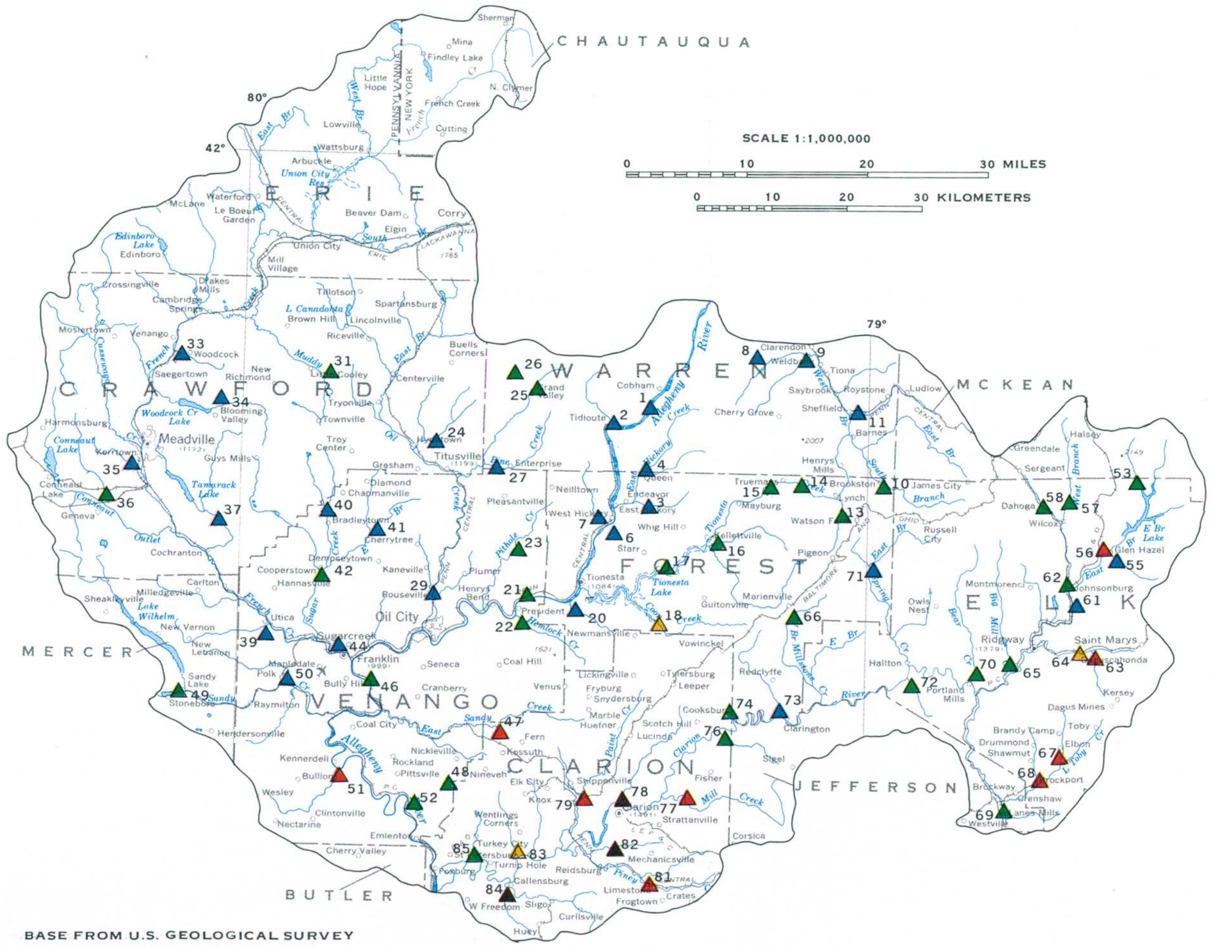
The median total-manganese concentration for 11 streams sampled in Clarion County, Area 2's top coal producer was 1,950 μg/L (micrograms per liter) (table 7.6-1). The median concentration for the other counties in the area ranged from 110 to 25 μg/L. Therefore, the median concentration for Clarion County was 18 to 78 times greater than the medians for the other counties.

Streams in most parts of Area 2 have maximum total-manganese concentrations (highest observed during sample period) less than 500 μg/L, and many streams in the north-central and northwestern sections have concentrations less than 100 μg/L (fig. 7.6-1). However, numerous streams in Clarion and Elk Counties have maximum total-manganese concentrations in excess of 2,000 μg/L, and several streams in Clarion County exceed 10,000 μg/L.

Maximum total-manganese concentrations for 71 Area 2 streams ranged from 20 to 22,000 μg/L; the mean and median maximum concentrations were 1,465 and 120 μg/L, respectively. Maximum dissolved-manganese concentrations ranged from 10 to 22,000 μg/L; the mean and median maximum concentrations were 1,440 and 100 μg/L, respectively. The large difference between the mean and median values is a reflection of the effect of several high concentrations on the mean. Of the 71 streams sampled in Area 2, 32 (45 percent) had maximum total-manganese concentrations of 100 μg/L or less, and 50 streams (70 percent) had maximum total-manganese concentrations of 200 μg/L or less (fig. 7.6-2). The distribution of maximum dissolved-manganese concentrations was similar to that for total manganese.

Total- and dissolved-manganese concentrations are closely related as illustrated in figure 7.6-3 which indicates that most of the manganese transported by Area 2 streams is in the dissolved form. This is confirmed by the fact that for 263 concurrent sample pairs, the mean total-manganese concentration is 987 μg/L and the mean dissolved-manganese concentration is 925 μg/L.

Samples for dissolved- and total-manganese determinations (section 12.2) were generally collected four times under base-flow conditions during the 1979 and 1980 water years. Samples were analyzed according to procedures described by Skougstad and others (1979). Total- and dissolved-manganese data for the 1979 and 1980 water years are published by the U.S. Geological Survey (1980, 1981).



BASE FROM U.S. GEOLOGICAL SURVEY
STATE BASE MAPS, 1:500,000, 1975

EXPLANATION

MAXIMUM TOTAL-MANGANESE CONCENTRATION CLASSES
In micrograms per liter

- ▲ 0 - 100
- ▲ 100 - 500
- ▲ 500 - 2000
- ▲ 2000 - 10,000
- ▲ Greater than 10,000
- △37 **Site number** See section 12.1 for detailed site description and section 12.2 for water-quality analysis.

Figure 7.6-1 Maximum total-manganese concentrations for selected sites.

Table 7.6-1 Average coal production, 1976-80, and median stream total-manganese concentrations, 1979-80, for selected counties.

County	Number of streams sampled	Median total-manganese concentrations (μg/L)	Average annual coal production (tons)
Clarion	11	1,950	5,213,414
Venango	14	40	913,009
Elk	13	110	732,923
Mercer	1	*	413,368
Crawford	8	40	0
Forest	12	40	0
Warren	10	25	0

*Data insufficient for median computation.

See adjacent map for site locations.

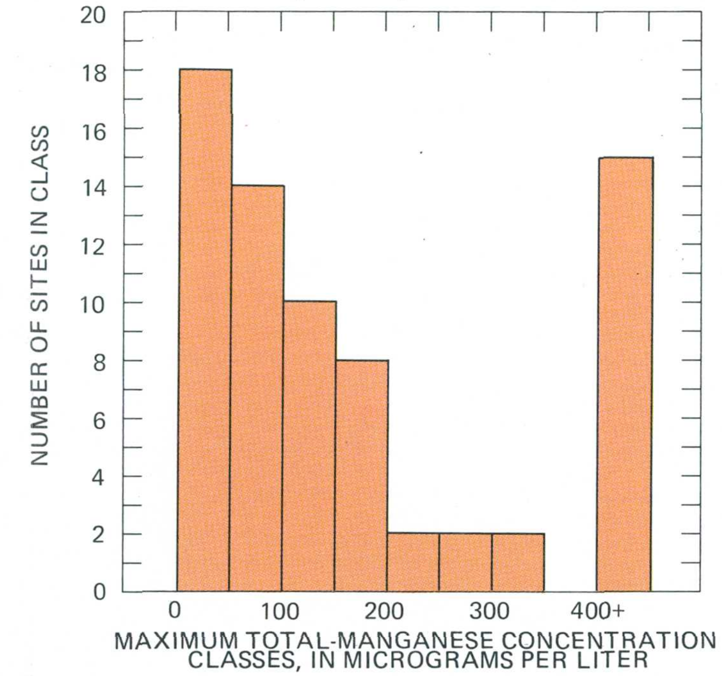


Figure 7.6-2 Maximum total-manganese concentration.

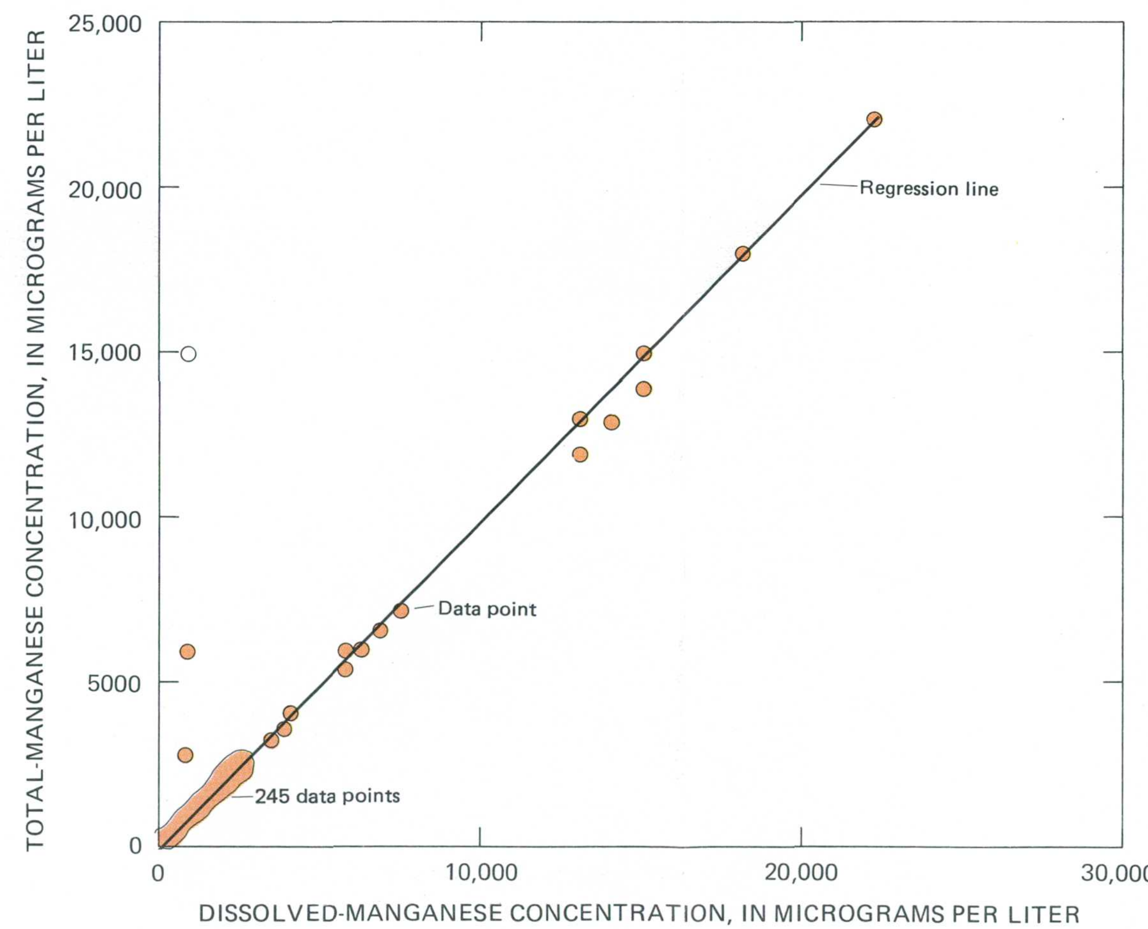


Figure 7.6-3 Relation between total- and dissolved-manganese concentration.

Highest Dissolved-Sulfate Concentrations Found in Coal-Producing Counties

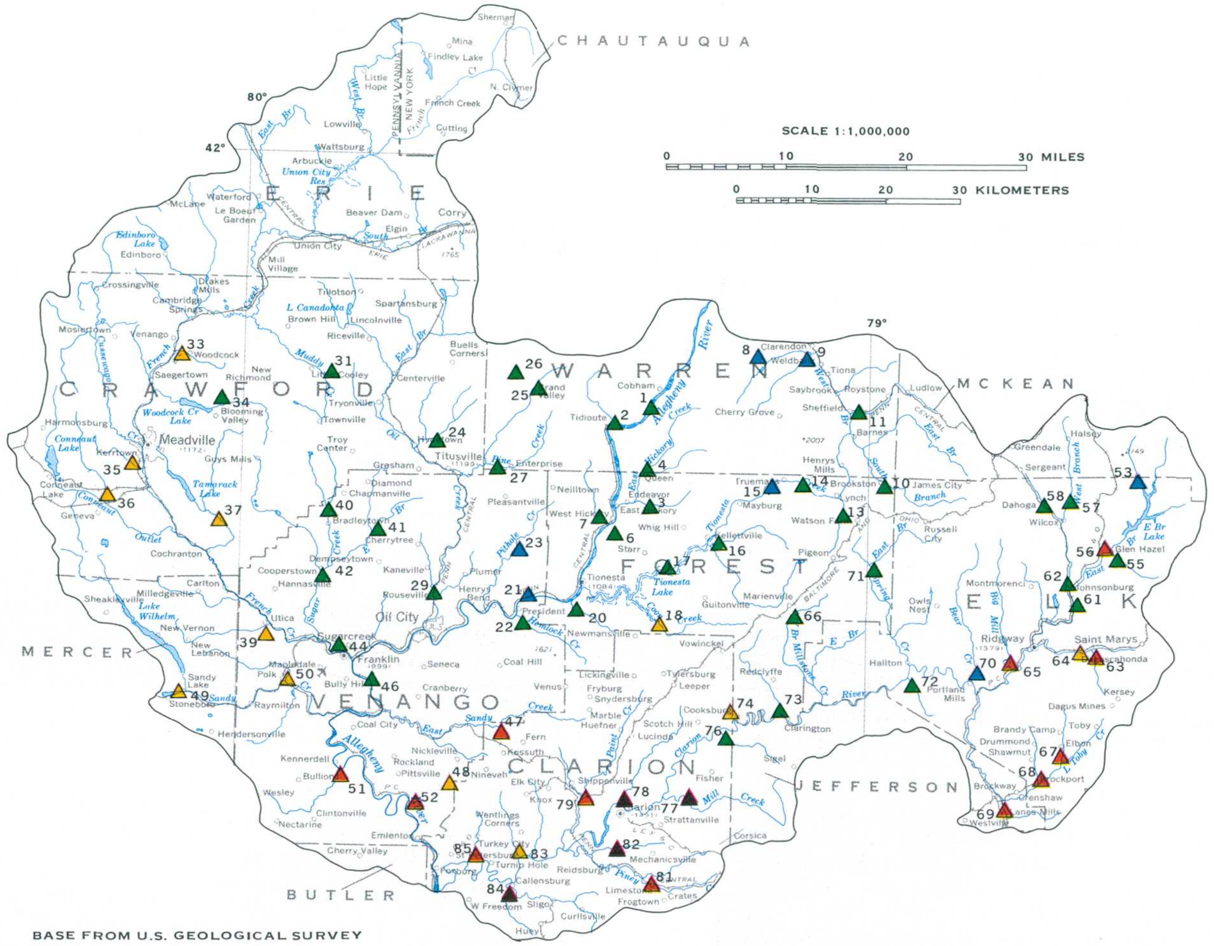
The highest dissolved-sulfate concentrations in Area 2 were found in streams in the area's three top coal-producing counties.

Of the 12 Area 2 streams that had dissolved-sulfate concentrations of 100 mg/L (milligrams per liter) or greater, 10 were in Elk and Clarion Counties and the other two were in Venango County (fig. 7.7-1). These three counties produced most of Area's 2 coal during 1976-80 (table 7.7-1). Four of the Clarion County streams had maximum sulfate concentrations (highest observed during sample period) of 300 mg/L or greater. Except for a narrow band along the southern border of Area 2, where maximum sulfate concentrations ranged from 20-99 mg/L, the remaining streams generally had maximum sulfate concentrations less than 20 mg/L.

Maximum dissolved-sulfate concentrations in Area 2 streams ranged from 8.9 to 1,100 mg/L. The mean and median maximum concentrations were 76 and 16 mg/L, respectively. The great difference between the mean and median is a reflection of the effect of several high concentrations on the mean. Fourteen streams (20 percent) had a maximum sulfate concentration of 10 mg/L or less (fig. 7.7-2) and 16 streams (23 percent) had maximum sulfate concentrations greater than 100 mg/L.

Samples for dissolved-sulfate determinations (section 12.2) were generally collected four times under base-flow conditions during the 1979 and 1980 water years. Samples were analyzed according to procedures outlined by Skougstad and others (1979). Dissolved-sulfate data for the 1979 and 1980 water years are published by the U.S. Geological Survey (1980, 1981).

Variation in dissolved-sulfate concentrations during the 1976-78 water years at four gaging stations is illustrated in figure 7.7-3. Except for station 59, the maximum observed concentration is two to three times greater than the minimum observed concentration. A comparison of the means for the four stations shows them to be significantly different (99-percent level) except for those comparisons involving station 59. There were no significant correlations (Snedecor, 1957) between sulfate concentration and the log (base 10) of discharge. Dissolved-sulfate data for the 1976-78 water years are published by the U.S. Geological Survey (1977, 1978, 1979).



BASE FROM U.S. GEOLOGICAL SURVEY
STATE BASE MAPS, 1:500,000, 1975

EXPLANATION

MAXIMUM DISSOLVED-SULFATE CONCENTRATION CLASSES
In milligrams per liter

- ▲ 0 - 10
- ▲ 10 - 20
- ▲ 20 - 100
- ▲ 100 - 300
- ▲ Greater than 300
- △27 **Site number** See section 12.1 for detailed site description and section 12.2 for water-quality analysis.

Figure 7.7-1 Maximum dissolved-sulfate concentrations for selected sites.

Table 7.7-1 Average coal production, 1976-80, and median stream dissolved-sulfate concentrations, 1979-80, for selected counties.

County	Number of streams sampled	Median dissolved-sulfate concentrations (mg/L)	Average annual coal production (tons)
Clarion	11	115	5,213,414
Venango	14	16	913,009
Elk	13	11	732,923
Mercer	1	*	413,368
Crawford	8	17	0
Forest	12	10	0
Warren	10	10	0

*Data insufficient for median computation.

See adjacent map for site locations.

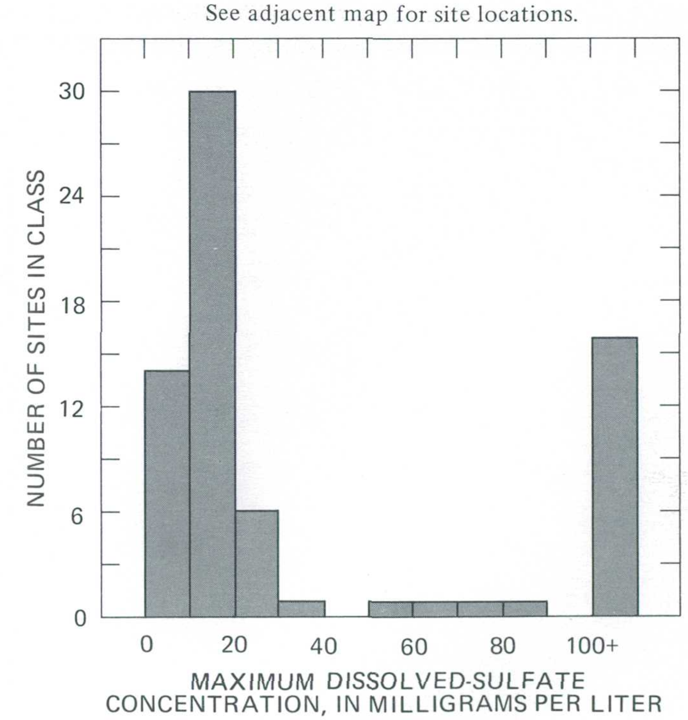


Figure 7.7-2 Maximum dissolved-sulfate concentration.

See section 12.1 for detailed site description.

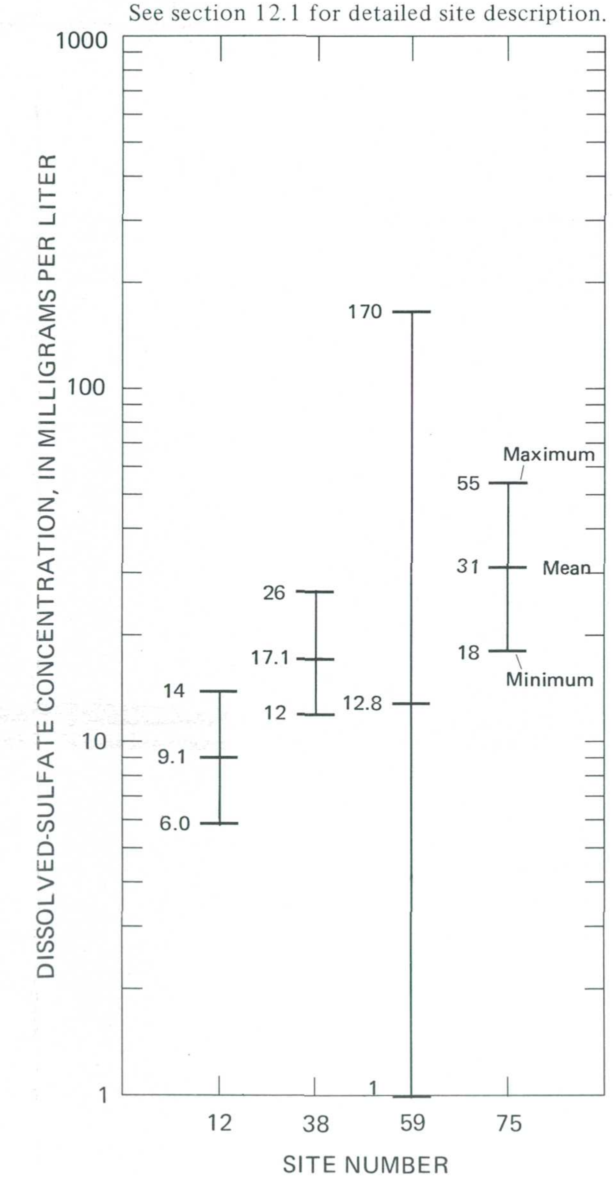


Figure 7.7-3 Variation in dissolved-sulfate concentration for water years 1976-78.

Suspended-Sediment Discharge Related to Streamflow

Suspended-sediment discharges in Area 2 streams are related to streamflow, but the relation shows wide variations. The variations are not related solely to mining, but probably to all land uses.

The suspended-sediment transport data derived from samples at the synoptic sites in Eastern Coal Province Area 2 are shown in figure 7.8-1. This particular graph relates instantaneous suspended-sediment discharge in tons per day to instantaneous streamflow in cubic feet per second per square mile. The shaded portion of figure 7.8-1 encloses 98 percent of the data collected at synoptic sites in Area 2. Note that these data show that for any given instantaneous unit discharge the instantaneous suspended-sediment discharge may vary by a factor of 46. This variability is close to that shown by Wark (1965) for samples from a single large river. The sediment-transport envelope illustrated in figure 7.8-1 should indicate the range of transport values for most streams in Area 2 having drainage areas between 1.5 and 65 square miles. The variability may be a function of the different land uses within the area.

Porterfield (1972) states that an instantaneous transport curve may agree, in practice, with a daily transport curve. If this is the case, it should be possible to compute average annual loads using the flow-duration transport-curve method described by Miller (1951). Under this assumption a minimum annual suspended-sediment discharge for Area 2 streams was computed as shown in table 7.8-1. Average water discharges per square mile for selected time intervals were determined from a composite flow-duration curve for streams in Area 2 (fig. 7.8-2). The development of the composite flow-duration curve is discussed in section 9.5. Minimum suspended-sediment discharges corresponding to the selected streamflows were determined from the composite suspended-sediment transport curve for Area 2 streams (fig. 7.8-1) and multiplied by the duration intervals of water discharge to calculate the average annual sediment load. For example, the average water discharge for Area 2 streams for 8.5 to 15 percent of the time is 3.7 $(ft^3/s)/mi^2$. The corresponding suspended-sediment discharge is 0.016 $(tons/mi^2)/day$ (tons per square mile per day). Multiplying the suspended-sediment discharge by the time interval for each interval in table 7.8-1 and dividing the sum of column 6 by 100 (table 7.8-1) yields the mean daily suspended-sediment discharge in $(tons/mi^2)/day$. Multiplying the mean daily suspended-sediment discharge by 365 yields the minimum annual suspended-sediment discharge in tons per square mile.

Table 7.8-1 indicates that the minimum annual suspended-sediment discharge for streams in Area 2 would be about 2.8 $tons/mi^2$. Wark (1965) states that the average annual suspended-sediment yield in Area 2 ranges from 20-250 $tons/mi^2$. Wark's 1965 figures indicate that the average suspended-sediment concentration would range from 11-140 mg/L (milligrams per liter). The concentrations are computed using an average discharge of 1.8 $(ft^3/s)/mi^2$ which is applicable for Area 2 streams. Because relatively large amounts of sediment move in short periods of storm runoff (Wark, 1965), the concentrations must be less than the average values much of the time.

Sediment-transport data for 8 streams exhibiting AMD (acid-mine drainage) indicators fell within the envelope as shown by the circles in figure 7.8-1. However, the data from AMD streams tended to indicate larger minimum suspended-sediment loads at all discharges than did the data from all synoptic sites in Area 2. This analysis, based on scant data, does not consider the effects of flows greater than 10 percent duration, nor does it include the effects of significant land disturbance near streams during surface mining. The suspended-sediment and discharge data used to develop the sediment-transport curve are published by the U.S. Geological Survey (1980, 1981).

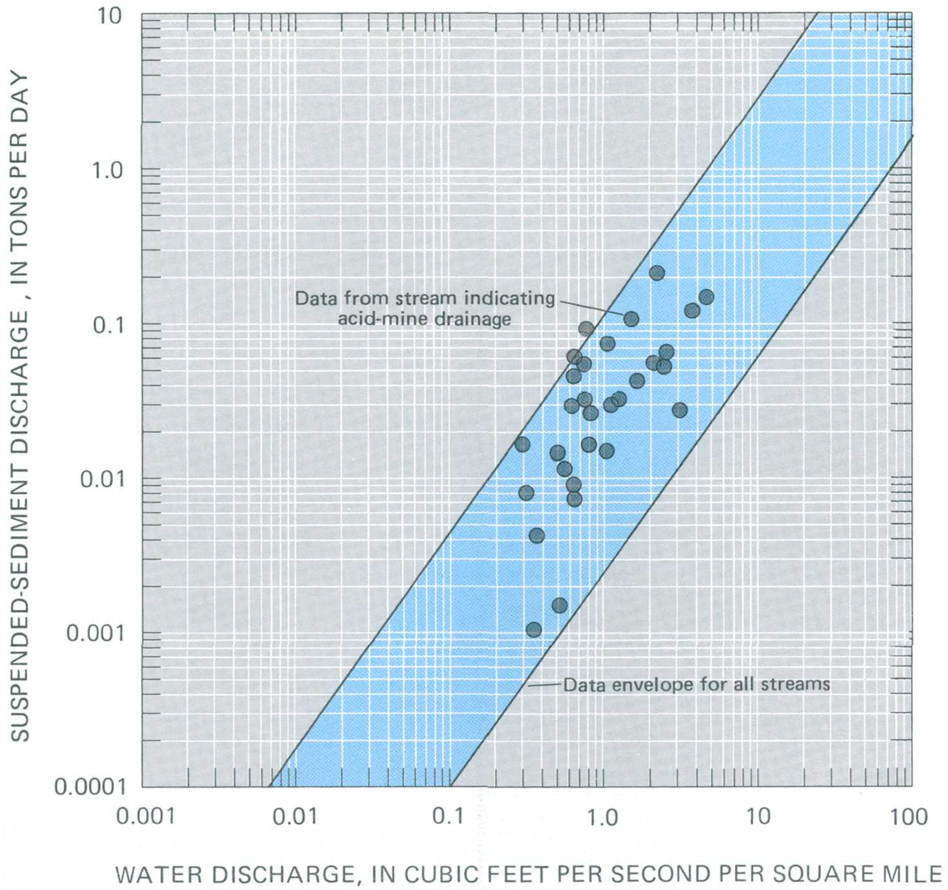


Figure 7.8-1 Suspended-sediment transport for selected sites.

Table 7.8-1 Computation of minimum annual suspended-sediment load using sediment transport and flow-duration data.

Mean minimum daily suspended-sediment load = 0.758/100 = 0.00758 tons/mi.^{2};
Average annual suspended-sediment load = 0.00758 x 365 = 2.8 tons/mi.^{2}.

Cumulative time (percent) (1)	Time interval (percent) (2)	Mid-ordinate (percent) (3)	Unit discharge [(ft.^{3}/s)/mi.^{2}] (4)	Suspended-sediment load (tons/mi.^{2}) (5)	Load for interval* (tons/mi.^{2}) (6)
0.25	0.25	0.125	20**	0.160	0.040
.75	.50	.500	15**	.120	.060
1.5	.75	1.125	12**	.080	.060
2.5	1.0	2.000	10	.072	.072
4.5	2.0	3.500	7.7	.042	.084
8.5	4.0	6.500	5.5	.027	.108
15	6.5	11.750	3.7	.016	.104
25	10	20.000	2.5	.010	.100
35	10	30.000	1.7	.0054	.054
45	10	40.000	1.2	.0030	.030
55	10	50.000	.88	.0022	.022
75	20	65.000	.50	.0010	.020
95	20	85.000	.22	.0002	.004
100	5	97.000	.11	.0001	---
Total					0.758

*Column 6 = column 2 x column 5
**Estimated

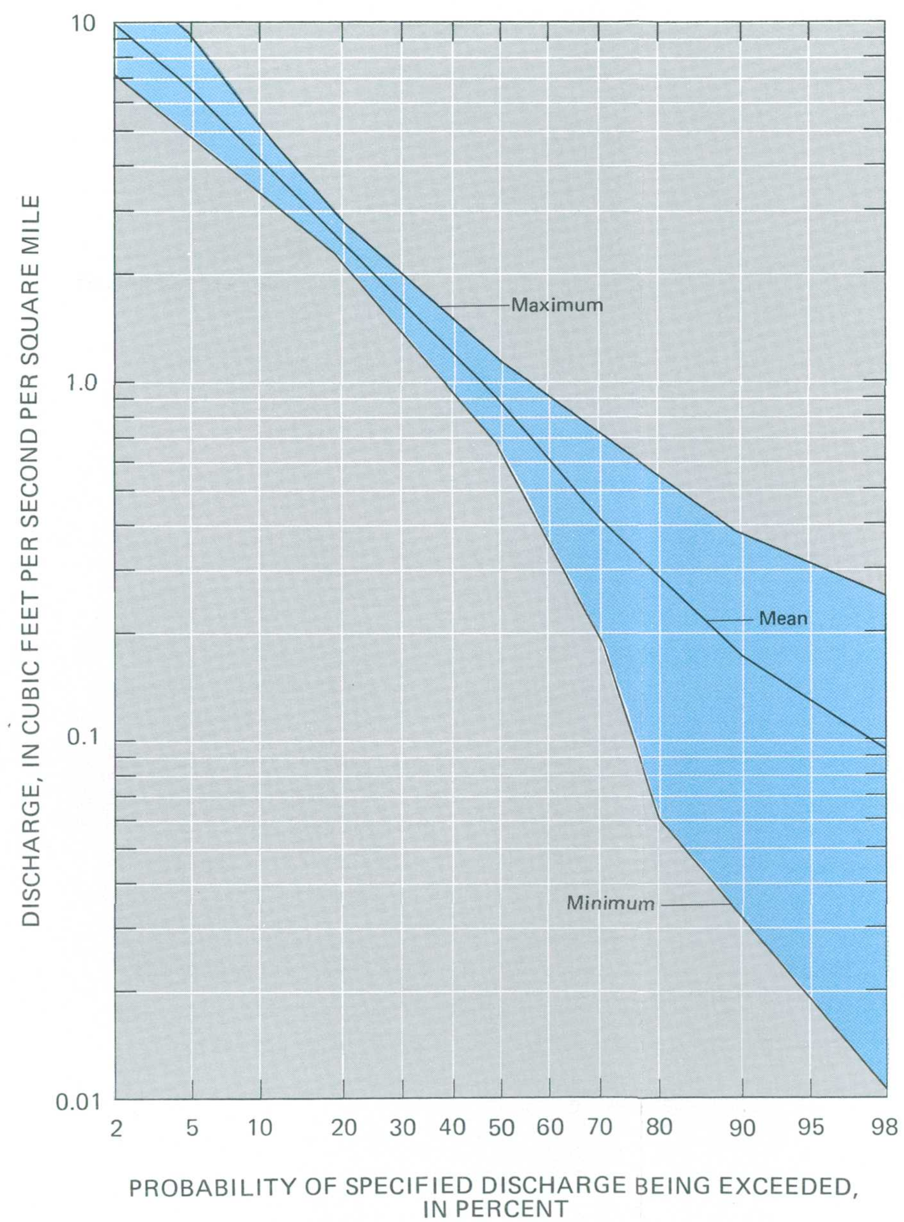


Figure 7.8-2 Composite unit flow-duration curves for selected sites.

Clarion County Streams have High Bed-Material Iron Concentrations

Streams in Clarion County, which produces about 70 percent of Area 2's coal, had a median bed-material iron concentration 1.7 to 4.2 times greater than those for streams in the other area counties.

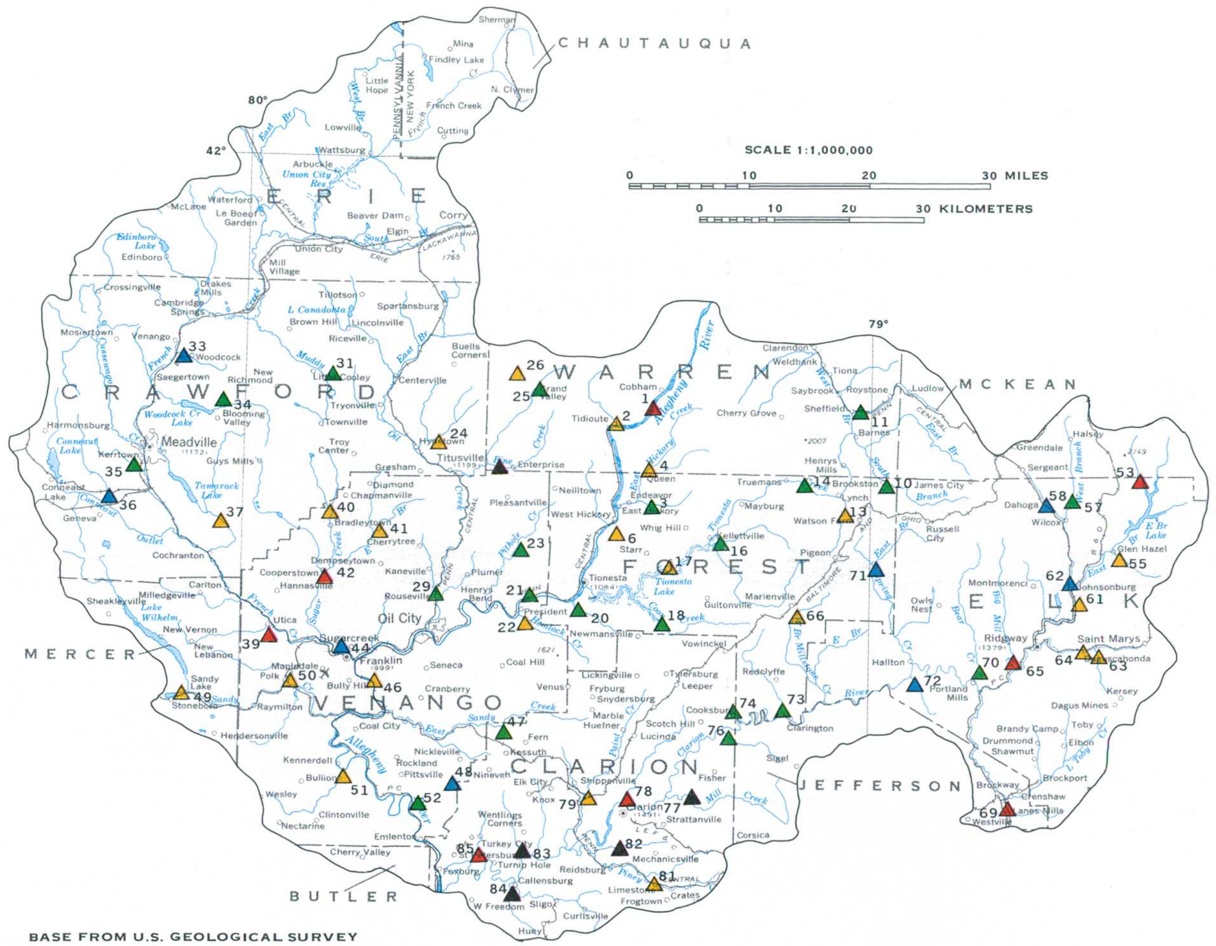
Eleven streams sampled in Clarion County had a median bed-material iron concentration of 57,000 μg/g (micrograms per gram), whereas streams in the other counties in the area had median concentrations ranging from 34,000 μg/g to 13,500 μg/g. The Clarion County median concentration was 1.7 to 4.2 times greater than those of the other counties. Clarion County produces about 72 percent of the coal mined in Area 2.

Of the 65 streams sampled in Area 2, 5 had bed-material iron concentrations of 75,000 μg/g or greater. Four of these streams were in Clarion County (fig. 7.9.1-1) in the vicinity of Clarion. The fifth stream with a bed-material iron concentration of 75,000 μg/g or greater is located in southwestern Warren County near Enterprise. Bed-material iron concentrations in the range of 35,000-75,000 μg/g were found in scattered locations across the area. Bed-material iron concentrations less than 10,000 μg/g were found in all sections of Area 2 except the central and north-central parts.

Bed-material iron concentrations for 65 selected streams in Area 2 ranged from 810 to 100,000 μg/g. The mean and median concentrations were 27,600 and 21,000 μg/g, respectively. Ten streams (15 percent) had bed-material iron concentrations of 10,000 μg/g or less, and 49 streams (75 percent) had concentrations of 30,000 μg/g or less (fig. 7.9.1-2).

Samples for bed-material iron determinations (section 12.2) were collected during low base flow in the 1979 water year. Analyses were performed according to procedures outlined by Skougstad and others (1979). Bed-material iron data are published by the U.S. Geological Survey (1980).

As materials pass through the stream channel network, they are incorporated into the bed material. Unless extremely high flows scour the bed material and transport it downstream, the deposits may serve as indicators of past water-quality conditions. Feltz (1980) states that concentrations of heavy metals found in bottom materials confirmed potential contamination in the Schuylkill River even though concentrations in the water itself indicated no apparent problem. The concentrations of heavy metals in the bottom materials were several orders of magnitude higher than the concentrations in the water. It is possible that bed-material iron may be useful as a similar indicator.



BASE FROM U.S. GEOLOGICAL SURVEY
STATE BASE MAPS, 1:500,000, 1975

EXPLANATION

BED-MATERIAL IRON CONCENTRATION CLASSES
In micrograms per gram

- ▲ 0 - 10,000
- ▲ 10,000 - 20,000
- ▲ 20,000 - 35,000
- ▲ 35,000 - 75,000
- ▲ Greater than 75,000
- △23 Site number See section 12.1 for detailed site description and section 12.2 for water-quality analysis.

Figure7.9.1-1 Iron concentrations in bed-material for selected sites.

Table 7.9.1-1 Average coal production, 1976-80, and median stream bed-material iron concentrations, 1979, for selected counties.

County	Number of streams sampled	Median bed-material iron concentration (µg/g)	Average annual coal production (tons)
Clarion	11	57,000	5,218,414
Venango	14	20,500	913,009
Elk	11	21,000	732,923
Mercer	1	*	413,368
Crawford	8	13,500	0
Forest	11	14,500	0
Warren	7	34,000	0

*Data insufficient for median computation.

See adjacent map for site locations.

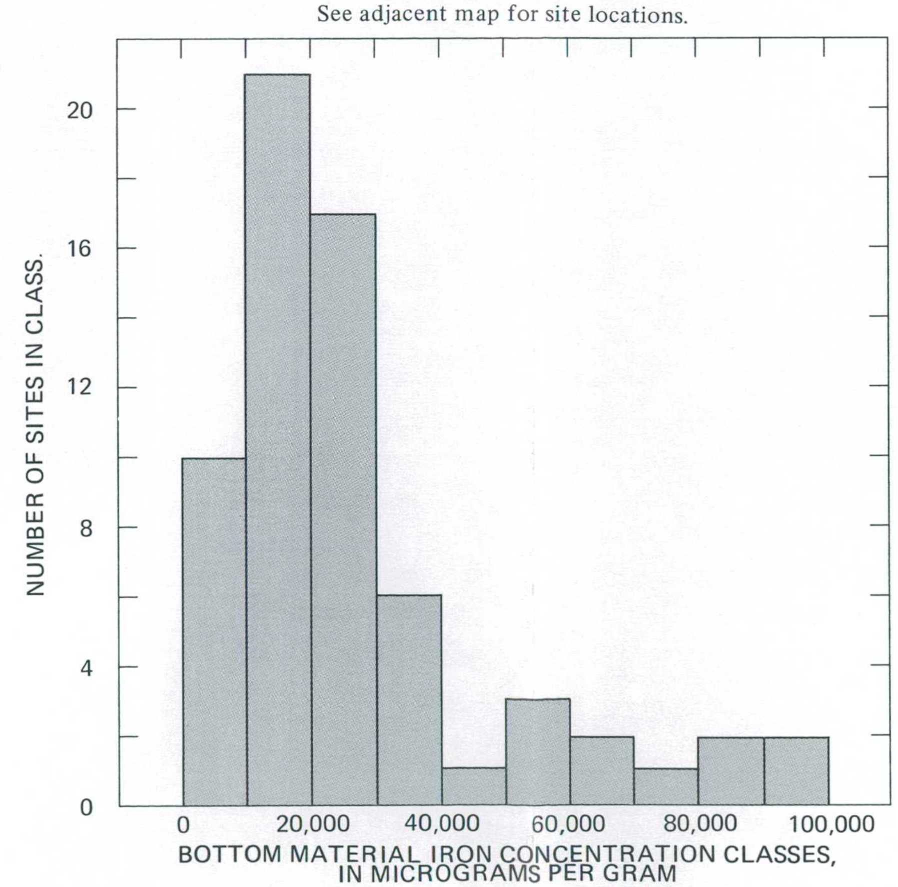


Figure 7.9.1-2 Iron concentration in bottom material.

High Bed-Material Manganese Concentrations Most Common in Coal-Producing Counties

The highest bed-material manganese concentrations in Area 2 streams were found in the three top coal-producing counties.

Of the 65 selected streams sampled in Area 2, 10 had bed-material manganese concentrations of 1,000 μg/g (micrograms per gram) or greater. All of these streams were in Venango, Clarion, and Elk counties, the leading coal producers in the area (fig. 7.9.2-1). Four of the 10 streams had a bed-material manganese concentration equal to or greater than 1,500 μg/g. Bed-material manganese concentrations in the rest of Area 2 generally ranged between 100 and 1,000 μg/g, but several streams in Clarion and Forest counties had concentrations less than 100 μg/g (fig. 7.9.2-1).

Bed-material manganese concentrations at 65 selected sites in Area 2 ranged from 10 to 2,000 μg/g. The mean and median concentrations were 600 and 490 μg/g, respectively. Eleven streams (17 percent) had concentrations of 200 μg/g or less, 27 streams (42 percent) had concentrations of 400 μg/g or less, and only 5 streams (8 percent) had concentrations greater than 1,200 μg/g (fig. 7.9.2-2).

Samples for bed-material manganese determinations (section 12.2) were collected during low base flow in the 1979 water year. Samples were analyzed by procedures described by Skougstad and others (1979). Bed-material manganese data for the 1979 water year are published by the U.S. Geological Survey (1980).

As materials pass through the stream channel network, they are incorporated into the bed material. Unless extremely high flows scour the bed material and transport it downstream, the deposits may serve as indicators of past water-quality conditions. Feltz (1980) states that concentrations of heavy metals found in bottom materials confirmed potential contamination in the Schuylkill River even though concentrations in the water itself indicated no apparent problem. The concentrations of heavy metals in the bottom materials were several orders of magnitude higher than the concentrations in the water. It is possible that manganese may act in a similar fashion.

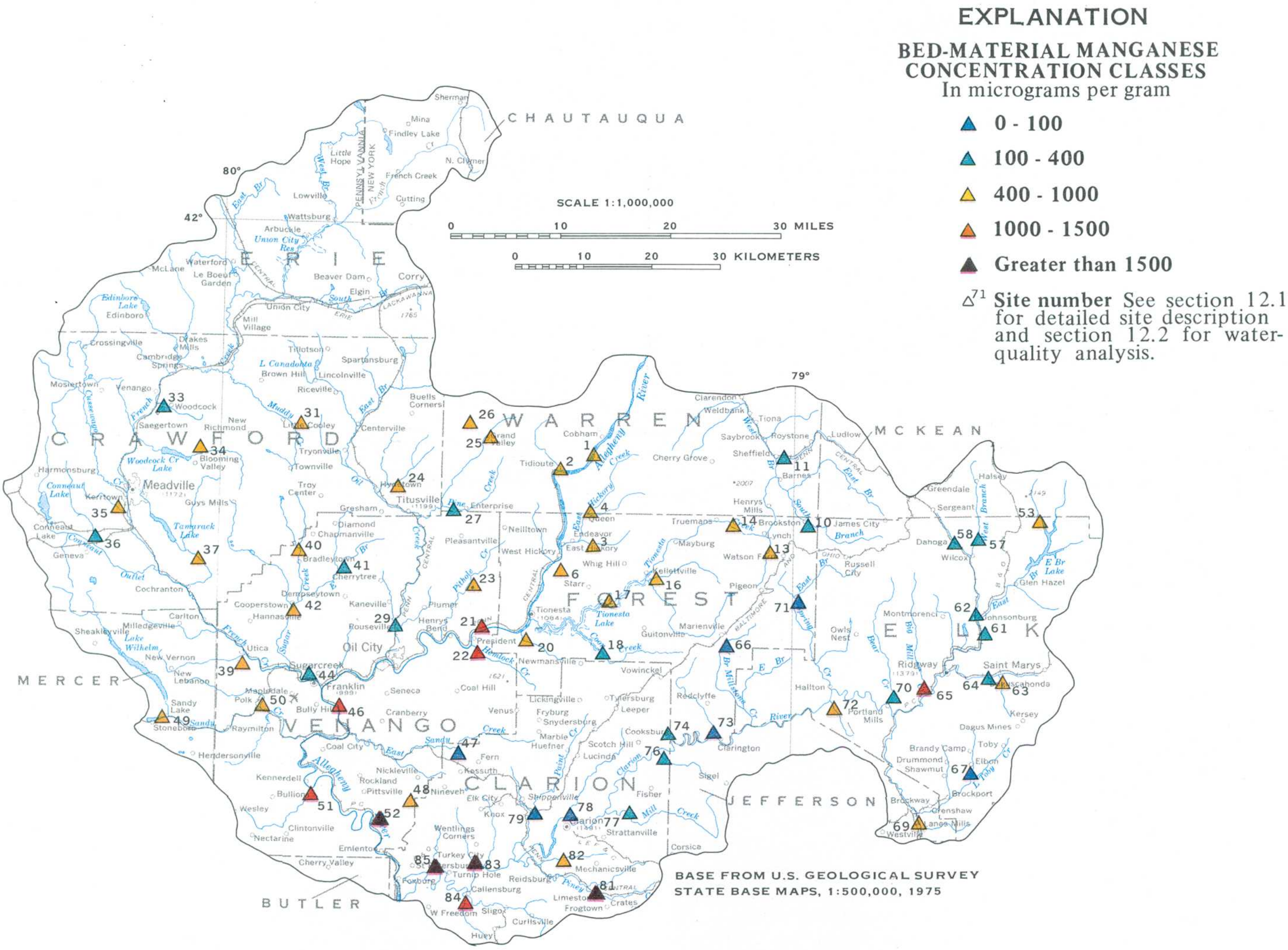


Figure 7.9.2-1 Manganese concentrations in bed material for selected sites.

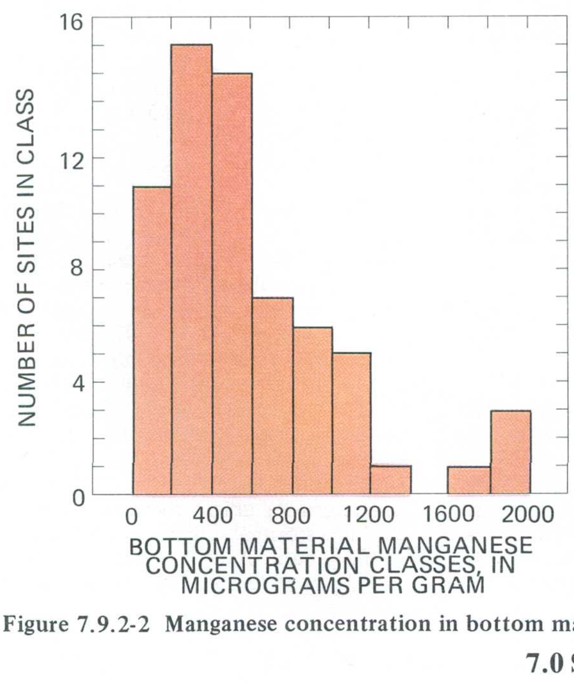


Figure 7.9.2-2 Manganese concentration in bottom material.

Composition of Benthic Invertebrates and Chemical Constituents Indicate Good Water Quality

Benthic invertebrate composition and chemical constituents for Area 2 generally indicated good water quality for 1979 and 1980, though the chemical constituents and numbers of benthic invertebrates found in portions of the Clarion basins indicated poor water quality.

Benthic invertebrates are used as indicators of water quality because of their relatively long life, restricted mobility, and sensitivity to water contaminants (Britton and Averett, 1974), such as acid mine drainage (AMD). Although variations in tolerance to AMD may not be evident unless benthic invertebrates are identified to the species level, some broad generalizations concerning composition and numbers can be made on the basis of identification to the order level. Good biological water quality in a stream can be characterized by a large variety of benthic invertebrate orders with no dominant population; whereas poor water quality can be characterized by a small variety of benthic invertebrate orders with one or two dominant populations or by very small populations. No benthic invertebrate population would generally indicate very poor water quality.

Benthic invertebrate composition is important in determining water quality. Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) are found in healthy streams, whereas unhealthy streams may be dominated by Diptera (flies, midges) and snails. Along with numbers and composition of benthic invertebrates, chemical constituents found in a stream are important in determining the over-all water quality. Sections 12.2, 12.3, and 12.4 show the benthic-invertebrate and chemical water-quality data collected at synoptic sites in Area 2.

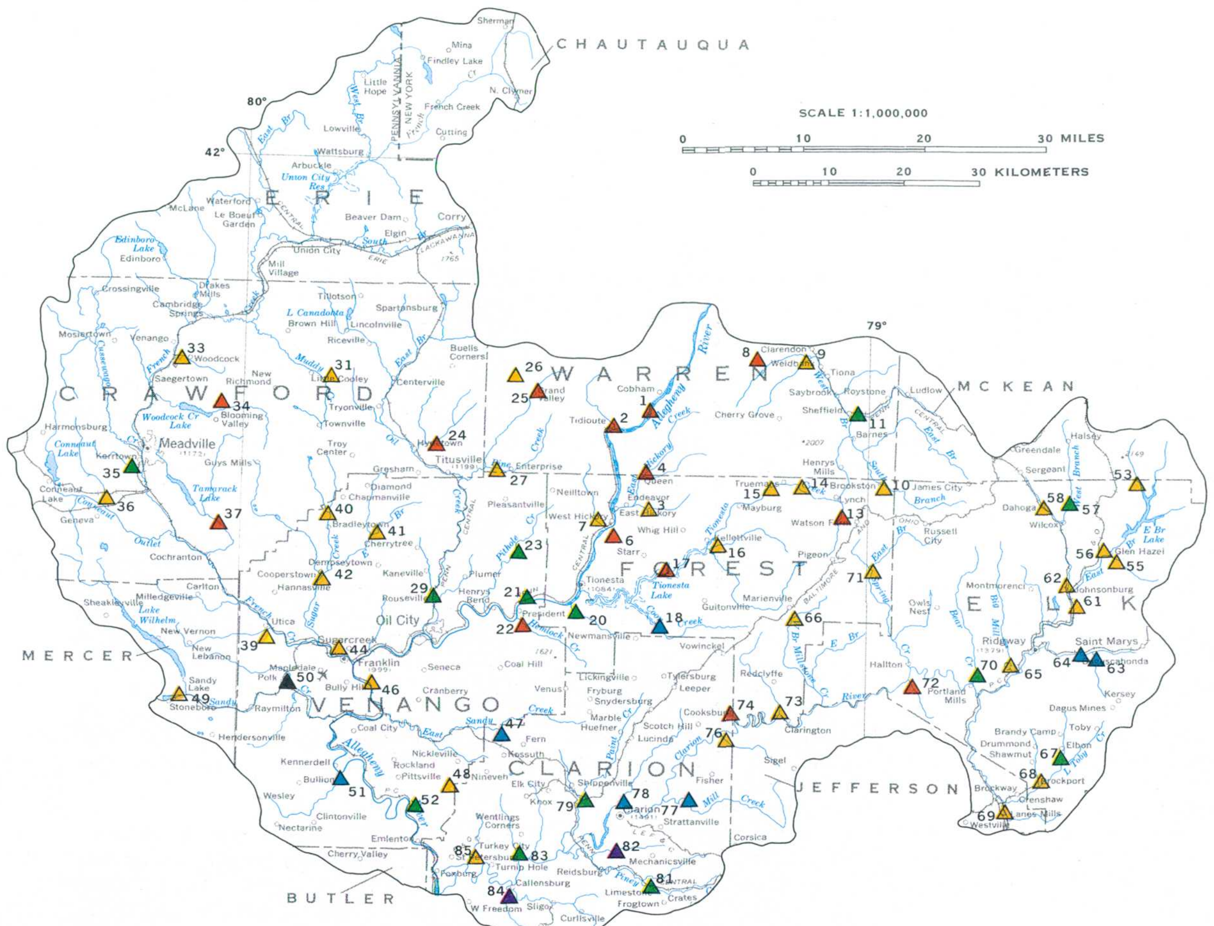
Benthic invertebrate samples were collected in August 1979 and August 1980 by spending 15 minutes sampling all habitats in a stream reach. The basic technique comprised of disturbing bed material and then allowing the debris and organisms to float via streamflow into a mesh net. Contents of the net were then placed in a No. 70 sieve, rinsed with stream water and placed in a white polymer tray where specimens were separated and put in an appropriately labeled jar containing 70 percent alcohol. In 1979 benthic invertebrates were identified in a laboratory, but in 1980 they were identified in the field.

Four phyla were found in Area 2: Arthropoda, Mollusca, Annelida, and Nematoda. Five orders dominated the area, though they varied in rank from basin to basin and year to year. In August 1979 Diptera (midges, flies) was found at 71 sites, Trichoptera (caddisfly) at 56 sites, Ephemeroptera (mayflies) at 53 sites and Plecoptera (stoneflies) at 42 sites. In August 1980 Ephemeroptera was found at 55 sites, Plecoptera at 52 sites, Trichoptera at 53 sites and Coleoptera (beetles) at 44 sites.

Two streams in the Clarion River basin lacked benthic invertebrates, while four others in the Clarion and Allegheny basins lacked aquatic biological communities. The Office of Surface Mining (1979) defines a stream with a biological community as having at least two species of benthic invertebrates in either of the phylums Arthropoda or Mollusca. Six streams out of 69 sampled in Area 2 lacked such biological communities. They were 51, 63, 77, 78, 82, and 84 (figures 7.10-1 and 7.10-2). Most of these sites had dissolved sulfate, total iron, total manganese, pH, and acidity values indicating AMD. According to the U.S. Department of the Interior (1968), dissolved sulfate values greater than 75 mg/L, total iron greater than .5 mg/L, pH values less than 6.0, and acidity values greater than alkalinity values are indicative of AMD.

Stations in Area 2 lacking a benthic invertebrate population or having two or fewer orders of benthic invertebrates had a mean dissolved-sulfate concentration of 338 mg/L (range 130 mg/L to 820 mg/L), whereas sites having seven or more benthic invertebrate orders had a mean dissolved sulfate concentration of 15 mg/L (range 7.5 mg/L to 110 mg/L). The mean total iron value of 4.04 mg/L for the former group of stations (range .04 mg/L to 22 mg/L) is 23 times greater than the mean total iron value of .169 mg/L for the latter group of stations (range 0.01 mg/L to 1.2 mg/L). Sites lacking benthic invertebrates or having two or fewer orders of benthic invertebrates had a mean pH of 4.5, (range 3.1 to 6.7), whereas sites with 7 or more benthic invertebrate orders had a mean pH of 7.2 (range 5.8 to 8.9).

The Shannon-Weaver diversity index was determined for the benthic invertebrate samples of August 1979. This diversity index (DI) is a measure of the numbers and kinds (Wilhm and Dorris, 1968) of benthic invertebrates sampled in a stream without regard to sample size (Doyle Stevens, written communication, 1979). A high DI is generally an indicator of good water quality and a low DI is generally an indicator of poor water quality. Fifty percent of the sites in Area 2 had order-level DI's greater than or equal to 2.0, indicating good water quality. Low flow can concentrate contaminants in streams causing benthic invertebrates or their food sources to die. High flow generally dilutes contaminants unless there is runoff from a mining area during a storm and then contaminants may be concentrated in the stream. Area 2 generally had intermediate base flow in August 1979 and 1980 when benthic invertebrates were collected.



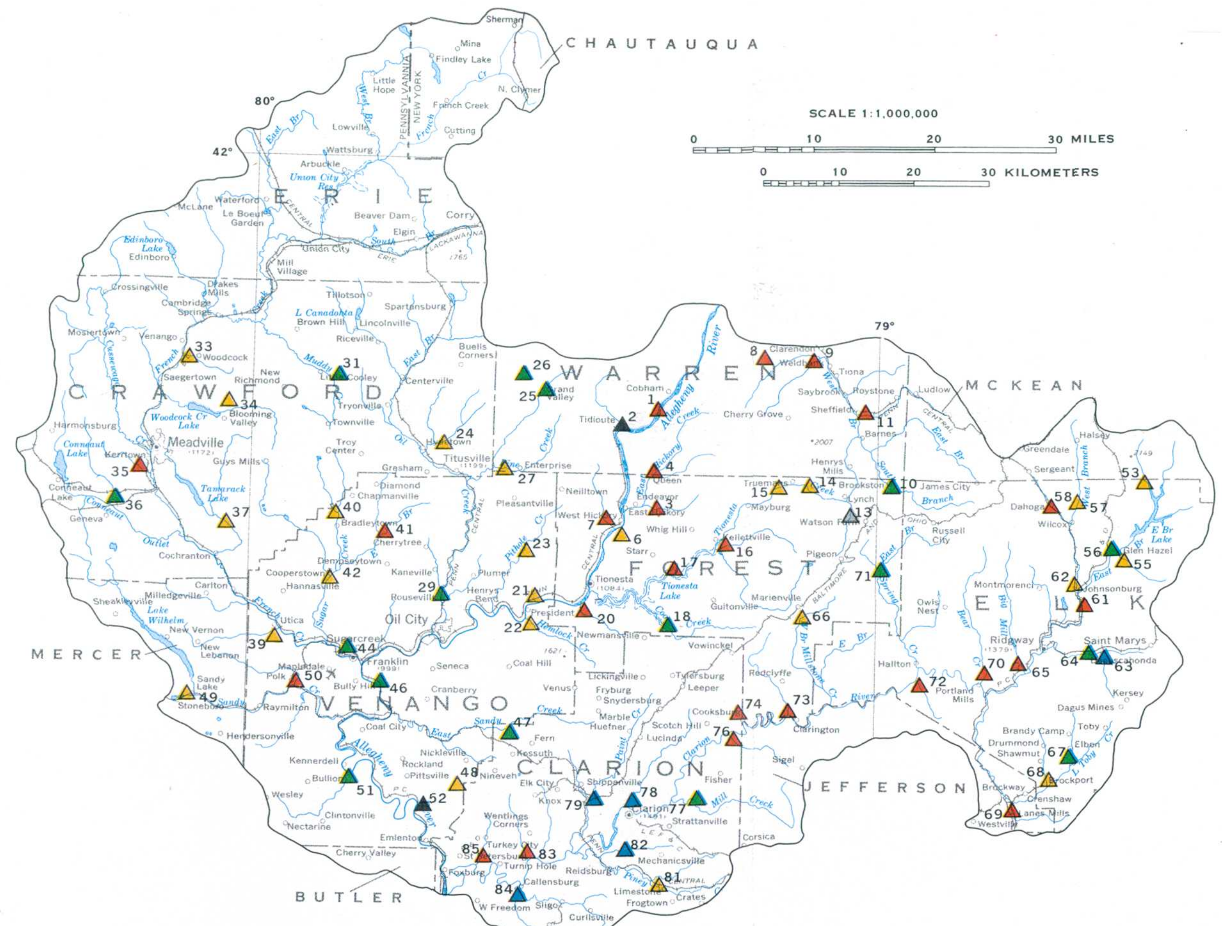
EXPLANATION

TAXONOMIC ORDERS

- ▲ 9 or 10
- ▲ 7 or 8
- ▲ 5 or 6
- ▲ 3 or 4
- ▲ 1 or 2
- ▲ 0
- △77 **Site number** See section 12.1 for detailed site description and section 12.3 for benthic invertebrate data.

Figure 7.10-1 Number of benthic invertebrate orders, August 1979.

In general the biological and chemical data for Area 2 streams are good except for the southern section of the Clarion River basin which had fewer than normal benthic invertebrates, and water quality constituents indicating AMD.



EXPLANATION

TAXONOMIC ORDERS

- ▲ 9 or 10
- ▲ 7 or 8
- ▲ 5 or 6
- ▲ 3 or 4
- ▲ 1 or 2
- ▲ 0
- ▲ Not sampled
- 26 **Site number** See section 12.1 for detailed site description and section 12.3 for benthic invertebrate data.

Figure 7.10-2 Number of benthic invertebrate orders, August 1980.

8.0 ACID-MINE DRAINAGE

Strong Indications of Acid Mine Drainage are Found in Eight Streams

Synoptic samples at eight streams in Area 2 exceeded the levels of pH, acidity-alkalinity, total iron, total manganese, and sulfate which are indicators of acid-mine drainage. Most of the streams were found in the Clarion River basin.

Several water-quality measures have been proposed as indicators of acid mine drainage (AMD). Five common indicators are (U.S. Department of the Interior, 1968):

- pH < 6.0
- acidity > alkalinity
- total iron > 0.5 mg/L (milligrams per liter)
- total manganese > 0.5 mg/L
- dissolved sulfate > 75 mg/L

Eight of the 71 sites in Eastern Coal Province Area 2 that were sampled during June 1979 to August 1980 exceeded all five indicator levels. All indicator levels may not have been exceeded during a single sampling, but each AMD indicator level was exceeded at some time when all samples were considered. The presence of AMD indicators is no guarantee of AMD, though the Office of Surface Mining Reclamation and Enforcement (1979) defines AMD as "Water with a pH less than 6.0 and in which total acidity exceeds total alkalinity, discharges from an active, inactive, or abandoned surface coal mine and reclamation operation or from an area affected by surface coal mining and reclamation activities."

Figure 8.0-1 shows the location of the eight synoptic sites meeting all five AMD indicator levels. Seven of the streams are in the Clarion River basin, one is in the Allegheny basin. The figure also shows the 63 remaining sites in the area that have been ranked by the number of AMD indicators found during the sampling period. All streams that had acid-mine drainage (AMD) indicators did not exhibit the usual connections among the AMD constituents. If a stream had a low pH, it did not necessarily follow that total iron or total manganese were found in high concentrations.

Equation 8.0-1 was developed from the relation between dissolved solids and specific conductance based upon concurrent samples at the eight sites that exhibited all 5 AMD indicators.

The regression equation for the relation is:

$$ROE = .95(SC) - 125 \qquad (8.0\text{-}1)$$

where ROE = dissolved solids, in milligrams per liter and SC = specific conductance, in micromhos per centimeter at 25°C.

The multiple correlation coefficient (R^2) and standard error of estimate (SE) for equation 8.0-1 are 96 percent and 78 mg/L dissolved solids, respectively. The range for dissolved solids was 64-1,800 mg/L with a mean of 461 mg/L.

Hem (1970) states that a specific conductance coefficient greater than about 0.75 is an indication of high sulfate concentrations. This is supported by equation 8.0-2 which shows the relation between dissolved solids and dissolved sulfate based on concurrent samples at the eight sites indicating AMD.

$$ROE = 1.6(SO_4) + 20 \qquad (8.0\text{-}2)$$

where ROE = dissolved solids, in milligrams per liter, and SO_4 = dissolved-sulfate concentration, in milligrams per liter.

Equation 8.0-2 has an R^2 of 99 percent and an SE of 42 mg/L of dissolved solids. The range of SO_4 values was 30-1,100 mg/L with a mean of 303 mg/L. The relations shown in this section are based upon relatively scant data, and may not be representative.

Sulfate is found in most coal areas because of sulfur-bearing minerals, such as pyrite. Weather and mining expose the pyrite to water and oxygen causing it to oxidize into a weak sulfuric acid. When the sulfuric acid contacts rock strata, most metals, including iron, manganese, aluminum, sodium, calcium, magnesium, and probably some trace metals are dissolved.

Harvard University (1970) presents the following overall reactions for the mine-water system:

$$FeS_2(S) + 7/2\,O_2 + H_2O = Fe^{+2} + 2SO_4^{-2} + 2H^+ \qquad (8.0\text{-}3)$$

$$Fe^{+2} + \tfrac{1}{4}\,O_2 + H^+ = Fe^{+3} + \tfrac{1}{2}\,H_2O \qquad (8.0\text{-}4)$$

$$Fe^{+3} + 3H_2O = Fe(OH)_3\,(S) + 3H^+ \qquad (8.0\text{-}5)$$

$$FeS_2(S) + 14Fe^{+3} + 8H_2O = 15Fe^{+2} + 2SO_4^{-2} + 16H^+ \qquad (8.0\text{-}6)$$

In the initial step (8.0-3) pyrite is exposed to water and atmospheric oxygen, producing ferrous iron and sulfate and releasing hydrogen ions into the water. Reaction 8.0-4 illustrates the oxidation of ferrous iron to ferric iron which hydrolyzes to form the insoluble ferric hydroxide (8.0-5), a step which releases more hydrogen ions into the water. Reaction 8.0-6 shows that pyrite itself can reduce ferric iron to ferrous iron accompanied by an additional release of hydrogen ions. The ferrous iron formed in the step can reenter the reaction cycle as shown in reaction 8.0-4. In waters having low pH the oxidation of ferrous iron to ferric iron proceeds quite slowly; however, in acidic mine waters, certain bacteria are thought to speed the reaction through bacterial catalysis (Harvard University, 1970).

The most obvious effect of AMD on a stream may be aesthetic. When the AMD meets alkaline waters, and ferric hydroxide precipitates, a reddish-orange coating is left on the stream bed.

Other effects of AMD may not be as noticeable, but may be of greater consequence than the aesthetic considerations. These effects may alter the ability of a stream to support aquatic life, or may adversely affect the quality of the stream's water for industrial, agricultural, or domestic use.

ACID-MINE DRAINAGE INDICATOR LEVELS

- pH is less than 6.0
- Acidity is greater than alkalinity
- Total iron is greater than 0.5 miligrams per liter
- Total manganese is greater than 0.5 miligrams per liter
- Dissolved sulfate is greater than 75 miligrams per liter

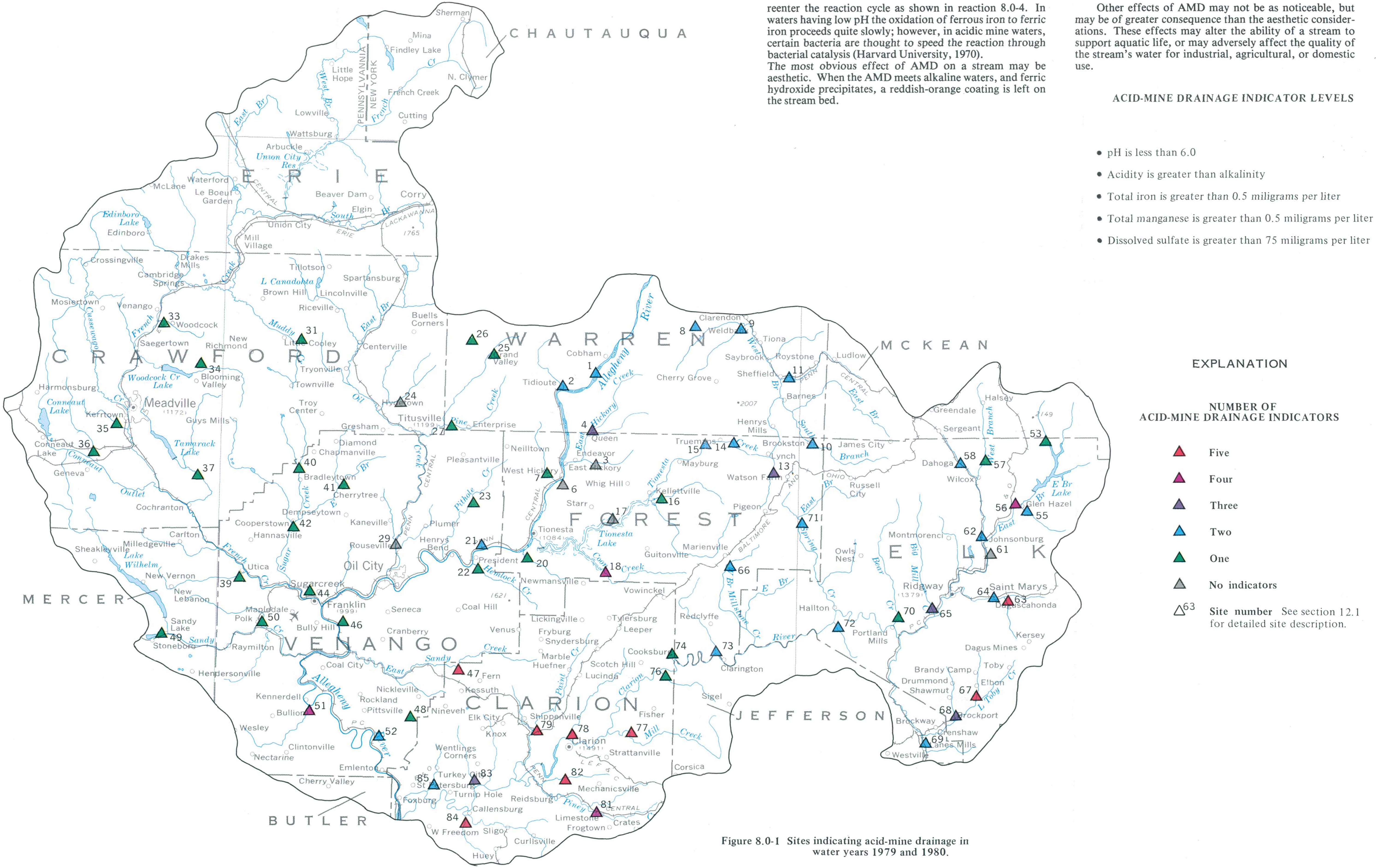


Figure 8.0-1 Sites indicating acid-mine drainage in water years 1979 and 1980.

Daily Discharge Data are Valuable for the Design of Hydraulic Structures and Determining Water-Supply Availability

Daily discharge is the average flow rate of water in a stream during each day. It is used in the computation of many hydrologic indices, which are needed to design hydraulic structures or to determine water-supply availability.

The basic reporting unit of streamflow is mean daily discharge in cubic feet per second. Mean daily discharge is determined by measuring stream stage (fig. 9.1-1) at intervals ranging from 5 minutes to 1 hour, and applying a stage-discharge relation.

Mean daily discharge, although a convenient unit of flow measurement, does not show the variation of flow throughout the day. Figure 9.1-2 is a discharge hydrograph for station 34, computed from the stage hydrograph shown in figure 9.1-1, and the appropriate stage-discharge relation. The mean discharge for November 30, 1977, was 139 ft^3/s (cubic feet per second), but the actual recorded instantaneous discharges ranged from a low of 56 ft^3/s to a high of 430 ft^3/s. The mean stage for November 30, 1977, was 6.51 feet, the recorded stage ranged from 6.15 to 7.44 feet.

Mean daily discharges during a period can be presented in tabular form, such as table 9.1-1 for station 34 for October 1978. The daily discharges can be presented graphically, as shown in figure 9.1-3 for station 34 for the 1979 water year.

Daily discharge data have greater utility than simply reporting average discharges for individual days. Daily discharge data are used in the computation of hydrologic indices such as mean flows, low flows, and flow-duration curves or tables. These indices are useful in the safe and economical design of a wide variety of hydraulic structures such as dams and bridges. These indices are also used in determining the availability of water under different flow conditions and at different times of the year.

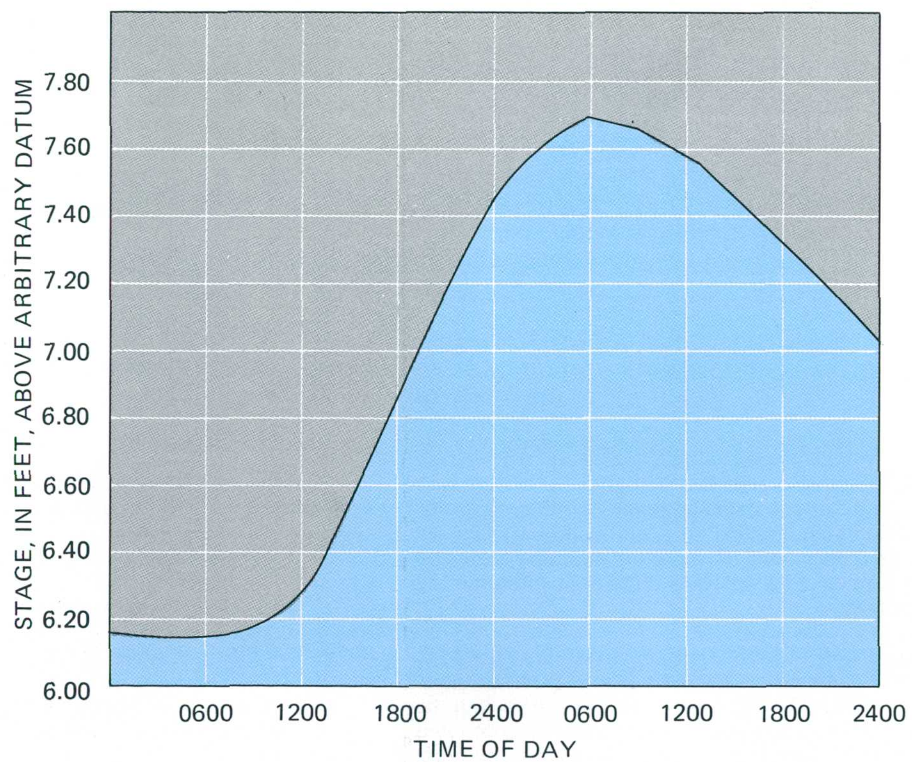


Figure 9.1-1 Stage hydrograph for station 34, November 30, 1977 and December 1, 1977.

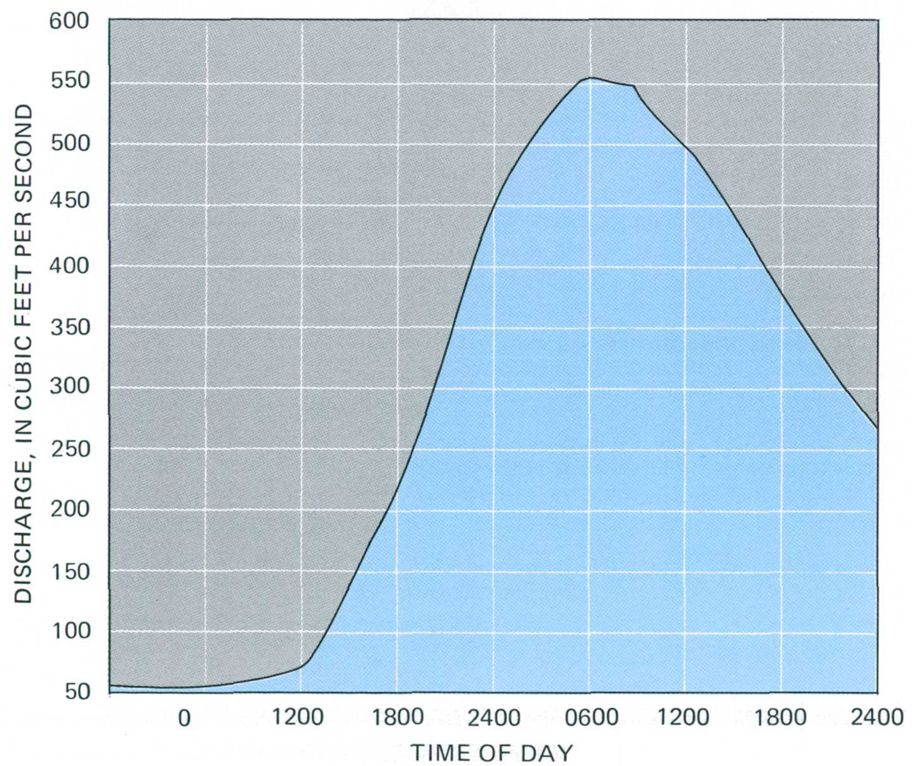


Figure 9.1-2 Discharge hydrograph for station 34, November 30, 1977 and December 1, 1977.

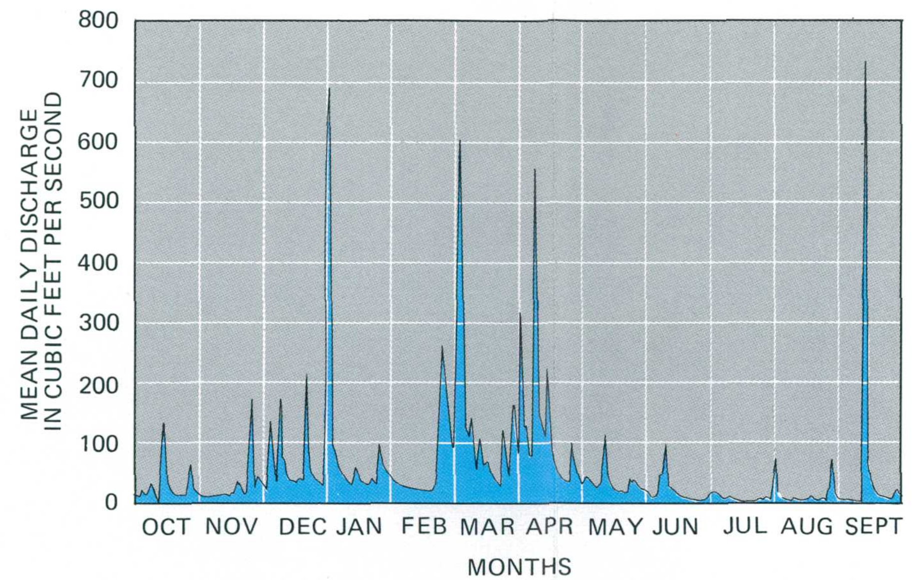


Figure 9.1-3 Daily discharge hydrograph for station 34, water year 1979.

Table 9.1-1 Mean daily discharge, in cubic feet per second, for station 34 during October 1978.
(Drainage area 31.1 square miles)

Day	Mean discharge (ft^3/sec)
1	13
2	11
3	8.5
4	27
5	17
6	14
7	19
8	36
9	26
10	16
11	12
12	14
13	76
14	132
15	80
16	36
17	24
18	20
19	18
20	16
21	15
22	14
23	14
24	16
25	15
26	40
27	67
28	31
29	22
30	18
31	16

Low-Flow Data Available for Gaged and Ungaged Streams

Low-flow statistics for gaged streams are computed from recorded daily discharge Regression equations can be used to estimate low-flow statistics for ungaged, unregulated streams.

Low-flow statistics can be computed for any stream that has daily-discharge data; however, the data is meaningful only for those streams not significantly affected by regulation and diversion. Regulation and diversion can unnaturally change flow patterns thereby invalidating the low-flow estimates.

Low-flow statistics are commonly computed for 1, 3, 7, 30, and 120 consecutive-day periods at recurrence intervals of 2, 5, 10, 20, 100 years. The statistics can be determined for an entire year, or they may be computed month-by-month. Naturally, monthly low flows, in most instances, will be computed for consecutive-day periods of 30 days or less.

Low-flow statistics can be presented as an x-day, y-year low flow, where x is the number of consecutive days and y is the recurrence interval. For example, a 7-day, 10-year low flow of 40 ft^3/s (cubic feet per second) means that the average discharge for the lowest 7 consecutive days would be less than 40 ft^3/s, on the average, once in ten years.

Flippo (1981) developed a series of equations for the estimation of low flows for ungaged, unregulated streams. Some of these equations are applicable to ungaged streams in Eastern Coal Province Area 2. Flippo divided Pennsylvania into a number of low-flow regions. Area 2 contains low-flow regions 9, 10, and 11 as delineated on figure 9.2-1. Low flows in each area must be estimated by a separate set of equations.

Flippo's equations can be used to estimate annual minimum discharge for 3, 7, 30, and 120 consecutive-day periods at recurrence intervals of 5, 10, 20, 50, and 100 years. Flippo also provides equations for estimating minimum discharges for 1, 3, 7, and 30 days at the same recurrence intervals for the six individual months of May through October. The monthly equations are too lengthy to include in this report.

The reader should consult Flippo (1981) for an explanation of the determination of the following parameters used in his equations:

An,mm = Annual low flow for (n) days with (mm) recurrence interval, in cubic feet per second,

DA = Drainage area, in square miles,

G = Geologic index, dimensionless, and,

S = Channel slope, in feet per mile.

The terminology in Flippo (1981) differs somewhat from that used in this report, but no major problems should be encountered.

As an example, the 3-day, 5-year annual low flow (A3,5) will be computed for a hypothetical stream in low-flow region 10 of Area 1. Assume we have determined the drainage area to be 20 mi^2 (square miles), the geologic index to be 1.5, and the channel slope to be 17 feet per mile; therefore, DA = 20, G = 1.5, and S = 17. Because our hypothetical stream is in region 10, the equation to be used is:

$\log(A3,5) = -2.831 + 1.410(\log DA) + 0.649(\log S)$

substitute determined values of DA and S

$\log(A3,5) = -2.831 + 1.410(\log 20) + 0.649(\log 17)$

take log (base 10) of DA and S and substitute

$\log(A3,5) = -2.831 + 1.410(1.301) + 0.649(1.230)$

multiply

$\log(A3,5) = -2.831 + [1.834] + 0.798$

combine

$\log(A3,5) = -0.199$

take antilog (base 10) of both sides

$A3,5 = 0.63$

We can interpret this answer to mean that during any given year, there is one chance in twenty that the lowest 3-consecutive-day discharge will average less than 0.63 ft^3/s.

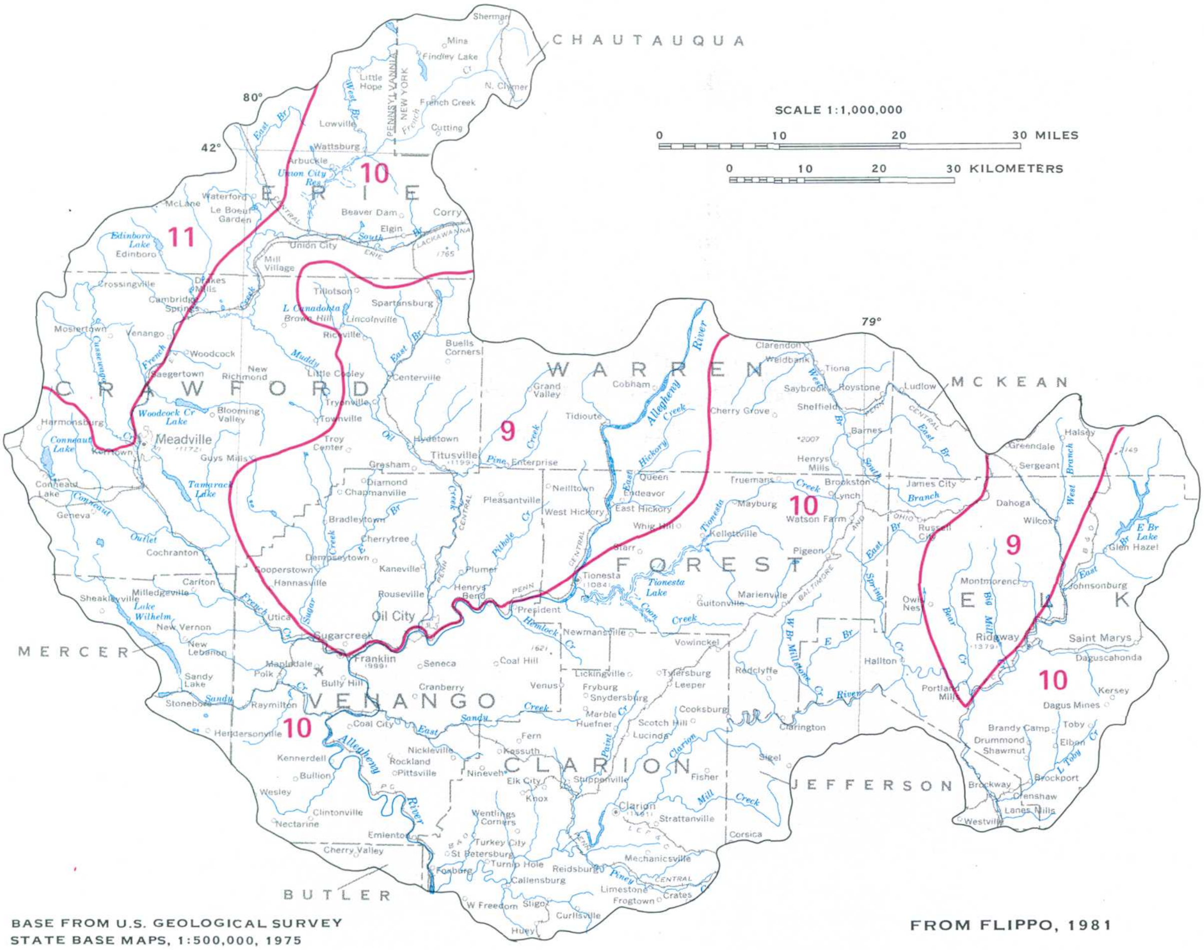


Figure 9.2-1 Low-flow regions.

Mean-Flow Data Available for Gaged and Ungaged Streams

Mean and mean monthly flows for gaged streams can be computed from recorded daily discharges. Regression equations can be used to estimate mean and mean monthly flows for ungaged streams.

Mean flow is the arithmetic average of all recorded daily discharge during the period of record. Mean monthly flow is the arithmetic average of all recorded daily discharges during a particular month for the period recorded. For example, the mean October discharge for a station having 40 years of record would be the arithmetic average of the daily discharges recorded during the 40 Octobers in the record period. Means computed from longer periods of record are more likely to be representative of long-term conditions than are means determined from short record periods.

Herb (1981) developed a series of regression equations for the estimation of mean and mean monthly flows for ungaged, unregulated streams in Pennsylvania. Some of these equations are applicable to streams in Eastern Coal Province Area 2 that are not affected by significant regulation or diversions. The applicability of the equations to streams having drainage areas less than 2 mi^2 (square mile) or to extensively surface-mined basins is unknown.

Table 9.3-1 presents the mean-flow equations and a description of the part of Area 2 to which each equation is applicable. The only data required for the estimates are the independent variables: drainage area, mean basin elevation, and average annual precipitation excess (average annual precipitation minus potential annual evapotranspiration).

Drainage area (DA) is determined by delineating the boundary of a drainage basin above a point-of-interest on a 7½-minute topographic map and planimetering. Mean basin elevation (E) is computed by averaging the elevation of 20 grid points overlaying the above delineated drainage area.

Annual precipitation excess (APX) is computed by subtracting annual potential evapotranspiration from average annual precipitation (Flippo, 1977). Average annual precipitation and annual potential evapotranspiration are interpolated at the centroid of the drainage basin of interest using the appropriate evapotranspiration map from Flippo's report. Flippo (1977) found, based on methods of Thornthwaite and Mather (1955), potential annual evapotranspiration could be used as an unadjusted estimator of actual annual evapotranspiration for Pennsylvania. The parameters used in the equations in table 9.3-1 are:

Qn = Mean discharge for specified period (where n = A, overall mean is computed; where n = 1, January mean is computed; where n = 2, February mean is computed; and so forth), in cubic feet per second,

DA = Drainage area, in square miles

E = Mean basin elevation, in thousands of feet above sea level, and

APX = Annual precipitation excess, in inches.

As an example, the mean May discharge will be computed for ungaged Station 33 (03022100) in the French Creek basin. Substituting values for the above parameters we have DA = 10.2 mi^2, E = 1.36 thousands of feet above sea level, and APX = 18 inches. Because station 33 is in the French Creek basin, the equation (from table 9.3-1) to be used is:

$Q_5 = 0.561\ DA^{1.00}\ E^{0.48}\ APX^{0.31}$
substitute determined values of DA, E, and APX

$Q_5 = 0.561\ (10.2)^{1.00}\ (1.36)^{0.48}\ (18)^{0.31}$
raise to indicated powers

$Q_5 = 0.561\ (10.2)\ (1.16)\ (2.45)$
multiply

$Q_5 = 16.3$ cubic feet per second
We can interpret this to indicate that the mean May flow for station 33 is 16.3 ft^3/s (cubic feet per second).

Each equation in table 9.3-1 is accompanied by its standard error of estimate and its coefficient of determination. The standard error of the estimate is a rough measure of the reliability of the equation. Two-thirds of the regression estimates of the low-flow characteristics for the streams used to develop the equation fell within the percentage errors shown. The coefficient of determination is a measure of the effectiveness of the selected basin characteristics in explaining observed variations in the low-flow characteristics. The more effective, or the more perfect, the equation is in relating selected basin characteristics to observed variations in low-flow, the closer the coefficient of determination comes to 100 percent. All of the equations in table 9.3-1 had a coefficient of 98 percent or greater.

Table 9.3-1 Equations for estimating mean discharges for ungaged, unregulated streams in Area 2.

To estimate specified discharge	Use equation	For designated part of area	Standard error (percent)	Coefficient of determination (percent)
Mean	$Q_A = 0.216\ DA^{1.00}\ APX^{0.68}$	All	8	99.8
Mean October	$Q_{10} = 0.002\ DA^{0.98}\ E^{-0.49}\ APX^{2.11}$	All of area except for that part of Clarion River basin upstream from Spring Creek. Spring Creek basin is included.	16	99.4
	$Q_{10} = 0.052\ DA^{0.99}\ APX^{0.93}$	Clarion River basin upstream from spring Creek, not including Spring Creek	17	98.7
Mean November	$Q_{11} = 0.161\ DA^{0.96}\ E^{-0.33}\ APX^{0.89}$	All	16	98.9
Mean December	$Q_{12} = 0.116\ DA^{0.98}\ APX^{1.01}$	All	20	98.7
Mean January	$Q_1 = 0.150\ DA^{1.03}\ APX^{0.89}$	All	13	99.5
Mean February	$Q_2 = 0.320\ DA^{1.00}\ APX^{0.72}$	French Creek basin, and all Allegheny River tributaries downstream from French Creek, excluding the Clarion River basin	11	99.6
	$Q_2 = 0.199\ DA^{1.01}\ APX^{0.79}$	All of area except for French Creek basin and Allegheny River tributaries downstream from French Creek. Clarion River basin is included.	10	99.7
Mean March	$Q_3 = 0.610\ DA^{1.01}\ APX^{0.59}$	All	13	99.6
Mean April	$Q_4 = 0.340\ DA^{1.00}\ E^{0.21}\ APX^{0.67}$	All	10	99.4
Mean May	$Q_5 = 0.561\ DA^{1.00}\ E^{0.48}\ APX^{0.31}$	Part of area upstream from French Creek including the French Creek basin.	16	99.0
	$Q_5 = 1.102\ DA^{1.06}\ E^{0.65}$	Part of area downstream from French Creek, not including the French Creek basin.	12	99.7
Mean June	$Q_6 = 0.586\ DA^{1.04}\ E^{1.05}$	Tionesta Creek basin and part of area downstream from the Clarion River including the Clarion River basin.	12	99.7
	$Q_6 = 0.481\ DA^{1.03}\ E^{1.30}$	Part of area upstream from Clarion River, but not including the Tionesta Creek basin	25	97.5
Mean July	$Q_7 = 0.041\ DA^{1.00}\ APX^{0.97}$	Part of area upstream from French Creek including the French Creek basin.	20	98.7
	$Q_7 = 0.024\ DA^{1.00}\ APX^{1.03}$	Part of area downstream from French Creek, not including the French Creek basin	33	95.8
Mean August	$Q_8 = 0.001\ DA^{0.98}\ APX^{1.95}$	All	19	99.0
Mean September	$Q_9 = 0.002\ DA^{0.96}\ APX^{1.87}$	Part of area downstream from Tionesta Creek including Tionesta Creek basin	35	96.2
	$Q_9 = 0.002\ DA^{0.88}\ E^{1.42}$	Part of area upstream from Tionesta Creek, not including the Tionesta Creek basin	23	97.5

Peak Flow Data Available for Gaged and Ungaged Streams

Peak discharges at specified exceedance probabilities can be computed from flood records at gaging stations. Regression equations can be used to estimate peak discharges for ungaged streams.

Recorded peak discharges at gaging stations can be used to compute peak flows at various exceedance probabilities. Exceedance probabilities commonly used are 50, 10, 4, 2, and 1 percent, although other exceedance-probability floods may be computed. Exceedance probability is defined as the probability or chance that a given flood peak will be greater than a computed value. Exceedance probability percentages are the reciprocals of recurrence intervals. An exceedance probability of 4 percent, 0.04, is analogous to a recurrence interval of 1/.04 or 25 years. A flood with a recurrence interval of 25 years would be expected to be exceeded, on the average, once in 25 years. Because these are estimates of averages, it is entirely possible to have floods with recurrence intervals of 100 and 25 years (exceedance probabilities of 1 and 4 percent), occurring in successive years, or even in the same year.

Flippo (1977) and Herb (1977) developed systems of regression equations for estimating floods at selected exceedance probabilities for Pennsylvania streams. Some of their equations are applicable to ungaged, unregulated streams in Eastern Coal Province Area 2. The equations developed by Flippo (1977) use basin and climatic characteristics as the independent variables, while those equations developed by Herb (1977) use channel characteristics.

Table 9.4.1-1 (from Flippo, 1977) presents equations for flood-peak estimation at exceedance probabilities of 43, 10, 4, 2, and 1 percent. These equations are applicable only in the flood-frequency region of Area 2 shown in the table heading. Figure 9.4.1-1 delineates the three flood-frequency regions in Area 2. Note that region 6 has separate equations for basins having drainage areas in two size classes. Table 9.4.1-2 (from Herb) presents equations for flood-peak estimation at exceedance probabilities of 99, 50, 20, 10, 4, and 2 percent.

The parameters used in the equations in tables 9.4.1-1 and 9.4.1-2 are:

P_n = Flood peak having exceedance probability of n percent (n = 99, 50, 43, 10, 4, 2, or 1), in cubic feet per second,

DA = Drainage area, in square miles

APX = Annual precipitation index, in inches

CAREA = Cross-sectional area of bankfull channel, in square feet,

CWIDE = Width of bankfull channel, in feet, and,

CDEEP = Average depth of bankfull channel, determined by dividing CAREA by CWIDE, in feet.

Each equation in tables 9.4.1-1 and 9.4.1-2 is accompanied by its standard error of estimate. The standard error of the estimate is a rough measure of the reliability of a particular equation. Two-thirds of the regression estimates of the peak flows used to develop the equations fell within the listed percentage errors.

Flippo (1977) indicates that the equations in table 9.4.1-1 are applicable to unregulated, non-urban streams having drainage areas larger than 2 square miles. He also cautions about the use of the equations in basins that have been extensively strip mined. Such basins may produce anomalously low flood peaks. Herb (1977) indicates that the equations in table 9.4.1-2 are applicable to unregulated, forested watersheds having drainage areas between 2 and 300 mi^2. The applicability of Herb's (1977) equations in extensively strip-mined basins is unknown. For more discussion of limitations and applications of the aforementioned equations please refer to Flippo (1977).

Once the independent variables (basin characteristics or channel characteristics) are determined for a particular basin, the computation of the estimated flood peaks is relatively simple. As an example, the peak discharge at an exceedance probability of 1 percent (100-year recurrence interval) will be determined by the basin characteristics method (Flippo, 1977) for a hypothetical stream in flood-frequency region 5 having a drainage area of 20 mi^2 and an annual precipitation index of 17 inches; DA = 20, APX = 17.

To estimate a flood peak having an exceedance probability of 1 percent in flood-frequency region 5, use the following equation (table 9.4.1-1):

$$P_1 = 39.4\, DA^{0.751}\, APX^{0.744}$$

Substitute values of DA and APX

$$P_1 = 39.4\, (20)^{0.751}\, (17)^{0.744}$$

raise to powers

$$P_1 = 39.4\, (9.486)\, (8.231)$$

multiply through

$$P_1 = 3{,}080$$

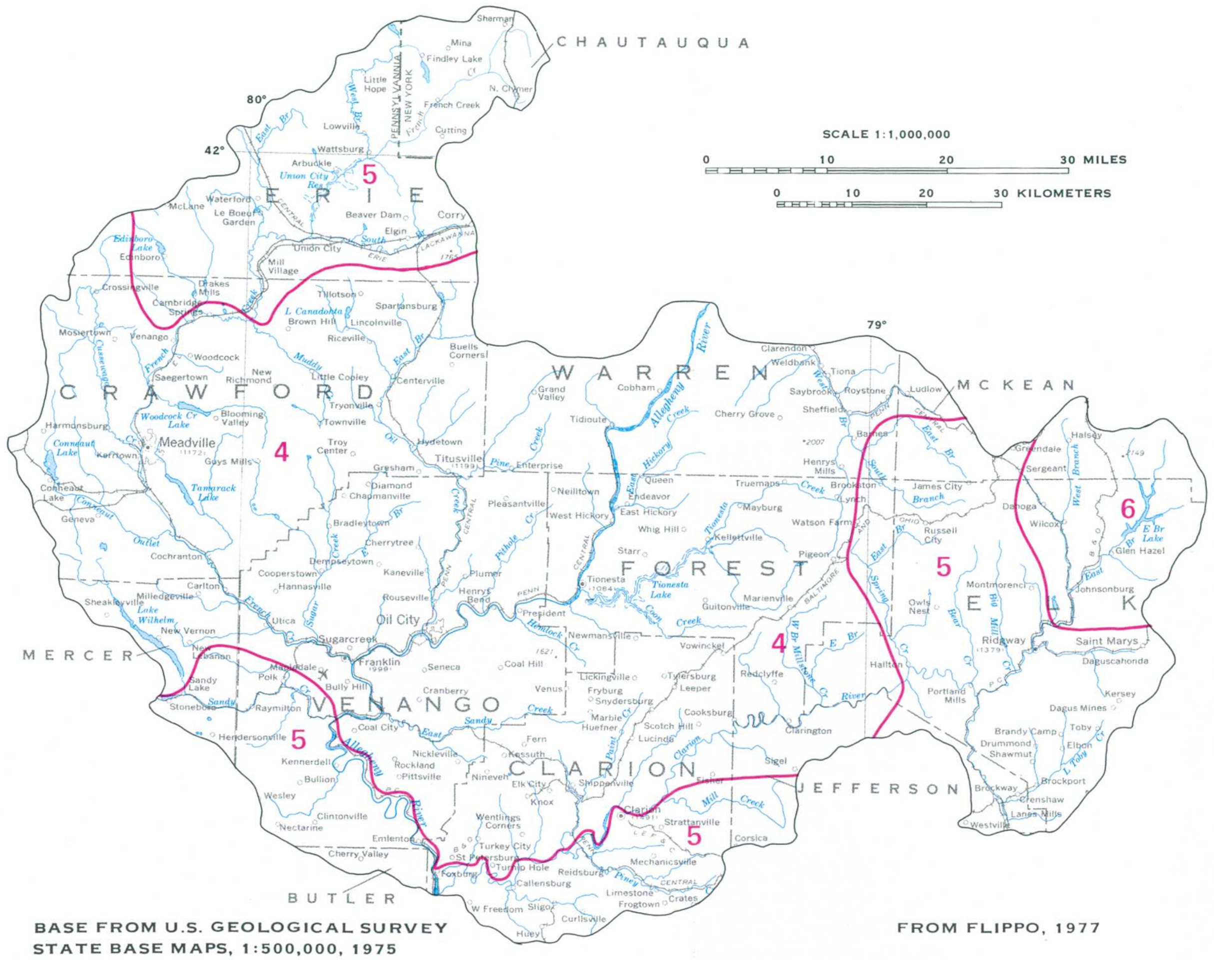


Figure 9.4.1-1 Peak flow regions.

We can interpret this to mean that our hypothetical stream has a 1-percent chance of experiencing a flood peak of greater than 3,080 ft^3/s during any year.

Table 9.4.1-1 Regression equations for flood-peak estimation at selected exceedance probabilities for Area 2 streams in flood-frequency regions* (Flippo, 1977).

Region 4

Exceedance probability (percent)	Equation (P_n=)	Standard error (percent)
43	73.5 $DA^{0.789}$	28
10	118 $DA^{0.778}$	27
4	143 $DA^{0.773}$	28
2	162 $DA^{0.770}$	30
1	181 $DA^{0.766}$	32

Region 5

Exceedance probability (percent)	Equation (P_n=)	Standard error (percent)
43	39.4 $DA^{0.827}$ $APX^{0.222}$	28
10	45.4 $DA^{0.789}$ $APX^{0.445}$	25
4	45.3 $DA^{0.772}$ $APX^{0.566}$	26
2	44.5 $DA^{0.759}$ $APX^{0.656}$	29
1	42.2 $DA^{0.751}$ $APX^{0.744}$	31

*Flood-frequency regions delineated on Figure 9.4.1-1.

Region 6

Drainage areas of more than 15 square miles.

Exceedance probability (percent)	Equation (P_n=)	Standard error (percent)
43	57.7 $DA^{0.879}$	23
10	156 $DA^{0.817}$	22
4	244 $DA^{0.788}$	25
2	330 $DA^{0.769}$	27
1	434 $DA^{0.751}$	30

Drainage areas of 15 square miles or less.

Exceedance probability (percent)	Equation (P_n=)	Standard error (percent)
43	63.2 $DA^{0.943}$	45
10	126 $DA^{1.001}$	46
4	173 $DA^{1.023}$	49
2	213 $DA^{1.037}$	51
1	259 $DA^{1.050}$	54

*Flood-frequency regions delineated on Figure 9.4.1-1.

Table 9.4.1-2 Regression equations for flood-peak estimation at selected exceedance probabilities for Area 2 streams (Herb, 1977).

Exceedance probability (percent)	Equation (P_n=)	Standard error (percent)
99	0.362 $(CAREA)^{1.811}$ $(CDEEP)^{-0.317}$	61
50	2.366 $(CAREA)^{1.609}$ $(CDEEP)^{-0.263}$	56
20	4.842 $(CWIDE)^{1.495}$	53
10	7.079 $(CWIDE)^{1.473}$	50
4	10.641 $(CWIDE)^{1.451}$	50
2	14.028 $(CWIDE)^{1.437}$	50

Flood-Prone Area Maps Available for Area

Flood-prone area maps are available for 69 7½-minute topographic maps in Area 2.

The National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973 established programs for identifying towns and streams subject to flood problems and for outlining flood-prone areas on topographic maps by approximate methods. In 1968 the Geological Survey began delineating flood-prone areas of the maximum known flood on 7½-minute topographic quadrangle maps using existing information. After 2 years it was decided that areal uniformity of the flood delineated would be desirable, so the 100-year flood (1-percent exceedance probability flood) was selected for mapping in 1970.

As of 1980, the area inundated by the 1-percent exceedance probability flood had been delineated for selected streams on 69 of the 103 7½-minute topographic quadrangle maps covering Area 2. The delineations were based upon existing flood-depth data and flood depths estimated from the area's flood hydrology. Flood-prone maps within or partially within Area 2 are indicated by shading on figure 9.4.2-1, which also shows the names and locations of all 7½-minute topographic quadrangle maps in the area.

Copies of the flood-prone area maps for Area 2 may be obtained from:

U.S. Geological Survey
Water Resources Division
P.O. Box 1107
Harrisburg, Pennsylvania 17108

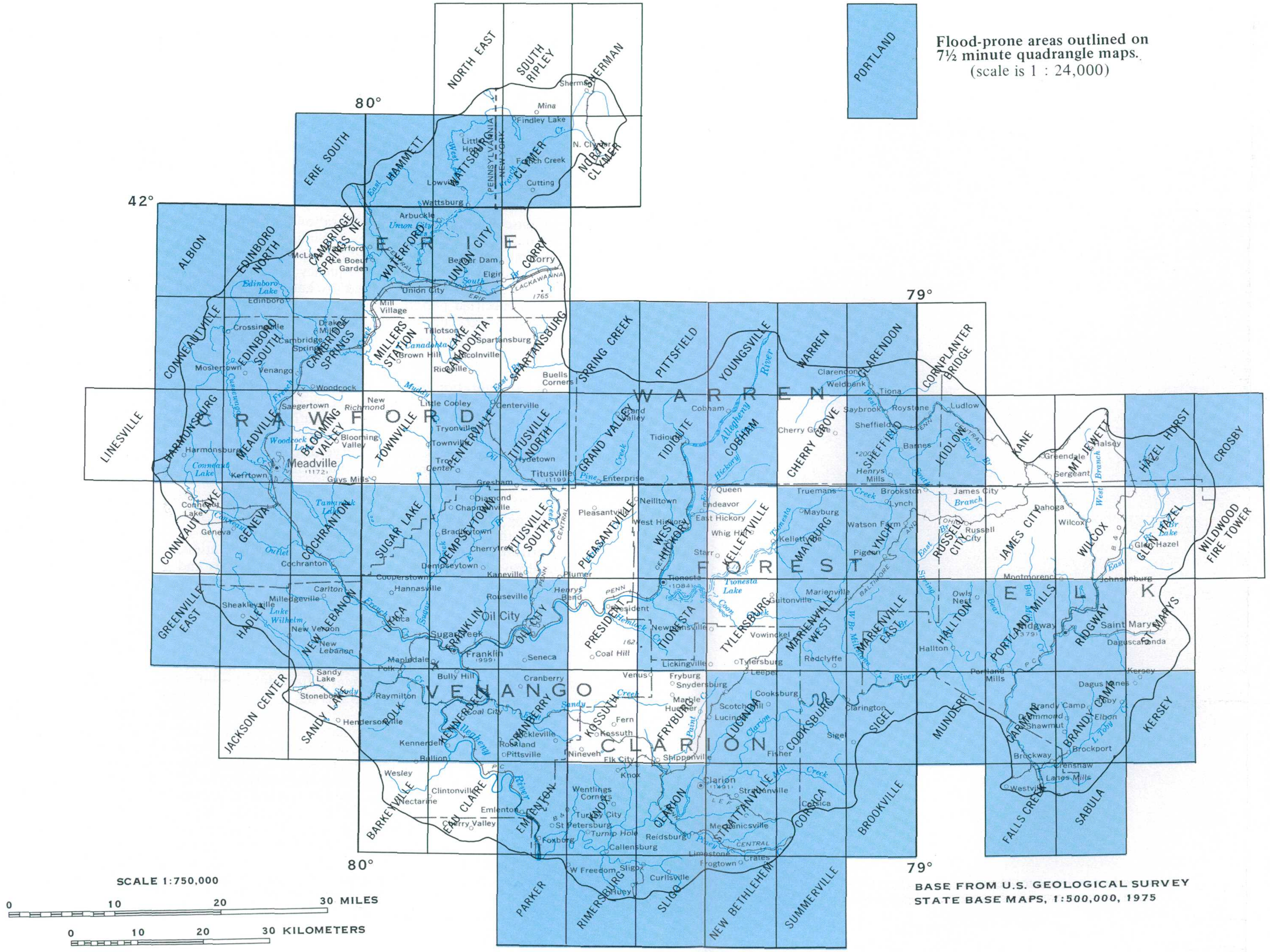


Figure 9.4.2-1 Availability of flood-prone maps for Area 2.

Flow-Duration Data Available for Gaged and Ungaged Streams

Recorded daily discharges are used to compute flow-duration data for gaging stations. A simple graph and knowledge of a stream's drainage area can be used to estimate flow-duration data for ungaged streams.

Figure 9.5-1 presents a flow-duration curve for station 12, an unregulated stream in Area 2. Similar curves or data tabulations can be made for any gaging station. A flow-duration curve is a cumulative frequency curve that shows the percentage of time a specified discharge was exceeded during a specified period (Searcy, 1959). The flow-duration curve depicts the flow characteristics of a stream over a wide range of discharges without any consideration of the sequence of flows.

A flow-duration curve is useful for more than simply depicting flow characteristics. If the period of record used in developing the curve is representative of long-term conditions, a flow-duration curve can be used in conjunction with the proper transport curve to compute loads of water-borne constituents such as suspended sediment or sulfate.

Using figure 9.5-1 to find the flow-duration of a specified discharge, extend a horizontal line from one of the vertical axes until it intersects the curve for the station. Then drop a vertical line to the lower horizontal axis and read the flow-duration percentage. To find the discharge associated with a specific flow-duration, extend a vertical line from the lower horizontal axis to its intersection with the curve for the stream. A horizontal line extended from that point will intersect one of the vertical axes at the desired discharge. The dashed line in figure 9.5-1 indicates that for station 12, the discharge at a flow duration of 50 percent is about 240 cubic feet per second.

Flow duration can be estimated for ungaged, unregulated streams in Eastern Coal Province Area 2 by a simple, graphical procedure. Figure 9.5-2 is a composite unit flow-duration curve where unit discharge is plotted against exceedance probability. Such a method of presentation allows the comparison of flow durations among streams having different drainage areas. The shaded part of the figure demonstrates the range of unit flow-duration data at the seven selected stations. The mean of the unit discharges is given by the heavy line within the shaded area.

Figure 9.5-2 can be used in the following manner.

1. Find the unit discharge that corresponds to an exceedance probability of 10 percent.

A. Extend a vertical line upward from the 10-percent point on the lower x-axis to its intersection with the mean unit discharge curve within the shaded part of figure 9.5-2.

B. Read the corresponding unit discharge, 4.2 $(ft^3/s)/mi^2$, on the y-axis.

2. This can be interpreted to mean that a unit discharge of 4.2 $(ft^3/s)/mi^2$ is exceeded 10 percent of the time.

Figure 9.5-2, in combination with a knowledge of an ungaged stream's drainage area can be used to estimate points on a flow-duration curve. As an example, we will compute the points on a flow-duration curve for a stream having a drainage area of 10 mi^2 (square miles). The mean unit flow-duration curve in figure 9.5-2 gives unit discharges of 10, 2.5, 0.89, 0.28, and 0.093 $(ft^3/s)/mi^2$ at exceedance probabilities of 2, 20, 50, 80, and 98 percent, respectively. Multiplying these unit discharges by the drainage area of 10 mi^2 gives discharges of 100, 25, 8.9, 2.8, and 0.93 cubic feet per second at the specified points on the flow-duration curve. More points could be determined to better define the shape of the curve.

The composite flow-duration curve was constructed using computed unit flow-duration data from seven streams in or near Area 2 having drainage areas ranging from 3.6 to 63 mi^2. Because of the relatively small sample size used in developing the curve its reliability is unknown. The width of the shaded part of the figure gives some indication of the uncertainity in estimates using the procedure. Searcy (1959) presents an alternate method of developing unit flow-duration curves, however, Searcy's method requires a knowledge of the stream's mean flow before an estimate can be made. The procedure outlined herein can be used for flow-duration estimates until a better system is developed.

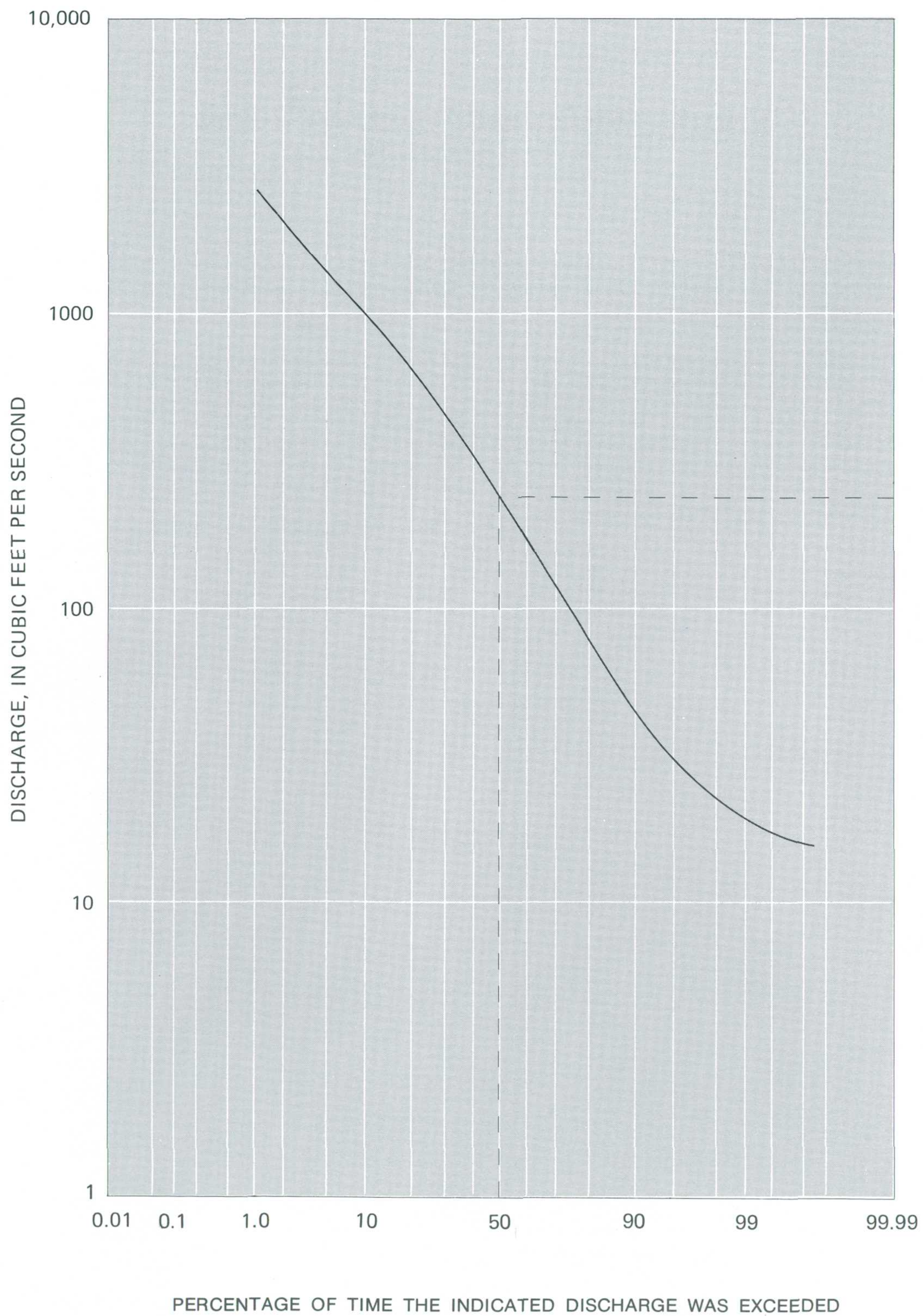


Figure 9.5-1 Flow duration curve showing the percentage of time that indicated discharge was exceeded for station 12.

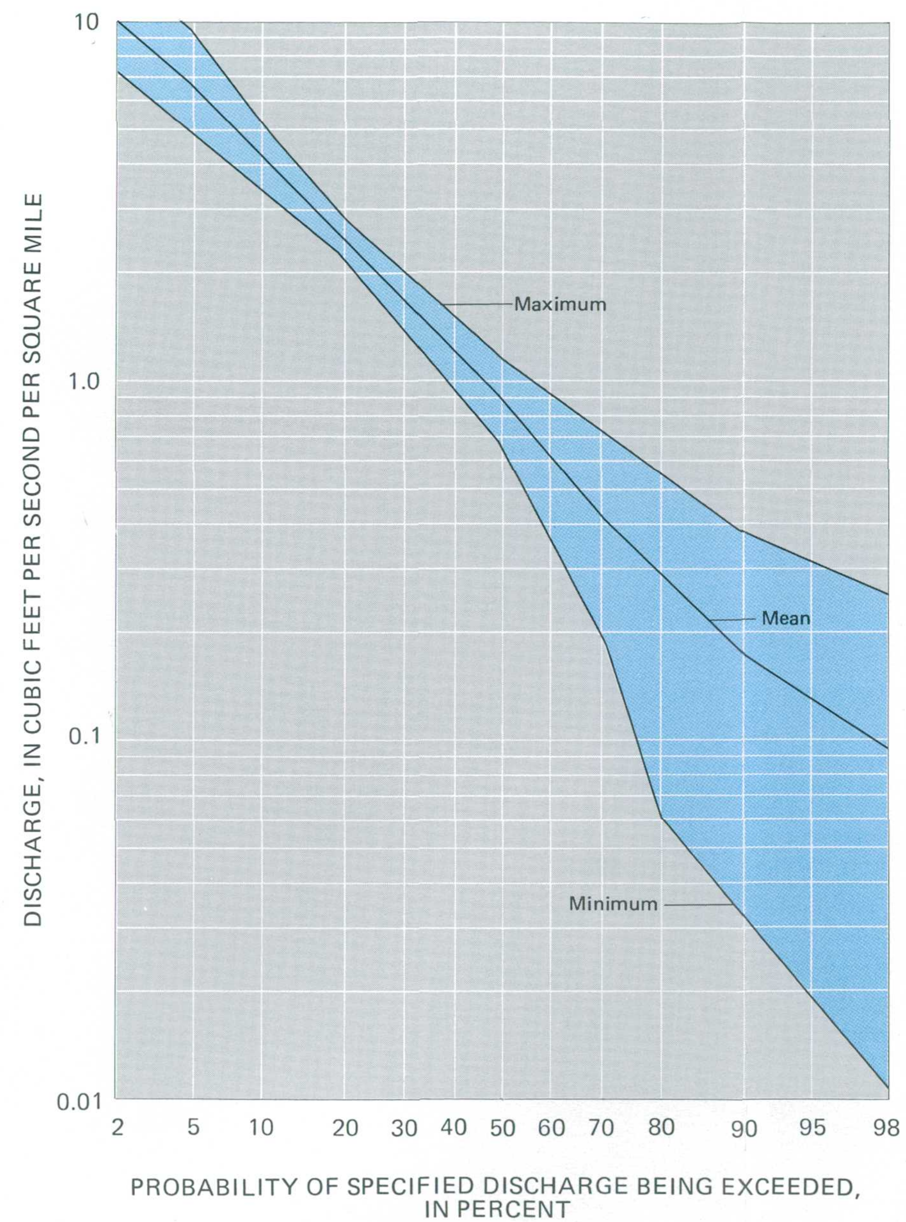


Figure 9.5-2 Composite flow-duration curves showing probability of specified discharge being exceeded for streams in Area 2.

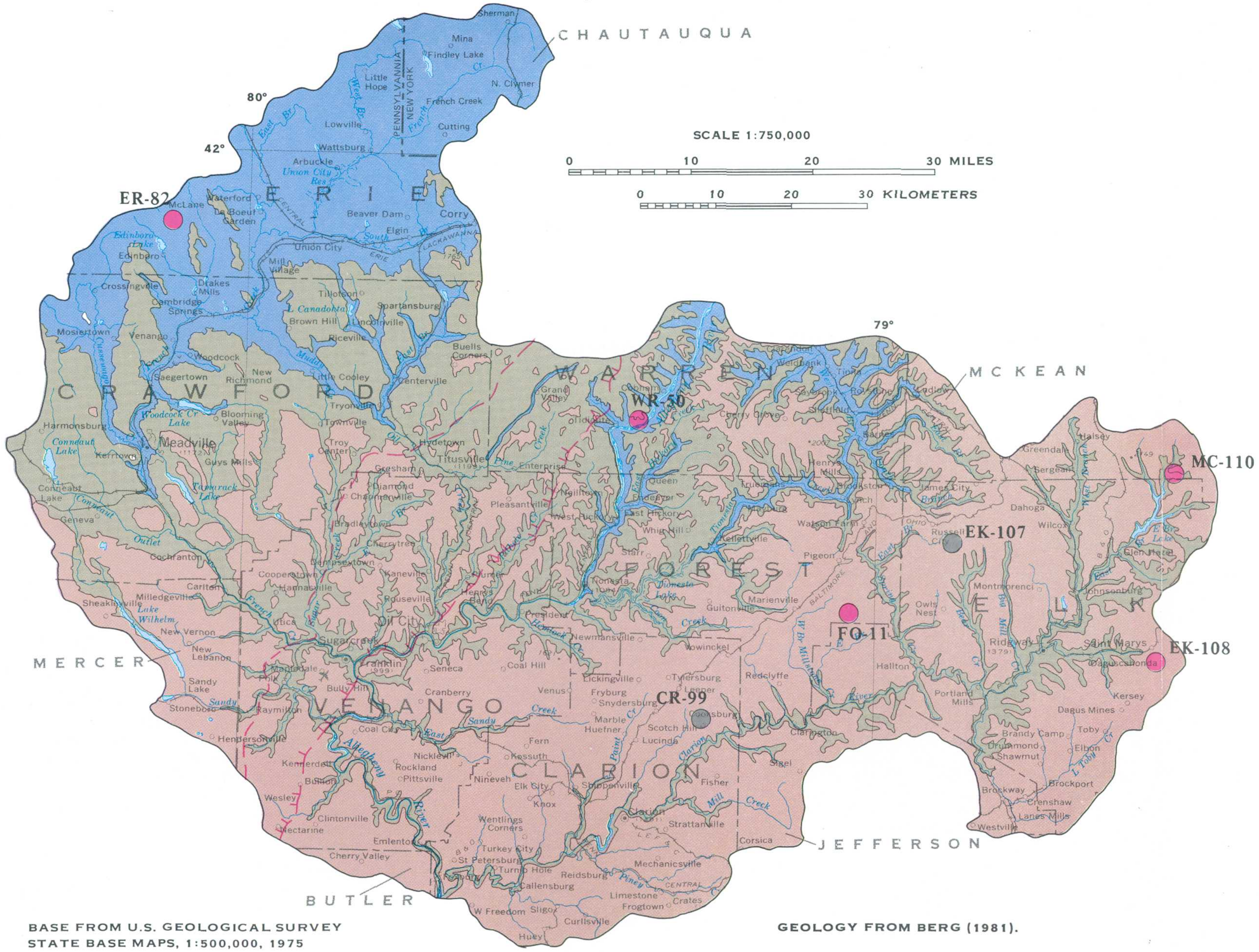
Information on Ground Water is Available for Several Locations

The U.S. Geological Survey ground-water network has continuous water-level data in 5 counties and hundreds of water samples from wells in Area 2.

The U.S. Geological Survey ground-water network provides a long term water-level data base to monitor the responses of climatic changes and induced stresses on the hydrologic system. The network originally had seven observation wells in Area 2; however, two wells have been discontinued. Station locations and identification numbers of the observation wells are shown on figure 10.1-1; the periods of record are given in table 10.1-1.

The U.S. Geological Survey and the Pennsylvania Bureau of Topographic and Geologic Survey have evaluated the ground-water resources of some parts of Area 2 in detail. Therefore, a large volume of water-level and water-quality data have been published. Water-quality samples have been collected periodically from some wells and once only from other wells. Koester and Miller (1980) have a complete listing of Area 2 wells and their respective water-quality analyses. Buckwalter and others (1979) include a listing of wells in the Clarion River basin with water-levels, well yields, specific capacities, aquifer names, and other pertinent well data.

More information about the type of data, in addition to actual data is available from computer storage through the National Water Data Exchange (NAWDEX) and in annually published U.S. Geological Survey reports "Water Resources Data for Pennsylvania, Volume 3."



EXPLANATION

BEDROCK

Pennsylvanian
Numerous beds of sandstone, siltstone, shale and some beds of limestone and conglomerate.

Mississippian
Sandstone, silstone, shale and conglomerate.

Devonian
Mostly shale with some thin fine-grained sandstone.

Active observation well

Inactive observation well

UNCONSOLIDATED

Southeastern limit of Wisconsin Glaciation

Southeastern limit of Illinoian Glaciation

Bedrock northwest of lines of glaciation is generally covered with unconsolidated material such as clay, silt, sand and gravel.

EK-108 Well number

Figure 10.1-1 Ground-water network.

Table 10.1-1 Record periods for observation wells*.

Well identification number	Period of record
Active wells:	
EK-108	October 1975 to present
ER-82	July 1966 to present
FO-11	August 1973 to present
MC-110	August 1973 to present
WR-50	August 1972 to present
Inactive wells:	
CR-99	December 1973 to September 1977
EK-107	August 1973 to December 1976

*Well location shown on Figure 10.1-1.

Precipitation Recharges Most Area 2 Aquifers Directly

Bedrock and unconsolidated aquifers receive recharge mostly near outcrops. Water movement is generally toward valleys but some water leaks to deeper aquifers.

The source of ground water is precipitation. Part of the precipitation returns to the atmosphere via evaporation and transpiration, part flows into streams and lakes as runoff, and part seeps downward through soils, glacial material, and rock to the zone of saturation (fig. 10.2-1).

Direct infiltration of rain or snowmelt is the major means of recharge to aquifers exposed in the area. Indirect recharge occurs in some aquifers by leakage from adjacent aquifers or streams. Glacial drift overlying bedrock usually enhances recharge to the bedrock aquifers. However, outwash and alluvial deposits in major drainages may receive recharge from bedrock aquifers as well as from precipitation. Deep bedrock aquifers generally receive recharge from overlying bedrock aquifers. Some bedrock aquifers contain saline connate water that, owing to the depth of occurrence, has not been flushed by fresher shallow water circulation.

Ground water is in motion from areas of recharge to discharge. Generally this movement is from hilltops and hillsides down and outward toward valleys. Between recharge and discharge areas, ground water always moves in the direction of decreasing head (water elevation) but not necessarily down dip with rock structure. The rate of movement in most aquifers is slow and depends on the size and degree of inter-connection of the water-bearing openings and the hydraulic gradient. Materials that transmit water readily are said to have high permeability or to be permeable. Among the more permeable rocks are well-sorted sand and gravel and fractured sandstone and coal. The largest volume of ground-water flow, either lateral or vertical between adjacent aquifers, occurs through the most permeable rock (fig. 10.2-1). rocks that do not transmit water readily are said to have low permeability or to be relatively impermeable. Among the low-permeable rocks are clay, shale, unfractured sandstone, and unfractured limestone. Water tables are commonly perched above low-permeable rocks in recharge areas, and hillside springs or seeps may occur (fig. 10.2-1A). Rocks immediately below a perched water table may be unsaturated; however, all rocks below the actual water table are saturated. Sometimes it is difficult to determine saturation conditions in the field as low-permeable rocks that are saturated may yield very little water to wells.

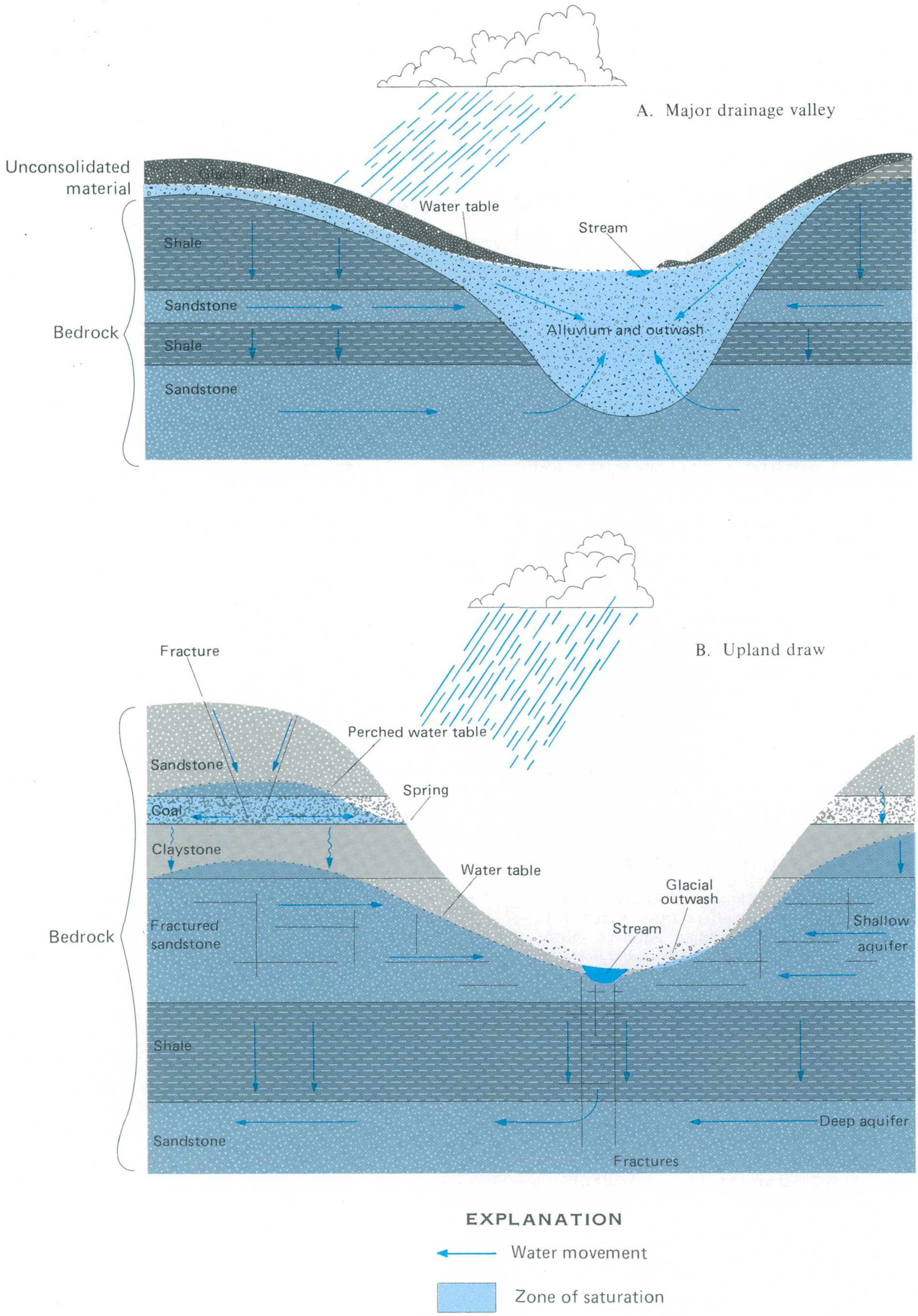


Figure 10.2-1 Occurrance and movement of water in aquifers.

Water Levels in Area 2 Fluctuate Seasonally

Factors such as precipitation, rock type, and fractures affect water level fluctuation in Area 2. In addition, topographic setting and casing length affect the depth to water among wells.

Water levels in Area 2 fluctuate seasonally, with the highest water levels occurring in early spring prior to the growing season in response to recharge from snowmelt and precipitation. The lowest levels occur in late summer and early fall generally as a result of continual down-gradient flow to springs and losses to evaporation and consumptive use by vegetation (evapotranspiration). Seasonal water-level fluctuations are fairly representative of fluctuations in other wells tapping similar formations in Area 2 (figs. 10.3-1 and 10.3-2).

Monthly water levels are shown for Pennsylvanian and Devonian aquifers (fig. 10.3-2). Values are averaged over periods of 7 to 14 years. Such data are not available for glacial drift and Mississippian aquifers in Area 2. Also included in figure 10.3-2 are concurrent mean monthly precipitation values from precipitation stations near the observation wells. Water levels have a greater annual fluctuation in the two wells that tap the Devonian aquifers than in the two wells that tap the Pennsylvanian aquifers. This is probably due to the lower storage capacities and permeabilities of the Devonian aquifers. The sandstone and shale aquifers, which are finer-grained and less fractured in the Devonian, have slightly larger fluctuations and respond more slowly to recharge from precipitation.

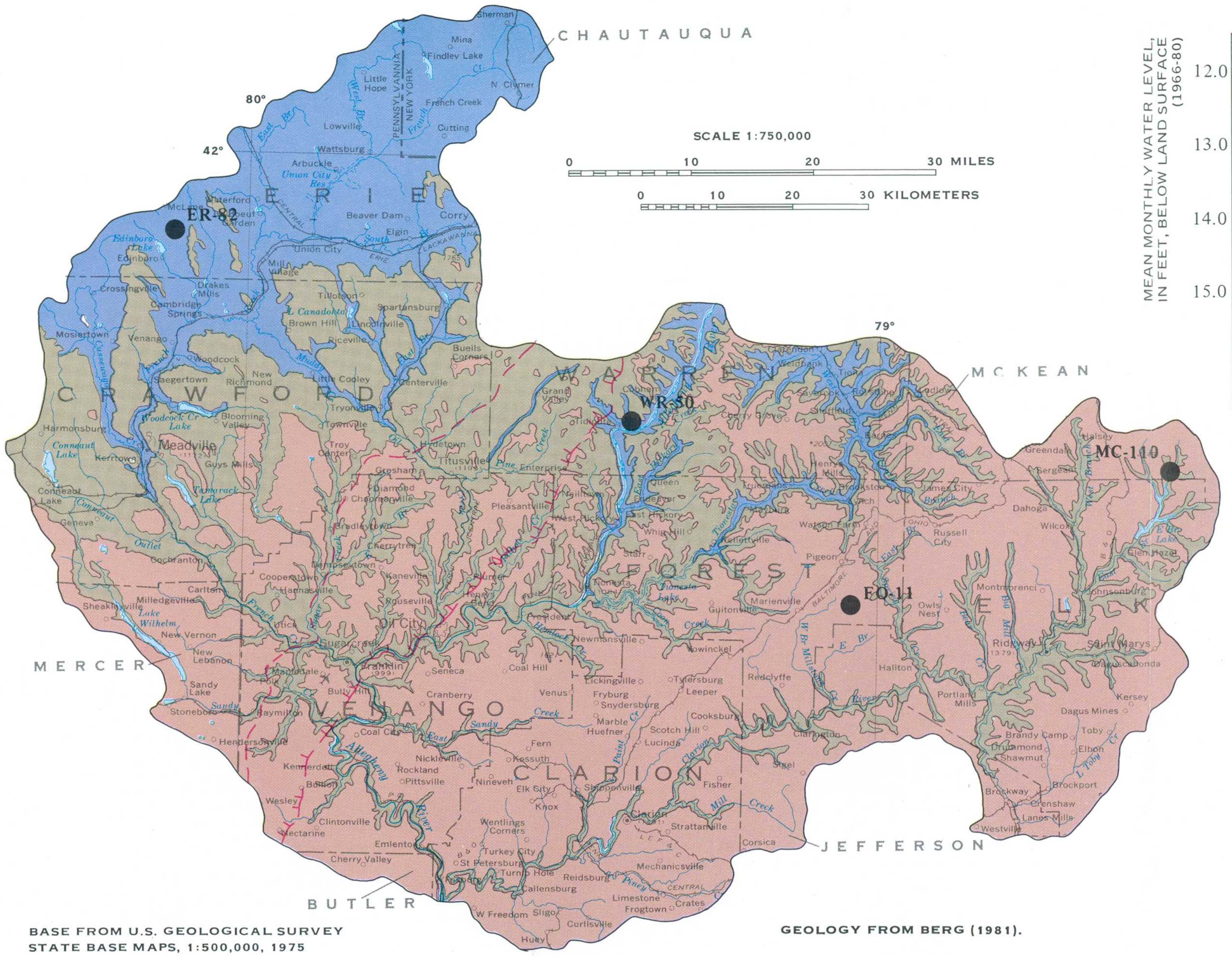
Because of the lithologic similarities, water-level fluctuations in the Mississippian aquifers are expected to be similar to that of the Pennsylvanian aquifers shown. Assuming an equal amount of recharge, water levels in wells that tap glacial and unconsolidated deposits probably fluctuate less than bedrock wells. This is due to the larger storage capability of the glacial and unconsolidated deposits.

Extreme values for the period of record are greater for the two wells tapping Devonian aquifers than for the two wells tapping Pennsylvanian aquifers. The water level in well ER-82 ranged from 10.00 feet below land surface on March 17, 1973, to 18.41 feet below land surface on September 20, 1966. Well ER-82 is located in the northwestern part of Area 2 and taps the Riceville Shale of Late Devonian age. The water level in well WR-50 ranged from 40 feet below land surface on June 9, 1973, to 45.27 feet below land surface on October 5, 1979. Well WR-50 is located in the northcentral part of Area 2 and taps the Venango Formation (Pennsylvania Geological Survey usage) also of Late Devonian age. Well FO-11 is located in the east-central part of Area 2 and taps the Allegheny Group of Pennsylvanian age. The water level in well FO-11 ranged from 7.78 feet below land surface on January 27-28, 1973, to 11.52 feet below land surface on September 9-17, 1976. Well MC-110 taps the Pottsville Group of Pennsylvanian age and is located at the northeastern edge of Area 2. The water level ranged from 27.08 feet below land surface on May 17, 1974, to 30.09 feet below land surface on August 8, 1973.

Topographic location and head in the water-bearing zones affect the water levels in wells. Water levels range from above land surface in some valleys to more than 300 feet below land surface in hilltop wells. An average depth to water is 25-30 feet for bedrock valley wells and about 50 feet for hilltop wells (Buckwalter and others, 1981). Depth to water usually increases as well depth increases in upland areas. Conversely, depth to water decreases or remains about the same as well depths increase in valleys.

Depth to water below land surface can also be affected by the amount of casing used in the well. If a large amount of surface casing is used, some shallow water-bearing zones may be sealed off, and water levels would then reflect head conditions in the deeper units.

Records of water levels for observation wells in Area 2 may be obtained from the U.S. Geological Survey in Harrisburg, Pennsylvania. Water levels are published in the U.S. Geological Survey report "Water Resources Data for Pennsylvania, Volume 3." Monthly and annual precipitation and air temperature records may be found in the U.S. Department of Commerce Climatological Data Reports for Pennsylvania.



BASE FROM U.S. GEOLOGICAL SURVEY
STATE BASE MAP, 1:500,000, 1975

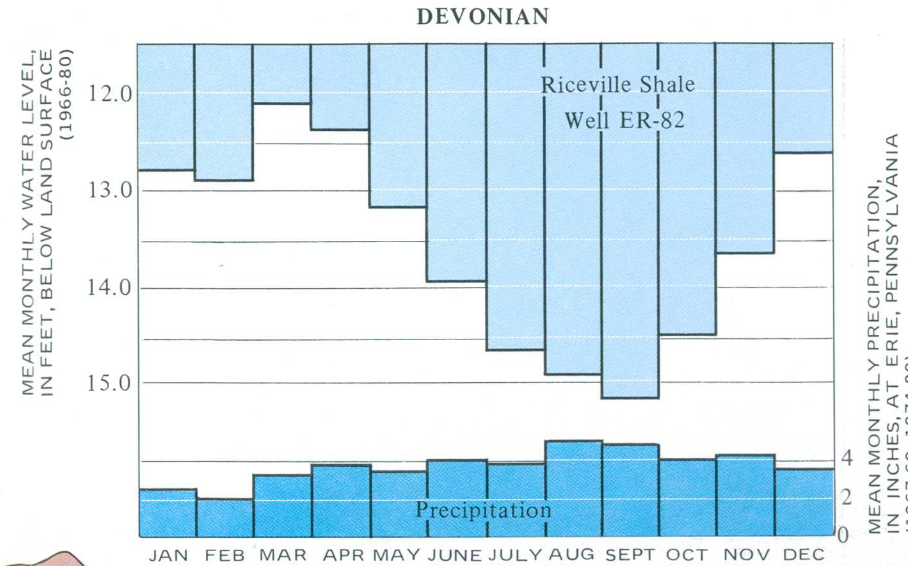
EXPLANATION

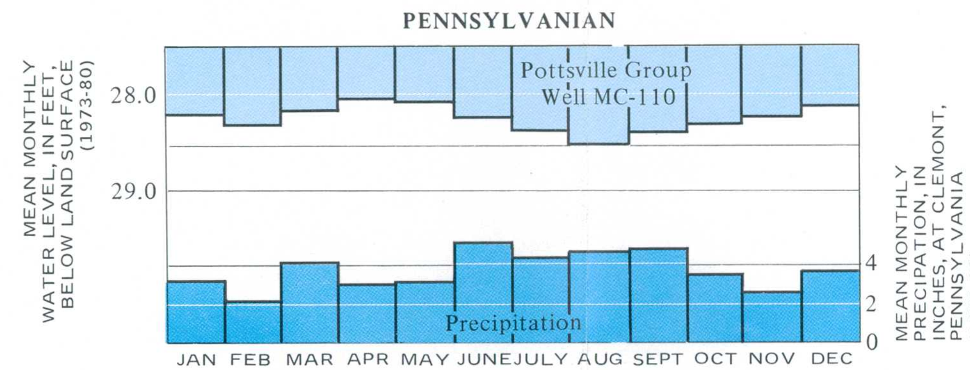
BEDROCK

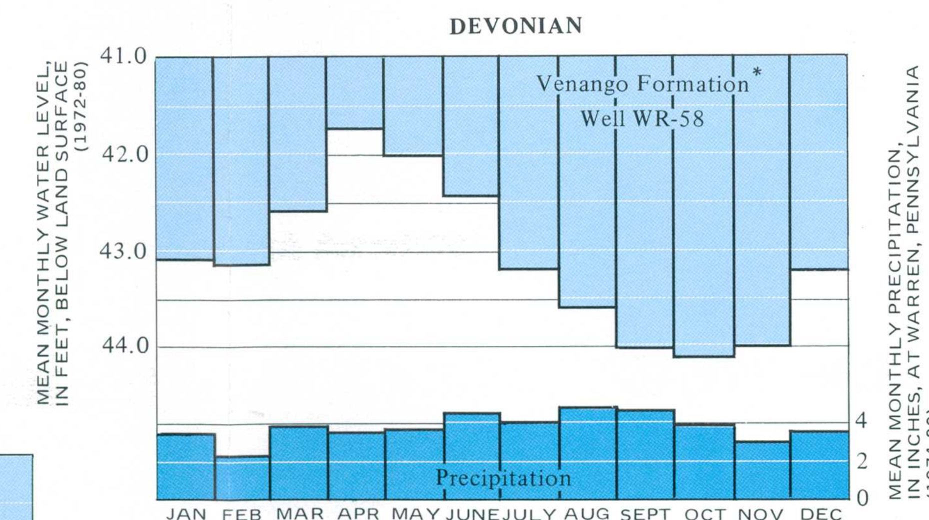
- Pennsylvanian
- Mississippian
- Devonian

- Southeastern limit of Wisconsin Glaciation
- Southeastern limit of Illinoian Glaciation
- ER-82 Observation well number and location

Figure 10.3-1 Selected well locations.







*Usage of the Pennsylvania Geological Survey

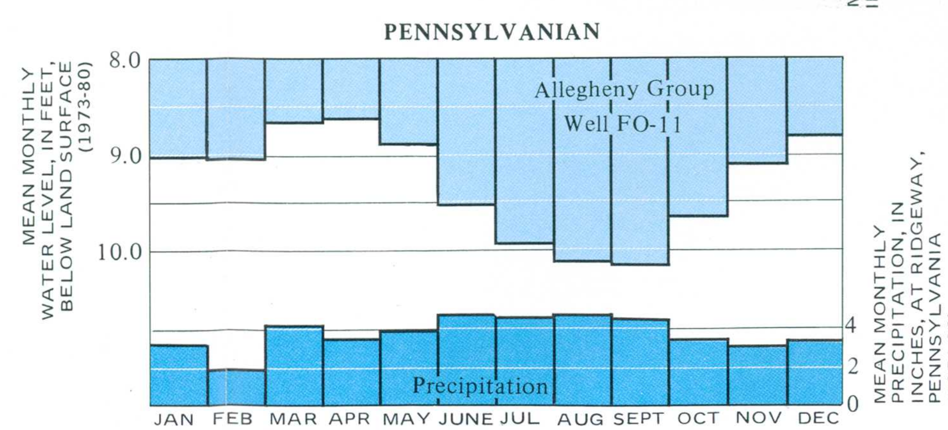


Figure 10.3-2 Seasonal water-level fluctuations.

Unconsolidated and Bedrock Aquifers in Area have Diverse Water-Bearing Characteristics

Well yields range from less than 1 to more than 2,000 gallons per minute depending on aquifer material, bedrock fracturing, and topographic location.

Water availability and well yields involve many variables. Water yields are greater in valleys than on hilltops as a result of greater aquifer permeability and storage and shallower depths to water. Wells in unconsolidated materials generally have higher yields than bedrock wells especially in locations of thick valley fill. Wide ranges of well yields can occur in bedrock wells due to the amount of fracturing and the lithology of the bedrock unit. Generally, greater recharge is available to bedrock aquifers overlain by glacial drift and aquifers in unconsolidated materials. Such areas are flatter and more pervious which result in reduced surface runoff.

Glacial deposits are locally the best source of large ground-water supplies. Glacial drift is generally divided into outwash and till deposits. Glacial outwash is generally well sorted coarse-grained sands and gravels that have large yields. The range of well yields from outwash is from less than 1 to 2,050 gpm (gallons per minute) and the median is 15 gpm. Lake deposits, which are also outwash, can be fine-grained sands, silts, and clays having low yields. Glacial outwash is commonly found along major drainages and their tributaries northwest of the Illinoian boundary (fig. 10.4-1). However, outwash also occurs southeast of this limit along the Allegheny River and Tionesta Creek. Outwash is over 100 feet thick locally in the major valleys. Till is poorly sorted material. Well yields range from less than 1 to 50 gpm with a median of 6 gpm. The till covering bedrock in the uplands is usually thin, but till in the valleys can be tens of feet thick.

Alluvium may also be a large source of ground-water supplies locally. Alluvial materials are usually highly permeable and are found along most drainage bottoms in the area. Well yields can range from less than 1 to 200 gpm with a median of 20 gpm.

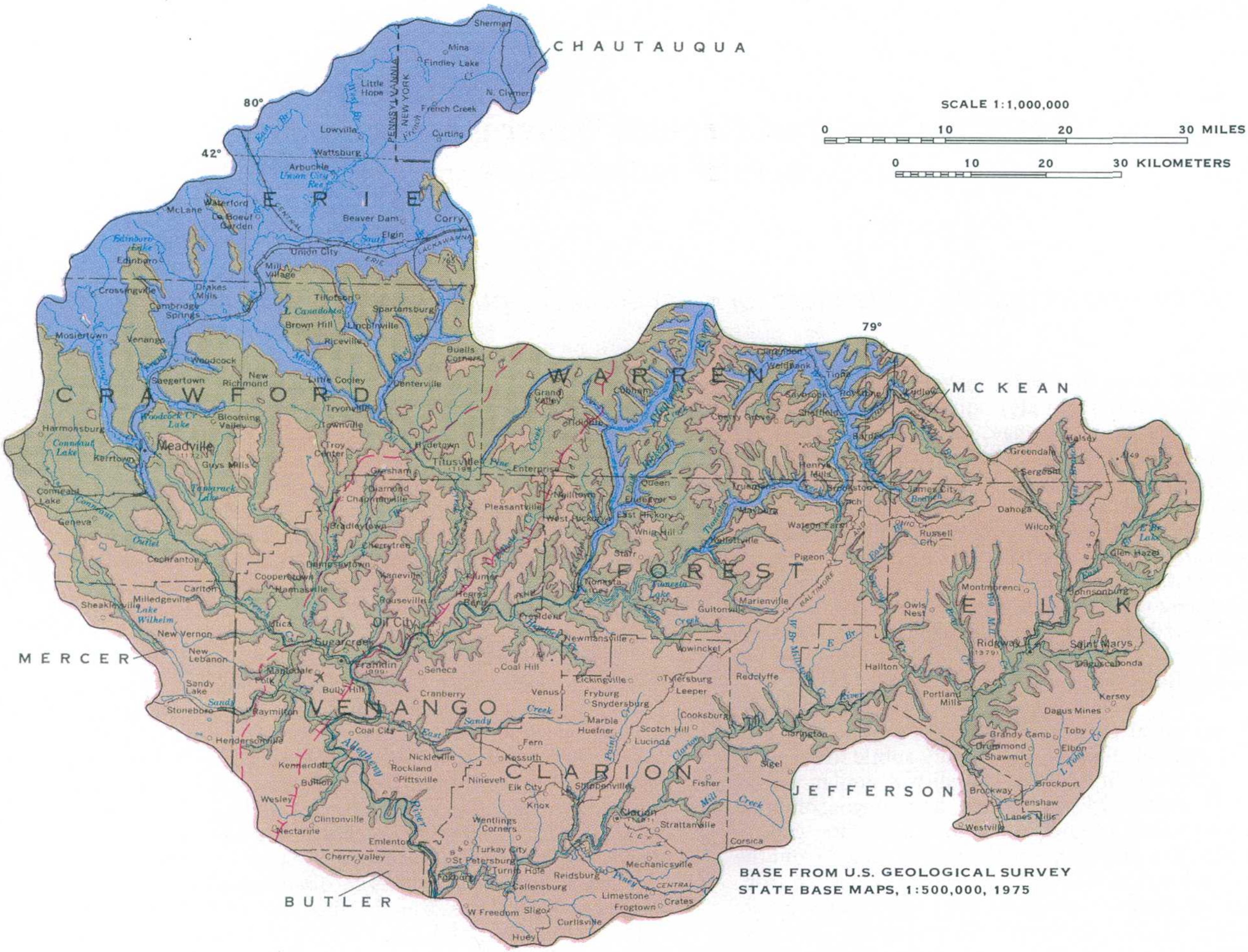
The rocks of the Mississippian generally have the highest well yields of all bedrock aquifers tapped by wells in Area 2 (fig. 10.4-1). The range is from less than 1 to 550 gpm, depending upon the extent of weathering and fractures. The median yield is about 20 gpm. The higher yields come from highly fractured sandstones whereas lower yields come from poorly fractured shales.

Generally the Pennsylvanian formations (fig. 10.4-1) contain a larger percentage of finer-grained sediments than formations of the Mississippian in Area 2. Most water occurs within fractured sandstones of the Allegheny and Pottsville Groups, but some occurs along the bedding planes of the numerous beds of alternating sandstone and shale. The well yields range from less than 1 to 300 gpm with a median of 10 gpm.

The Upper Devonian rocks are predominantly shales and siltstones that are poorly fractured and yield little water to wells (fig. 10.4-1). Well yields range from less than 1 to 60 gpm with a median of 6 gpm.

Springs discharge a limited water supply in Area 2. Springs usually occur above relatively impermeable rock layers found along hillsides and upland draws.

Hydrologic and geologic data used in this section are from Bloyd (1974), Buckwalter and others (1981), and Schiner and Gallaher (1979).



EXPLANATION

Yields to wells, in gallons per minute

BEDROCK

Pennsylvanian
From less than 1 to 300, median 10

Mississippian
From less than 1 to 550, median 20

Devonian
From less than 1 to 60, median 6

UNCONSOLIDATED

Southeastern limit of Wisconsin Glaciation

Southeastern limit of Illinoian Glaciation

Glacial drift (not shown on map)
Outwash from less than 1 to more than 200, median 15
Till from less than 1 to 50, median 6

Figure 10.4-1 Sources of ground water.

Chemical Quality of Ground Water is Variable, but Generally Satisfactory

Ground-water quality is adequate for most domestic purposes, except locally.

The quality of ground water in Area 2 is highly variable. Chemical quality for major aquifer units (fig. 10.5-1) is shown in table 10.5-1. Range, mean, and median are given for each constituent. Medians provide the best indication of typical chemical character over the area. Extremely high and low values, generally resulting from local effects, have less influence on the computation of the median as compared to the mean. The overall chemical character of water tabulated for the Devonian aquifers may not be accurately represented because of the low number of samples. Nevertheless, iron, chloride, specific conductance, and hardness are probably representative of the Devonian aquifers.

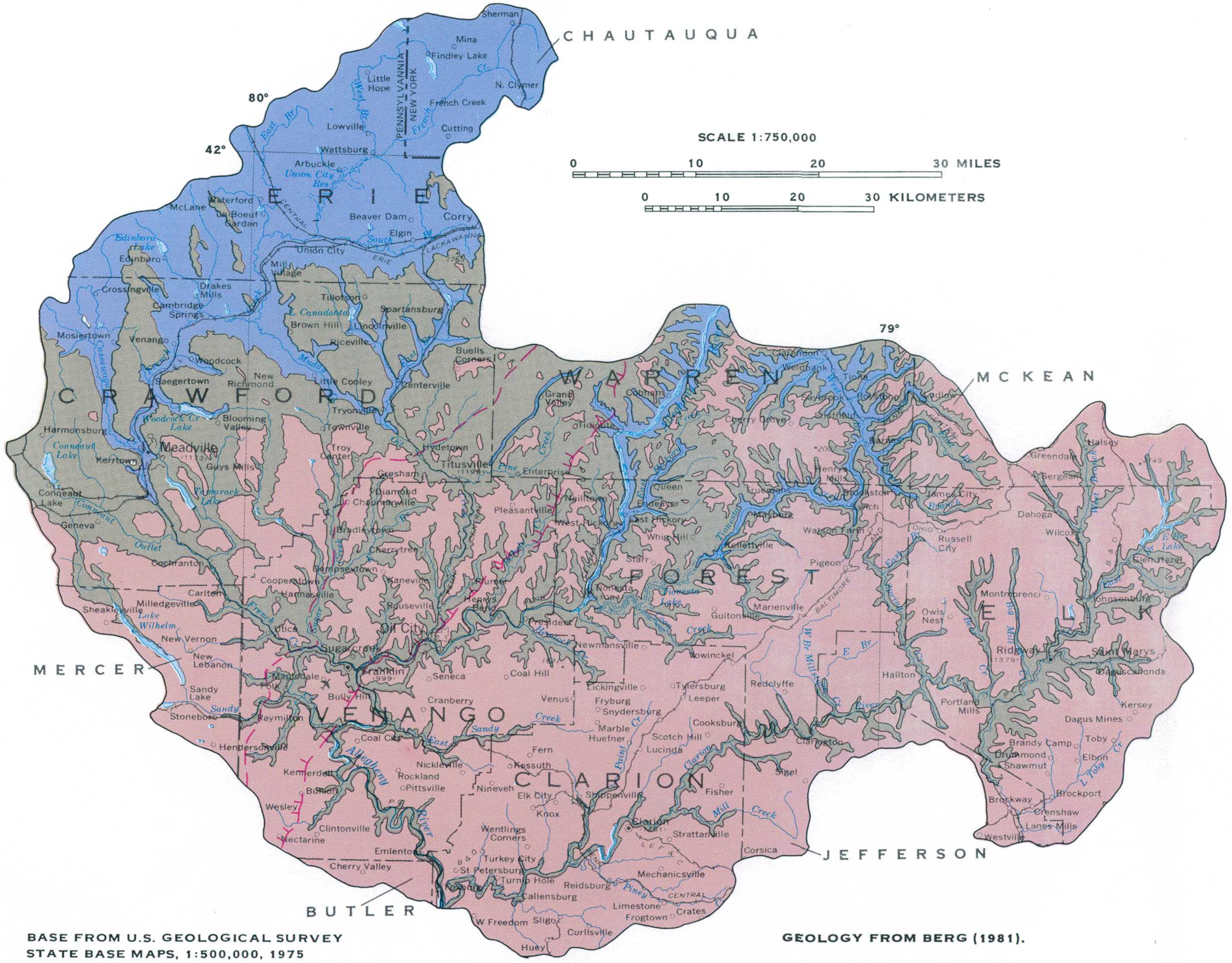
Comparison of constituent medians between the major aquifer units of the area shows only subtle differences in natural water quality. Overall quality is similar among the Pennsylvanian, Mississippian, and unconsolidated aquifers; the water is good for most uses, but greater hardness ($CaCO_3$) and higher pH can be expected from the Devonian and unconsolidated aquifers. Values of iron, manganese, and pH which are outside the limits for public water supply (U.S. Environmental Protection Agency, 1977) occur locally within these aquifers. Iron exceeds the 0.3 mg/L (milligrams per liter) limit in Pennsylvanian and Mississippian age rocks. Manganese exceeds the 0.05 mg/L limit in Pennsylvanian, Mississippian and unconsolidated rocks. Median pH values in Pennsylvanian rocks are locally below the 6.5 recommended limit.

Even though the most saline water of the area occurs in the Devonian aquifers, none of the median values exceed the recommended limits for public water supply. Water from these rocks has the lowest median concentrations of iron, manganese, and sulfate. Median dissolved solids are 300 mg/L.

The most important factors affecting ground-water quality in the area are rock type and residence time (duration of contact between water and rock). The occurrence of coal, organic-type claystones, and associated iron pyrite in the Pennsylvanian rocks marks the most significant lithologic difference between these and Mississippian rocks. Consequently, iron and sulfate concentrations are higher and pH is lower in water of the Pennsylvanian aquifer. Other concentrations of constituents compare favorably between the major aquifers. Devonian rocks, which contain numerous marine-deposited shales and brine, yield water of relatively high salinity for the area. The unconsolidated deposits contain poorly soluble siliceous material. Ground-water quality from these aquifers more closely resembles the Pennsylvanian and Mississippian water quality.

Residence time causes large variations of chemical character within each major aquifer unit in Area 2. Ground water near recharge areas typically is a calcium and or magnesium bicarbonate type with low dissolved solids, and moderate sulfate and pH. Such water is therefore common in the unconsolidated aquifers and in most shallow bedrock aquifers along hilltops. Along the ground-water flow path away from recharge and toward discharge areas, residence time becomes greater. Ground water becomes softer and increases in dissolved solids. Sodium and bicarbonate are usually the principal ions. Deep bedrock aquifers and aquifers at intermediate depth beneath valleys generally have sodium-bicarbonate type water. Connate waters (water entrapped in sediments at the time for their deposition) have high dissolved solids, mostly sodium and chloride, and some heavy metals. Such poor quality water occurs at shallow depths (generally more than 50 feet) below some Devonian unit outcrops. Saline water can also be found at depths greater than 300 feet below major drainage bottoms in the area.

Coal mining activity in Area 2 typically exposes iron sulfides (pyrite) to oxidation. Water in contact with these materials usually is high in dissolved solids, iron, manganese, sulfate, and acidity (low pH). Such conditions in ground water are responsible for the higher mean values of these constituents in the Pennsylvanian and Mississippian rocks. Basic data used to compile table 10.5-1 may be obtained from published reports. (See Frimpter, 1974; p. 96-98 and Koester and Miller, 1980, p. 26-52.)



BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAPS, 1:500,000, 1975

GEOLOGY FROM BERG (1981).

EXPLANATION

BEDROCK

Pennsylvanian
Numerous beds of sandstone, siltstone, shale and some beds of limestone and conglomerate.

Mississippian
Sandstone, silstone, shale and conglomerate.

Devonian
Mostly shale with some thin fine-grained sandstone.

UNCONSOLIDATED

Southeastern limit of Wisconsin Glaciation

Southeastern limit of Illinoian Glaciation

Bedrock northwest of lines of glaciation is generally covered with unconsolidated material such as clay, silt, sand and gravel.

Figure 10.5-1 Geology.

Table 10.5-1 Ground-water chemical quality.

BEDROCK AQUIFERS

Water-quality constituent	Pennsylvanian: Number of samples	Minimum	Maximum	Mean	Median	Mississippian: Number of samples	Minimum	Maximum	Mean	Median
Calcium (mg/L)	61	1.0	280	47	15	37	1	84	30	24
Magnesium (mg/L)	60	0.5	550	35	6.5	36	0.1	25	7.8	5.2
Sodium (mg/L)	75	0.2	340	22	1.7	34	0.1	980	92	16
Potassium (mg/L)	46	0.3	9.8	2.6	1.6	32	1.4	8.5	2.9	2.2
Iron (mg/L)	152	0.0	500	24	3.4	62	0.01	250	10	.95
Manganese (mg/L)	149	0.0	40	2.6	.55	48	0.0	40	1.4	.28
Bicarbonate (mg/L)	153	0.0	260	47	22	48	0.0	410	140	110
Sulfate (mg/L)	75	0.2	3,400	290	25	43	0.2	670	63	15
Chloride (mg/L)	85	0.3	580	23	5.3	57	0.6	1,600	85	8.7
Nitrate (mg/L)	47	0.0	40	2.6	0.3	28	0.0	4.2	0.8	0.2
Specific conductance (umho/cm at 25°C)	147	25	5,800	486	185	53	85	4,230	667	355
Dissolved solids (mg/L)	61	19	7,400	566	119	40	46	2,710	363	219
pH (units)	134	2.7	8.1	6.0	6.2	43	3.9	8.3	6.7	6.8
Hardness (mg/L $CaCO_3$)	154	5	3,000	190	68	59	3	500	120	100

Water-quality constituent	Devonian: Number of samples	Minimum	Maximum	Mean	Median	Unconsolidated aquifers: Number of samples	Minimum	Maximum	Mean	Median
Calcium (mg/L)	6	11	180	92	62	29	4.5	90	46	42
Magnesium (mg/L)	6	2.4	48	23	15	23	3.8	14	9.4	9.3
Sodium (mg/L)	8	4	2,700	870	80	25	1.5	57	17	14
Potassium (mg/L)	4	1.6	40	25	13	20	0.5	14	3.4	1.6
Iron (mg/L)	35	0.0	38	1.2	.10	84	0.0	3.3	.32	.14
Manganese (mg/L)	7	0.0	.70	.20	.05	21	0.0	.40	.09	.06
Bicarbonate (mg/L)	7	90	3,340	680	240	37	6	270	160	160
Sulfate (mg/L)	9	0.2	74	27	13	37	0.2	80	30	22
Chloride (mg/L)	39	3	4,500	310	11	88	2	1,200	36	9.0
Nitrate (mg/L)	5	0.0	6.2	2.1	0.3	35	0.0	9.3	1.4	0.6
Specific conductance (umho/cm at 25°C)	36	245	13,000	1,370	320	65	200	4,800	477	326
Dissolved solids (mg/L)	10	165	8,100	2,300	300	30	88	461	245	228
pH (units)	8	7.1	8.1	7.8	7.8	26	5.0	8.2	7.5	7.8
Hardness (mg/L $CaCO_3$)	37	25	630	160	130	84	10	720	140	120

NAWDEX, WATSTORE, OWDC have Water Data Information

Water data are collected in coal areas by a large number of organizations in response to a wide variety of missions and needs.

Within the U.S. Geological Survey there are three activities that help to identify and improve access to the vast amount of existing water data.

(1) The National Water Data Exchange (NAWDEX), which indexes the water data available for over 400 organizations and serves as a central focal point to help those in need of water data to determine what information already is available.

(2) The National Water Data Storage and Retrieval System (WATSTORE), which serves as the central repository of water data collected by the U.S. Geological Survey and which contains large volumes of data on the quantity and quality of both surface and ground waters.

(3) The Office of Water Data Coordination (OWDC), which coordinates Federal water-data acquisition activities and maintains a "Catalog of Information on Water Data." To assist in identifying available water-data activities in coal provinces of the United States special indexes to the Catalog are being printed and made available to the public.

A more detailed explanation of these three activities is given in sections 11.2, 11.3, and 11.4.

NAWDEX Simplifies Access to Water Data

The National Water-Data Exchange (NAWDEX) is a nationwide program managed by the U.S. Geological Survey to assist users of water data or water-related data in identifying, locating, and acquiring needed data.

NAWDEX is a national confederation of water-oriented organizations working together to make their data more readily accessible and to facilitate a more efficient exchange of water data.

Services are available through a Program Office located at the U.S. Geological Survey's National Center in Reston, Virginia, ana a nationwide network of Assistance Centers located in 45 States and Puerto Rico, which provide local and convenient access to NAWDEX facilities (see fig. 11.2-1). A directory is available on request that provides names of organizations and persons to contact, addresses, telephone numbers, and office hours for each of these locations [Directory of Assistance Centers of the National Water Data Exchange (NAWDEX), U.S. Geological Survey Open-File Report 79-423 (revised)].

NAWDEX can assist any organization or individual in identifying and locating needed water data and referring the requester to the organization that retains the data required. To accomplish this service, NAWDEX maintains a computerized Master Water Data Index (fig. 11.2-2), which identifies sites for which water data are available, the type of data available for each site, and the organization retaining the data. A Water Data Sources Directory (fig. 11.2-3) also is maintained that identifies organizations that are sources of water data and the locations within these organizations from which data may be obtained. In addition NAWDEX has direct access to some large water-data bases of its members and has reciprocal agreements for the exchange of services with others.

Charges for NAWDEX services are assessed at the option of the organization providing the requested data or data service. Search assistance services are provided free by NAWDEX to the greatest extent possible. Charges are assessed, however, for those requests requiring computer cost, extensive personnel time, duplicating services, or other costs encountered by NAWDEX in the course of providing services. In all cases, charges assessed by NAWDEX Assistance Centers will not exceed the direct costs incurred in responding to the data request. Estimates of cost are provided by NAWDEX upon request and in all cases where costs are anticipated to be substantial.

For additional information concerning the NAWDEX program or its services contact:

Program Office
National Water Data Exchange (NAWDEX)
U.S. Geological Survey
421 National Center
12201 Sunrise Valley Drive
Reston, Virginia 22092

Telephone: (703) 860-6031
FTS 928-6031

Hours: 7:45-4:15 Eastern Time

or

U.S. Geological Survey
Water Resources Division
4th Floor, Federal Building
P.O. Box 1107
Harrisburg, Pennsylvania 17108

Telephone: (717) 782-3851
FTS 590-3851

Hours: 8:00-4:00 Eastern Time

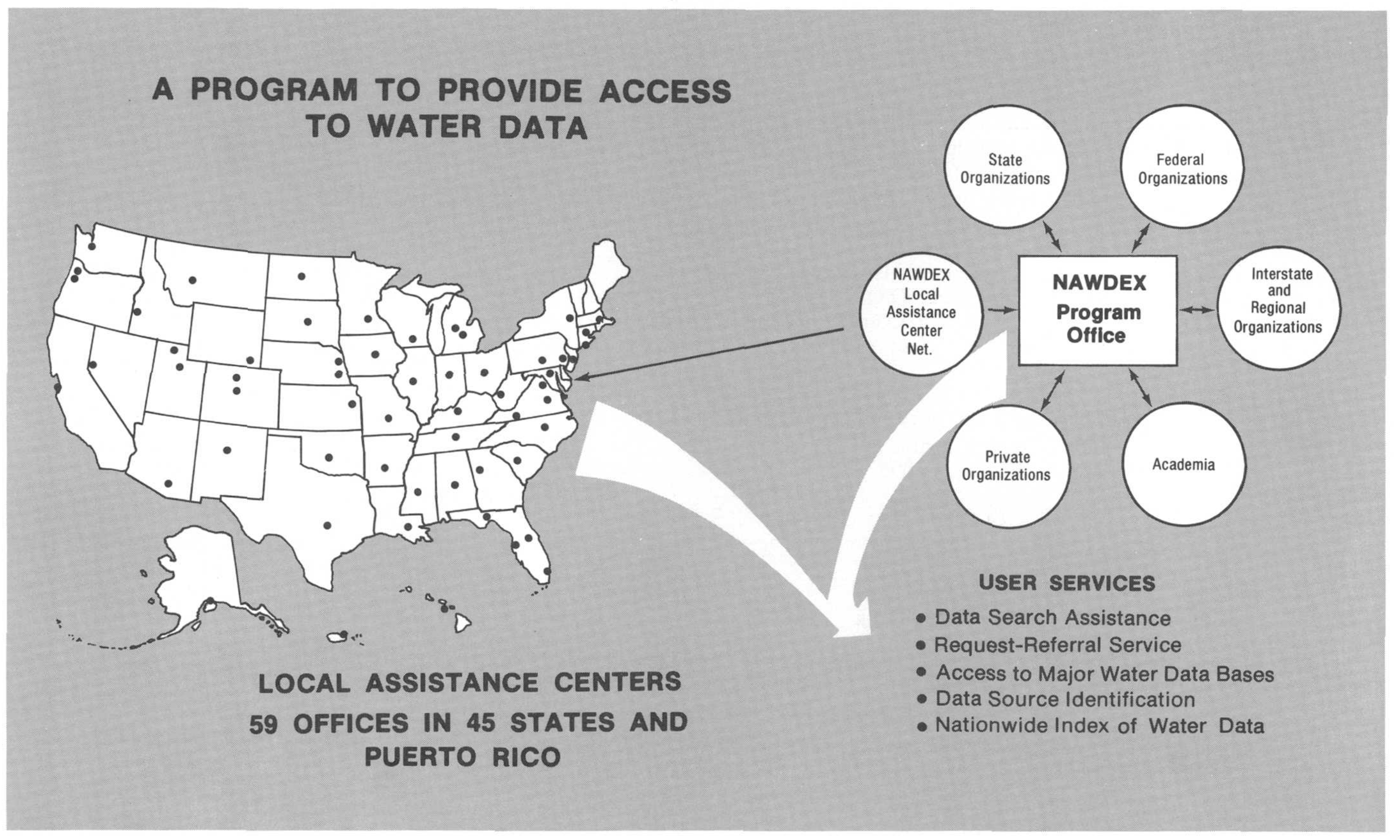


Figure 11.2-1 Access to water data.

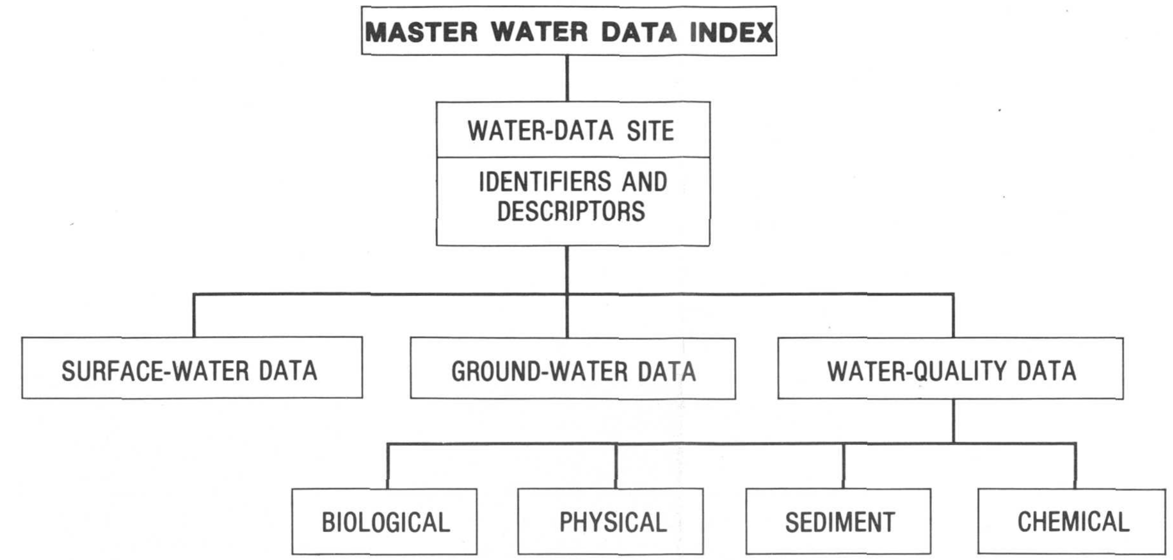


Figure 11.2-2 Master water-data index.

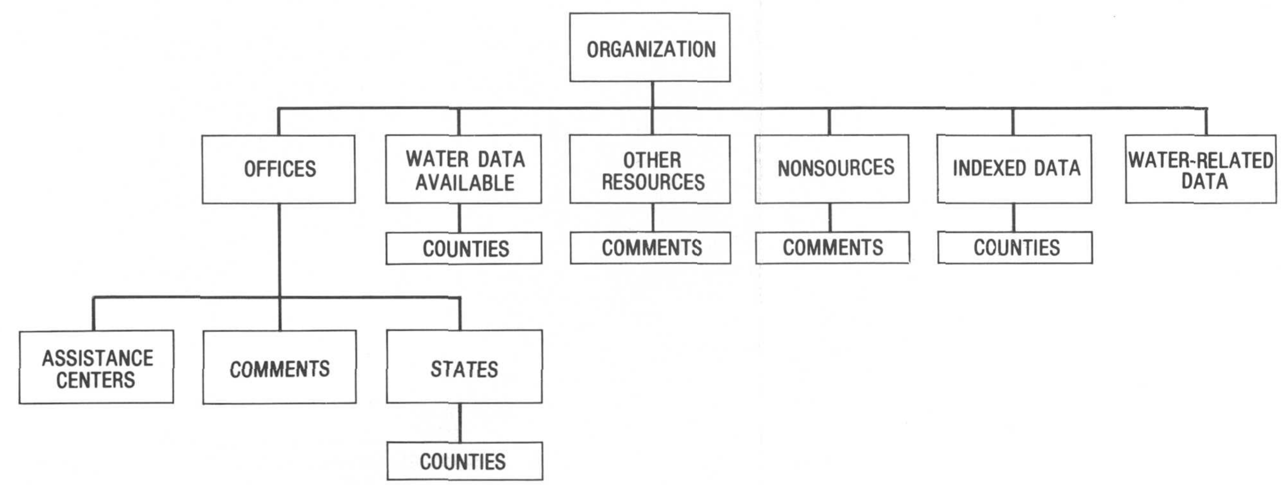


Figure 11.2-3 Water-data sources directory.

WATSTORE Automated Data System

The National Water Data Storage and Retrieval System (WATSTORE) of the U.S. Geological Survey provides computerized procedures and techniques for processing water data and provides effective and efficient management of data-releasing activities.

The National Water Data Storage and Retrieval System (WATSTORE) was established in November 1971 to computerize the U.S. Geological Survey's existing water-data system and to provide for more effective and efficient management of its data-releasing activities. The system is operated and maintained on the central computer facilities of the Survey at its National Center in Reston, Virginia. Data may be obtained from WATSTORE through the Water Resources Division's 46 district offices. General inquiries about WATSTORE may be directed to:

Chief Hydrologist
U.S. Geological Survey
437 National Center
Reston, Virgina 22092

or

U.S. Geological Survey
Water Resources Division
4th Floor, Federal Building
P.O. Box 1107
Harrisburg, Pennsylvania 17108

The Geological Survey currently (1980) collects data at approximately 16,000 streamgaging stations, 1,000 lakes and reservoirs, 5,200 surface-water quality stations, 1,020 sediment stations, 30,000 water-level observation wells, and 12,500 ground-water quality wells. Each year many water-data collection sites are added and others are discontinued; thus, large amounts of diversified data, both current and historical, are amassed by the Survey's data-collection activities.

The WATSTORE system consists of several files in which data are grouped and stored by common characteristics and data-collection frequencies. The system also is designed to allow for the inclusion of additional data files as needed. Currently, files are maintained for the storage of: (1) surface-water, quality-of-water, and ground-water data measured on a daily or continuous basis; (2) annual peak values for streamflow stations; (3) chemical analyses for surface- and ground-water sites; (4) water parameters measured more frequently than daily; and (5) geologic and inventory data for ground-water sites. In addition, an index file of sites for which data are stored in the system is also maintained (fig. 11.3-1). A brief description of each file is as follows.

Station Header File: All sites for which data are stored in the Daily Values, Peak Flow, Water-Quality, and Unit Values files of WATSTORE are indexed in this file. It contains information pertinent to the identification, location, and physical description of nearly 220,000 sites.

Daily Values File: All water-data parameters measured or observed either on a daily or on a continuous basis and numerically reduced to daily values are stored in this file. Instantaneous measurements at fixed-time intervals, daily mean values, and statistics such as daily maximum and minimum values also may be stored. This file currently contains over 200 million daily values including data on streamflow, river stages, reservoir contents, water temperatures, specific conductance, sediment concentrations, sediment discharges, and ground-water levels.

Peak Flow File: Annual maximum (peak) streamflow (discharge) and gage height (stage) values at surface-water sites comprise this file, which currently contains over 400,000 peak observations.

Water-Quality File: Results of over 1.4 million analyses of water samples that describe the chemical, physical, biological, and radiochemical characteristics of both surface and ground waters are contained in this file. These analyses contain data for 185 different constituents.

Unit Values File: Water parameters measured on a schedule more frequent than daily are stored in this file. Rainfall, stream discharge, and temperature data are examples of the types of data stored in the Unit Values File.

Ground-Water Site-Inventory File: This file is maintained within WATSTORE independent of the files discussed above, but it is cross-referenced to the Water-Quality File and the Daily Values File. It contains inventory data about wells, springs, and other sources of ground water. The data included are site location and identification, geohydrologic characteristics, well-construction history, and one-time field measurements such as water temperature. The file is designed to accommodate 255 data elements and currently contains data for nearly 700,000 sites.

All data files of the WATSTORE system are maintained and managed on the central computer facilities of the Geological Survey at its National Center. However, data may be entered into or retrieved from WATSTORE at a number of locations that are part of a nationwide telecommunication network.

Remote Job Entry Sites: Almost all of the Water Resources Division's district offices are equipped with high-speed computer terminals for remote access to the WATSTORE system. These terminals allow each site to put data into or retrieve data from the system within several minutes to overnight, depending upon the priority placed on the request. The number of remote job entry sites is increased as the need arises.

Digital Transmission Sites: Digital recorders are used at many field locations to record values for parameters such as river stages, conductivity, water temperature, turbidity, wind direction, and chlorides. Data are recorded on l6-channel paper tape, which is removed from the recorder and transmitted over telephone lines to the receiver at Reston, Va. The data are recorded on magnetic tape for use on the central computer. Extensive testing of satellite data collection platforms indicates their feasibility for collecting real-time hydrologic data on a national scale. Battery-operated radios are used as the communication link to the satellite. About 200 data relay stations are being operated currently (1980).

Central Laboratory System: The Water Resources Division's two water-quality laboratories, located in Denver, Colorado, and Atlanta, Georgia, analyze more than 150,000 water samples per year. These laboratories are equipped to automatically perform chemical analyses ranging from determinations of simple inorganic compounds, such as chloride, to complex organic compounds, such as pesticides. As each analysis is completed, the results are verified by laboratory personnel and transmitted via a computer terminal to the central computer facilities to be stored in the Water-Quality File of WATSTORE.

Water data are used in many ways by decisionmakers for the management, development, and monitoring of our water resources. In addition to its data processing, storage, and retrieval capabilities, WATSTORE can provide a variety of useful products ranging from simple data tables to complex statistical analyses. A minimal fee, plus the actual computer cost incurred in producing a desired product, is charged to the requester.

Computer-Printed Tables: Users most often request data from WATSTORE in the form of tables printed by the computer. These tables may contain lists of actual data or condensed indexes that indicate the availability of data stored in the files. A variety of formats is available to display the many types of data.

Computer-Printed Graphs: Computer-printed graphs for the rapid analysis or display of data are another capability of WATSTORE. Computer programs are available to produce bar graphs (histograms), line graphs, frequency distribution curves, X-Y point plots, site-location map plots, and other similar items by means of line printers.

Statistical Analyses: WATSTORE interfaces with a proprietary statistical package (SAS) to provide extensive analyses of data such as regression analyses, the analysis of variance, transformations, and correlations.

Digital Plotting: WATSTORE also makes use of software systems that prepare data for digital plotting on peripheral offline plotters available at the central computer site. Plots that can be obtained include hydrographs, frequency distribution curves, X-Y point plots, contour plots, and three-dimensional plots.

Data in Machine-Readable Form: Data stored in WATSTORE can be obtained in machine-readable form for use on other computers or for use as input to user-written computer programs. These data are available in the standard storage format of the WATSTORE system or in the form of punched cards or card images on magnetic tape.

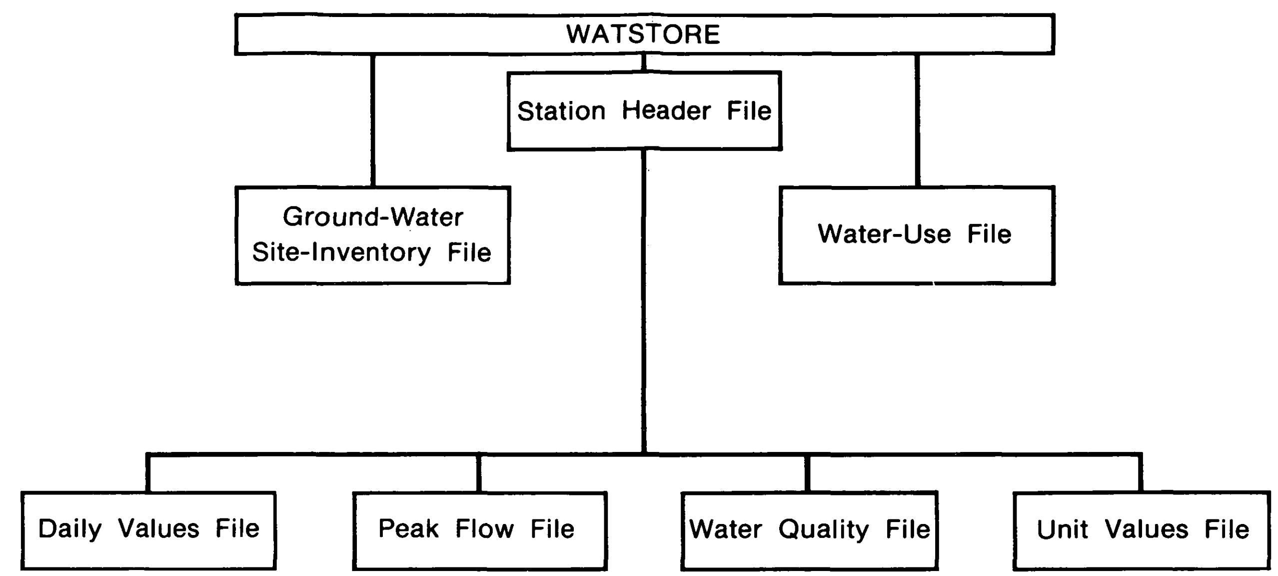


Figure 11.3-1 Index file stored data.

Water Data Indexed for Coal Provinces

A special index, "Index to Water-Data Activities in Coal Provinces of the United States," has been published by the U.S. Geological Survey's Office of Water Data Coordination (OWDC).

The "Index to Water-Data Activities in Coal Provinces of the United States" was prepared to assist those involved in developing, managing, and regulating the Nation's coal resources by providing information on the availability of water-resources data in the major coal provinces of the United States. It is derived from the "Catalog of Information on Water Data," which is a computerized information file about water-data acquisition activities in the United States, and its territories and possessions, with some international activities included.

This special index consists of five volumes (fig. 11.4-1): Volume I, Eastern Coal province; Volume II, Interior Coal province; Volume III, Northern Great Plains and Rocky Mountain Coal provinces; Volume IV, Gulf Coast Coal province; and Volume V, Pacific Coast and Alaska Coal provinces. The information presented will aid the user in obtaining data for evaluating the effects of coal mining on water resources and in developing plans for meeting additional water-data needs. The report does not contain the actual data; rather, it provides information that will enable the user to determine if needed data are available.

Each volume of this special index consists of four parts: Part A, Streamflow and Stage Stations; Part B, Quality of Surface-Water Stations; Part C, Quality of Ground-Water Stations; and Part D, Areal Investigations and Miscellaneous Activities. Information given for each activity in Parts A-C includes: (1) the identification and location of the station, (2) the major types of data collected, (3) the frequency of data collection, (4) the form in which the data are stored, and (5) the agency or organization reporting the activity. Part D summarizes areal hydrologic investigations and water-data activities not included in the other parts of the index. The agencies that submitted the information, agency codes, and the number of activities reported by type are shown in a table.

Those who need additional information from the Catalog file or who need assistance in obtaining water data should contact the National Water Data Exchange (NAWDEX) (See section 11.2).

Further information on the index volumes and their availability may be obtained from:

U.S. Geological Survey
Water Resources Division
4th Floor, Federal Building
P.O. Box 1107
Harrisburg, Pennsylvania 17108

Telephone (717) 782-3851
FTS 590-3851

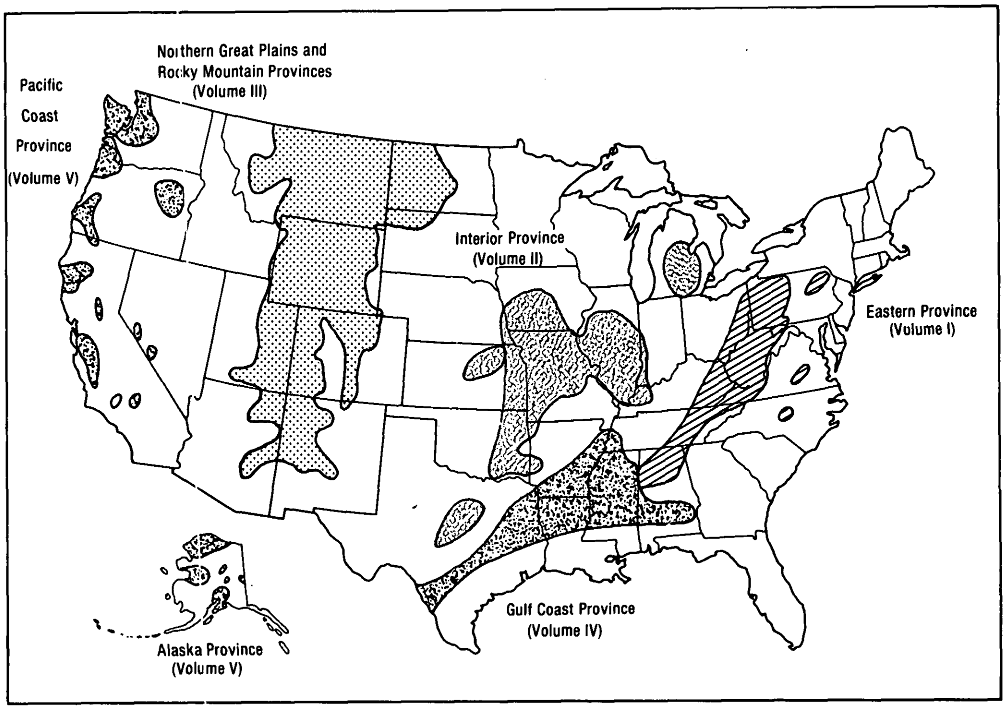


Figure 11.4-1 Index volumes and related provinces.

Surface-water sites in Area 2.

Reference[1] No.	USGS station number	Station name	Drainage area (mi^2)	Latitude	Longitude	Surface-water records: Quantity: Station type[2]	Quantity: Record period	Quality: Station type[3]	Quality: Record period
1	03015550	Perry McGee Run near Tidioute	5.78	414219	0792115	MI	6/79-8/80	SY	6/79-8/80
2	03015560	Tidioute Creek at Tidioute	19.8	414000	0792435	MI	6/79-8/80	SY	6/79-8/80
3	03015700	Beaver Run at Endevor	9.4	413512	0792117	MI	6/79-8/80	SY	6/79-8/80
4	03015798	E Hickory Run at Queen	23.6	413732	0792144	MI	6/79-8/80	SY	6/79-8/80
5	03016000	Allegheny River at West Hickory	3,660	413415	0792429	CR	10/41-9/80	--	---
6	03016005	L Hickory Run at West Hickory	7.52	413328	0792456	MI	6/79-8/80	SY	6/79-8/80
7	03016100	W Hickory Creek near West Hickory	18.0	413432	0792620	LF	6/79-8/80	SY	6/79-8/80
8	03016200	Elkhorn Run at Buchers Mills	4.31	414535	0791011	MI	6/79-8/80	SY	6/79-8/80
9	03016300	Farnsworth Br near Clarendon	11.7	414437	0790821	MI	6/79-8/80	SY	6/79-8/80
10	03016805	S Br Tionesta Creek at Cherry Run	41.3	413803	0785950	MI	6/79-8/80	SY	6/79-8/80
11	03016900	Twomile Run at Sheffield	29.4	414215	0790121	MI	6/79-8/80	SY	6/79-8/80
12	03017500	Tionesta Creek at Lynch	233	413607	0790301	CR	10/37-9/79	--	---
13	03017510	Bluejay Creek at Lynch	16.6	413435	0790256	MI	6/79-8/80	SY	6/79-8/80
14	03017700	Upper Sheriff Run near Lynch	4.44	413704	0790647	MI	6/79-8/80	SY	6/79-8/80
15	03017800	Minister Creek near Truemans	10.8	413716	0790912	CR-LF	6/79-8/80	SY	6/79-8/80
16	03017810	The Branch at Kellettville	14.0	413231	0791440	MI	6/79-8/80	SY	6/79-8/80
17	03017820	Ross Run near Crystal Springs	8.53	413053	0791930	MI	6/79-8/80	SY	6/79-8/80
18	03018900	Coon Creek near Newmansville	34.2	412624	0791944	MI	6/79-8/80	SY	6/79-8/80
19	03020000	Tionesta Creek at Tionesta Dam	479	412844	0792626	CR	6/40-9/80	--	---
20	03020055	L Tionesta Creek at Tionesta	11.4	412755	0792825	MI	6/79-8/80	SY	6/79-8/80
21	03020100	Stewart Run at Baum	12.6	412828	0793232	MI	6/79-8/80	SY	6/79-8/80
22	03020200	Hemlock Run at President	49.2	412704	0793325	MI	6/79-8/80	SY	6/79-8/80
23	03020250	Pithole Creek near Lovell Corners	21.5	413205	0793351	MI	6/79-8/80	SY	6/79-8/80
24	03020428	Thompson Creek near Hydetown	23.7	413942	0794158	MI	7/79-8/80	SY	7/79-8/80
25	03020438	Caldwell Creek at Grand Valley	10.9	414236	0793244	MI	7/78-8/80	SY	7/79-8/80
26	03020445	W Br Caldwell Creek near Grand Valley	12.9	414316	0793449	MI	7/79-8/80	SY	7/79-8/80
27	03020455	Pine Creek near Enterprise	30.7	413756	0793649	MI	7/79-8/80	SY	7/79-8/80
28	03020500	Oil Creek at Rouseville	300	412854	0794144	CR	6/32-9/80	PC	9/79-9/80
29	03020510	Cherrytree Run near Rouseville	16.9	412851	0794147	MI	6/79-8/80	SY	6/79-8/80
30	03021500	French Creek at Carters Corner	208	415720	0795240	CR	10/09-9/71	--	---
31	03021610	E Br Muddy Creek near Koochogey Corners	9.53	414306	0795107	MI	7/79-8/80	SY	7/79-8/80
32	03021700	L Conneauttee Creek near McKean	3.6	415553	0800502	CR	10/60-9/80	--	---
33	03022100	Gravel Run near Woodcock	10.2	414531	0800634	MI	7/79-8/80	SY	7/79-8/80
34	03022540	Woodcock Creek at Blooming Valley	30.3	414126	0800254	CR	10/74-9/80	SY	7/79-8/80
35	03023301	Van Horne Creek at Kentown	5.26	413704	0801015	MI	7/79-8/80	SY	7/79-8/80
36	03023338	Watson Run at Watson Run	14.4	413523	0801312	MI	7/79-8/80	SY	7/79-8/80
37	03023400	L Sugar Creek at Cochranton	52.5	413121	0800300	MI	7/79-8/80	SY	7/79-8/80
38	03024000	French Creek at Utica	1,028	412115	0795722	CR	8/32-9/80	PN	2/56-8/78
39	03024003	Mill Creek at Utica	15.3	412558	0795719	MI	7/79-8/80	SY	7/79-8/80
40	03024200	W Br Sugar Creek near Bradleytown	10.5	413431	0795154	MI	7/79-8/80	SY	7/79-8/80
41	03024210	Prather Creek near Dempseytown	19.9	413254	0794739	MI	7/79-8/80	SY	7/79-8/80
42	03024300	Lake Creek at Cooperstown	34.3	412952	0795222	MI	7/79-8/80	SY	7/79-8/80
43	03025000	Sugar Creek at Sugar Creek	166	412543	0795248	CR	8/32-9/80	--	---
44	03025200	Patchel Run near Franklin	5.69	412520	0795058	CR	10/64-9/80	SY	7/79-8/80
45	03025500	Allegheny River at Franklin	5,982	412322	0794914	CR	10/14-9/80	PN	10/75-9/78
46	03025505	Lower Two Mile Run at Venango	12.3	412236	0794757	MI	7/79-8/80	SY	7/79-8/80
47	03025790	E Sandy Creek near Kossuth	29.9	411900	0793514	MI	6/79-8/80	SY	6/79-8/80
48	03025810	Pine Run at Nickleville	8.48	411700	0793831	MI	6/79-8/80	SY	6/79-8/80
49	03026005	McCutcheon Run at Sandy Lake	1.46	412107	0800530	MI	6/79-8/80	SY	6/79-8/80
50	03026100	L Sandy Creek at Polk	20.4	412214	0795523	MI	7/79-8/80	SY	7/79-8/80
51	03026200	Scrubgrass Creek at Kennerdell	39.6	411518	0795027	MI	6/79-8/80	SY	6/79-8/80

Surface-water sites in Area 2 (continued).

Reference[1] No.	USGS station number	Station name	Drainage area (mi^2)	Latitude	Longitude	Surface-water records: Quantity: Station type[2]	Quantity: Record period	Quality: Station type[3]	Quality: Record period
52	03026300	Mill Creek near Emlenton	13.9	411330	0794320	MI	6/79-8/80	SY	6/79-8/80
53	03026500	Sevenmile Run at Rasselas	7.84	413751	0783437	CR	10/51-9/80	SY	6/79-8/80
54	03027500	E Br Clarion River at E Br Clarion River	73.2	413311	0783547	CR	10/48-9/80	--	---
55	03027550	Crooked Creek at Glen Hazel	9.71	413215	0783649	MI	6/79-8/80	SY	6/79-8/80
56	03027610	Johnson Run at Ketner Dam	8.32	413223	0783734	MI	6/79-8/80	SY	6/79-8/80
57	03027830	W Br Clarion River near Wilcox	27.4	413620	0784045	MI	6/79-8/80	SY	6/79-8/80
58	03027990	Wilson Run at Dahoga	20.0	413556	0784335	MI	6/79-8/80	SY	5/79-8/80
59	03028000	W Br Clarion River at Wilcox	63	413431	0784133	CR	10/53-9/80	--	---
60	03028500	Clarion River at Johnsonburg	204	412910	0784043	CR	10/45-9/80	--	---
61	03028520	Powers Run at Johnsonburg	11.8	412845	0784012	MI	6/79-8/80	SY	6/79-8/80
62	03028595	Silver Creek at Wilcox	7.96	412957	0784103	MI	6/79-8/80	SY	6/79-8/80
63	03028800	Daguscahonda Creek near Daguscahonda	13.4	412509	0783832	MI	6/79-8/80	SY	6/79-8/80
64	03028803	Elk Creek at Daguscahonda	48.6	412504	0783917	MI	6/79-8/80	SY	6/79-8/80
65	03029120	Mill Creek near Ridgway	31.5	412457	0784637	MI	6/79-8/80	SY	6/79-8/80
66	03029139	W Br Millstone Creek at Marienville	11.4	412725	0790713	MI	6/79-8/80	SY	6/79-8/80
67	03029140	Brandy Camp Creek at Challenge	13.2	411720	0784119	MI	6/79-8/80	SY	6/79-8/80
68	03029144	Mead Run at Brockport	7.37	411538	0784333	MI	6/79-8/80	SY	6/79-8/80
69	03029149	Rattlesnake Creek near Lanes Mills	17.0	411341	0784652	MI	6/79-8/80	SY	6/79-8/80
70	03029180	Bear Creek near Ridgway	37.0	412351	0784924	MI	6/79-8/80	SY	6/79-8/80
71	03029182	Spring Creek at Duhring	36.9	413057	0785936	MI	6/79-8/80	SY	6/79-8/80
72	03029188	Maxwell Run near Hallton	14.7	412305	0785608	MI	6/79-8/80	SY	6/79-8/80
73	03029250	Maple Creek near Clarington	18.9	412030	0790818	MI	6/79-8/80	SY	6/79-8/80
74	03029400	Toms Run at Cooksburg	11.8	412016	0791250	CR	10/59-9/80	SY	6/79-8/80
75	03029500	Clarion River at Cooksburg	807	411950	0791233	CR	10/38-8/80	PN	10/62-8/78
76	03029510	Cathers Run at Gravel Lick	17.9	411900	0791359	MI	6/79-8/80	SY	6/79-8/80
77	03029700	Mill Creek near Strattanville	53.7	411414	0791711	MI	6/79-8/80	SY	6/79-8/80
78	03030105	Toby Creek near Clarion	34.5	411405	0792305	MI	6/79-8/80	SY	6/79-8/80
79	03030365	Deer Creek near Shippenville	62.5	411404	0792706	MI	6/79-8/80	SY	6/79-8/80
80	03030500	Clarion River near Piney	951	411133	0792625	CR	10/44-8/80	--	---
81	03030570	Piney Creek near Limestone	19.2	410757	0792054	MI	6/79-8/80	SY	6/79-8/80
82	03030580	Brush Run at Williamsburg	11.2	411024	0792355	MI	6/79-8/80	SY	6/79-8/80
83	03030803	Beaver Creek below Blairs Corner	15.6	411038	0793337	MI	6/79-8/80	SY	6/79-8/80
84	03030900	Licking Creek near Callensburg	50.6	410725	0793406	MI	6/79-8/80	SY	6/79-8/80
85	03030948	Turkey Run at Alum Park	11.3	411002	0793718	MI	6/79-8/80	SY	6/79-8/80
86	03031500	Allegheny River at Parker	7,671	410602	0794053	CR	10/32-8/80	PN	11/75-5/78

[1]Used on figures
[2]Types of surface-water quantity stations (description and frequency of measurements given in Section 6.1).
CR = continuous-record
CS = crest-stage, partial record
LF = low-flow, partial record
MI = miscellaneous
[3]Types of surface-water quality stations (description and frequency of sampling given in Sections 6.2 and 6.3).
PC = partial-record (coal hydrology)
PN = partial-record (non-coal hydrology)
SY = synoptic

12.2 Selected Water-Quality Data for Surface-Water Stations 1979-80 Water Years

Water quality at surface-water sites in Area 2.

STATION NUMBER	DATE OF SAMPLE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	TEMPER-ATURE (DEG C)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)	PH (UNITS)	ACIDITY (MG/L AS CACO3)	ALKA-LINITY FIELD (MG/L AS CACO3)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE)	IRON, DIS-SOLVED (UG/L AS FE)	MANGA-NESE, TOTAL RECOV-ERABLE (UG/L AS MN)	MANGA-NESE, DIS-SOLVED (UG/L AS MN)	SULFATE DIS-SOLVED (MG/L AS SO4)	SEDI-MENT, SUS-PENDED (MG/L)	IRON, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS FE)	MANGA-NESE, RECOV. FM BOT-TOM MA-TERIAL (UG/G)
03015550	79-06-11	1610	12	14.0	50	--	6.6	.0	6	480	70	40	<10	11	13	--	--
	79-08-16	1440	.53	16.0	50	40	7.1	.0	12	510	90	30	20	8.5	6	37000	730
	80-03-30	1000	26	5.5	70	25	6.6	5.0	1	250	40	10	10	9.8	3	--	--
	80-08-22	0845	3.9	17.0	<50	49	7.0	--	10	680	100	10	10	8.0	13	--	--
03015560	79-06-11	1445	60	15.0	57	--	6.6	.0	4	800	110	<10	20	9.7	15	--	--
	79-08-16	1315	2.4	16.0	50	57	7.4	.0	16	410	170	<10	<10	8.9	3	34000	580
	80-03-27	1615	64	6.0	50	32	6.6	5.0	4	250	40	20	10	10	2	--	--
	80-08-22	1000	8.2	18.0	67	43	7.2	--	14	510	120	20	10	8.1	7	--	--
03015700	79-06-19	1405	2.4	14.0	55	--	7.0	.0	8	180	50	<10	<10	8.2	2	--	--
	79-08-15	1630	.98	14.0	50	41	7.1	.0	16	420	130	<10	<10	5.5	4	18000	540
	80-03-26	1710	25	4.5	45	31	7.1	5.0	8	200	50	40	30	11	5	--	--
	80-08-22	1700	1.7	17.5	63	45	7.2	--	14	430	100	30	10	7.6	7	--	--
03015798	79-06-19	1240	6.9	15.0	<50	--	6.9	.0	10	310	130	<10	<10	12	3	--	--
	79-08-16	1135	3.5	14.0	50	44	6.9	.0	10	700	430	<10	20	7.7	3	34000	640
	80-03-30	1100	130	6.0	45	28	5.7	5.0	2	320	100	60	50	11	6	--	--
	80-08-27	0845	5.5	17.5	51	36	7.1	--	10	500	270	20	30	7.9	2	--	--
03015800	80-06-20	1050	28	13.0	<50	36	7.1	1.0	6	--	--	--	--	9.4	--	--	--
03016005	79-06-19	1700	2.2	15.0	74	--	7.3	.0	12	120	<10	<10	<10	9.7	3	--	--
	79-08-16	0815	1.3	12.0	90	59	7.3	.0	20	200	<10	20	<10	9.8	5	34000	790
	80-03-25	1815	26	3.0	50	32	6.8	5.0	5	180	20	20	10	12	3	--	--
	80-08-27	1030	2.6	16.5	82	81	7.5	--	18	250	20	20	10	8.8	1	--	--
03016200	80-03-29	0930	20	4.0	55	32	6.0	5.0	2	630	70	90	80	9.6	--	--	--
	80-08-20	0945	1.7	18.0	62	58	7.1	--	14	1200	320	80	50	7.5	--	--	--
03016300	80-03-29	1050	70	6.0	50	27	5.6	5.0	1	--	30	--	90	9.3	--	--	--
	80-08-20	1145	10	15.0	<50	45	6.8	.0	6	250	30	20	20	7.7	--	--	--
03016805	79-06-12	1735	26	14.0	82	--	7.4	.0	16	370	160	40	40	9.4	4	--	--
	79-08-01	1140	39	18.5	82	51	7.1	.0	12	1500	170	100	40	10	31	13000	270
	80-03-29	1400	259	4.5	55	37	6.3	5.0	4	260	60	20	10	9.2	78	--	--
	80-08-21	0815	39	16.0	77	46	7.3	--	16	340	90	50	20	8.6	5	--	--
03016900	79-06-12	0940	27	12.0	66	--	6.8	.0	10	350	130	40	40	9.5	4	--	--
	79-08-01	1320	26	21.5	80	47	7.2	.0	14	670	170	60	50	11	20	14000	230
	80-03-29	1200	188	4.5	55	36	6.4	5.0	2	1000	50	90	40	10	276	--	--
	80-08-20	1445	27	18.0	52	36	7.2	--	8	320	60	40	20	8.6	6	--	--
03017500	79-09-19	1600	108	18.0	100	--	8.1	.0	16	410	180	30	20	9.5	2	--	--
	79-11-15	1200	347	4.5	80	--	--	.0	--	300	200	30	40	11	20	--	--
03017510	79-06-12	1120	12	12.5	50	--	6.7	.0	6	730	130	50	50	8.8	8	--	--
	79-08-02	1320	8.1	20.5	60	40	7.4	.0	16	850	230	90	40	8.3	8	20000	830
	80-03-29	1545	137	4.5	50	29	5.3	5.0	2	490	40	210	190	10	18	--	--
	80-08-21	1015	14	16.5	51	40	6.9	5.0	8	730	20	70	30	8.0	7	--	--
03017700	79-06-12	1245	3.2	12.0	<50	--	6.8	.0	6	<10	<10	20	<10	9.9	1	--	--

Water quality at surface-water sites in Area 2 (continued).

STATION	NUMBER	DATE OF SAMPLE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	TEMPER-ATURE (DEG C)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)	PH (UNITS)	ACIDITY (MG/L AS CACO3)	ALKA-LINITY FIELD (MG/L AS CACO3)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE)	IRON, DIS-SOLVED (UG/L AS FE)	MANGA-NESE, TOTAL RECOV-ERABLE (UG/L AS MN)	MANGA-NESE, DIS-SOLVED (UG/L AS MN)	SULFATE DIS-SOLVED (MG/L AS SO4)	SEDI-MENT, SUS-PENDED (MG/L)	IRON, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS FE)	MANGA-NESE, RECOV. FM BOT-TOM MA-TERIAL (UG/G)
03017700		79-08-02	0920	1.8	18.0	50	42	6.9	.0	8	210	20	<10	<10	10	4	16000	870
		80-03-29	1700	33	4.0	6	35	5.0	5.0	20	430	40	170	160	10	12	--	--
		80-08-21	1200	3.6	16.0	63	56	6.7	5.0	4	160	20	40	30	9.5	1	--	--
03017810		79-06-20	0950	4.8	13.5	65	--	6.9	.0	10	210	80	20	20	8.6	2	--	--
		79-08-15	1500	3.6	15.0	50	44	7.3	.0	16	390	160	20	<10	6.3	6	11000	580
		80-03-26	1600	45	5.0	50	30	6.4	5.0	3	280	70	100	90	11	6	--	--
		80-08-21	1545	6.7	21.0	58	38	7.2	--	12	450	200	20	10	8.0	1	--	--
03017820		79-06-20	1130	1.9	12.5	58	--	6.9	.0	8	200	30	<10	<10	9.4	2	--	--
		79-08-15	1325	13	15.0	50	53	7.2	.0	12	410	60	30	<10	9.4	6	27000	480
		80-03-26	1430	26	4.0	40	34	7.6	5.0	6	320	30	20	10	11	23	--	--
		80-08-23	0830	2.8	16.0	59	52	7.1	--	12	270	50	20	10	8.9	3	--	--
03018900		79-06-20	1410	16	17.5	140	--	6.8	.0	6	340	40	700	700	43	2	--	--
		79-08-15	1140	12	15.0	180	130	6.3	.0	4	430	40	1300	1300	61	6	13000	330
		80-03-26	1230	105	4.5	70	44	5.4	5.0	1	1800	150	390	340	22	6	--	--
		80-08-23	1200	15	16.5	140	106	6.7	5.0	6	340	30	780	790	45	1	--	--
03020055		79-06-21	0925	4.2	15.0	76	--	6.6	.0	8	120	30	<10	<10	17	4	--	--
		79-08-17	0820	2.8	12.0	50	68	6.9	.0	--	270	60	<10	<10	12	8	10000	440
		80-03-26	0800	35	3.0	55	38	6.7	5.0	2	290	50	40	30	14	6	--	--
		80-08-23	1015	6.0	16.0	73	47	6.9	5.0	8	210	50	20	10	12	5	--	--
03020100		79-06-21	1045	6.0	15.0	461	--	7.4	.0	20	250	<10	50	20	6.4	4	--	--
		79-08-10	1240	3.1	19.0	500	372	7.8	.0	36	350	<10	80	30	7.6	16	15000	1400
		80-03-25	1645	48	4.0	310	202	7.1	5.0	4	690	30	200	170	9.7	22	--	--
		80-08-27	1145	6.6	17.0	587	392	7.5	--	24	170	10	30	30	4.6	5	--	--
03020200		79-06-20	1655	34	18.0	81	--	7.1	.0	8	160	30	30	20	15	2	--	--
		79-08-10	1058	11	20.0	115	68	6.2	.0	10	300	40	30	20	18	3	20000	1200
		80-03-25	1515	176	4.5	60	42	6.7	5.0	2	430	20	150	120	16	14	--	--
		80-08-27	1300	29	18.0	90	54	7.2	--	12	230	40	30	30	18	1	--	--
03020250		79-06-21	1245	9.8	15.0	362	--	7.7	.0	32	350	120	110	100	8.7	11	--	--
		79-08-08	1720	10	21.0	360	248	7.6	.0	32	840	180	130	80	7.0	6	12000	870
		80-03-27	1020	66	3.5	198	114	7.2	5.0	20	390	60	150	130	9.1	7	--	--
		80-08-22	1330	17	15.5	343	227	7.6	--	26	430	170	110	100	6.3	5	--	--
03020428		79-07-03	1730	13	20.5	144	--	7.3	.0	40	300	100	20	<10	14	2	--	--
		79-08-08	1505	4.8	25.0	165	101	8.9	.0	48	250	40	20	<10	12	6	25000	820
		80-03-25	0815	120	3.5	85	59	6.0	5.0	18	230	150	30	30	14	10	--	--
		80-08-26	1400	14	19.0	145	86	8.2	--	68	280	30	10	0	13	5	--	--
03020438		79-07-03	1430	5.1	18.0	98	--	6.4	.0	22	3100	1700	260	230	8.8	10	--	--
		79-08-08	1100	2.2	20.0	125	95	7.1	.0	24	3200	1200	330	300	8.9	22	18000	580
		80-03-27	1500	27	5.0	65	40	6.6	5.0	8	520	130	50	40	11	9	--	--
		80-08-18	1400	5.6	17.5	89	63	7.2	--	18	17000	680	120	110	9.6	11	--	--

Water quality at surface-water sites in Area 2 (continued).

STATION NUMBER	DATE OF SAMPLE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	TEMPER-ATURE (DEG C)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)	PH (UNITS)	ACIDITY (MG/L AS CACO3)	ALKA-LINITY FIELD (MG/L AS CACO3)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE)	IRON, DIS-SOLVED (UG/L AS FE)	MANGA-NESE, TOTAL RECOV-ERABLE (UG/L AS MN)	MANGA-NESE, DIS-SOLVED (UG/L AS MN)	SULFATE DIS-SOLVED (MG/L AS SO4)	SEDI-MENT, SUS-PENDED (MG/L)	IRON, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS FE)	MANGA-NESE, RECOV. FM BOT-TOM MA-TERIAL (UG/G)
03020445	79-07-03	1325	6.3	16.0	93	--	6.4	.0	8	1000	540	50	30	9.5	3	--	--
	79-08-08	0915	5.1	18.0	105	66	7.4	.0	32	1200	510	70	70	9.0	--	25000	630
	80-03-27	1400	40	6.0	55	36	7.1	5.0	16	1000	70	140	100	10	5	--	--
	80-08-18	1545	11	16.0	74	81	7.5	--	18	460	190	30	20	8.8	6	--	--
03020455	79-07-03	1600	11	18.0	200	--	6.0	.0	24	470	180	40	20	11	2	--	--
	79-08-08	1245	15	20.5	150	82	7.7	.0	24	930	160	60	30	10	16	75000	110
	80-03-27	1230	82	4.5	85	52	7.2	.0	12	250	80	20	20	12	4	--	--
	80-08-18	1145	25	15.0	150	51	7.5	--	20	350	140	40	30	10	5	--	--
03020500	79-09-13	1100	59	18.5	260	--	7.9	.0	76	290	50	40	<10	16	4	--	--
	79-12-20	1100	254	.0	105	--	7.3	.0	24	160	70	20	20	17	7	--	--
	80-04-28	1600	470	9.5	150	91	8.6	--	34	250	80	10	10	14	3	--	--
	80-06-17	1000	459	16.0	140	74	7.6	--	8	790	160	50	20	12	15	--	--
	80-08-01	1100	338	20.0	170	87	7.3	--	42	940	170	60	20	14	21	--	--
	80-09-17	1515	154	19.0	230	121	6.9	5.0	36	310	80	40	30	16	126	--	--
03020510	79-06-21	1535	5.6	20.0	200	--	7.9	.0	30	180	40	20	<10	15	4	--	--
	79-08-10	0845	2.5	19.0	250	144	7.7	.0	42	120	20	20	<10	16	3	11000	390
	80-03-25	0700	51	6.0	105	67	7.4	5.0	22	150	80	50	40	14	8	--	--
	80-08-26	0730	6.9	16.0	160	102	7.2	--	32	--	10	--	0	14	1	--	--
03021610	79-07-04	1110	5.7	16.0	106	--	6.6	.0	62	1100	450	160	100	15	11	--	--
	79-08-07	1350	2.2	20.0	200	126	7.7	.0	58	850	360	110	70	15	7	13000	500
	80-03-26	1030	26	2.0	116	70	7.7	5.0	26	400	100	40	40	17	7	--	--
	80-08-26	1600	3.4	20.0	200	126	7.4	--	74	840	240	60	50	14	4	--	--
03022100	79-07-04	1415	12	17.0	264	--	7.1	.0	68	520	90	60	30	21	7	--	--
	79-08-07	0840	2.1	17.5	300	181	7.8	.0	110	370	60	90	60	21	5	810	300
	80-03-26	0840	31	2.0	117	94	7.2	5.0	44	250	60	30	20	20	8	--	--
	80-08-27	0745	6.8	17.5	265	161	7.9	--	108	310	60	30	30	19	3	--	--
03022540	79-07-04	1230	16	16.0	202	--	6.5	.0	62	1200	280	60	30	17	9	--	--
	79-08-07	1110	5.7	19.0	335	130	8.0	.0	76	640	250	60	40	17	6	12000	560
	80-03-26	0730	88	2.0	112	63	7.1	5.0	28	400	70	30	20	17	10	--	--
	80-08-27	0945	16	17.0	197	118	7.7	--	58	480	180	30	10	15	6	--	--
03023301	79-07-04	1720	8.4	18.5	378	--	7.4	.0	78	920	100	70	30	26	24	--	--
	79-08-06	1615	4.0	24.5	400	250	8.2	.0	84	550	120	70	50	28	6	14000	520
	80-03-25	1700	20	4.0	240	151	7.2	5.0	40	500	70	50	40	25	15	--	--
	80-08-27	1200	1.5	20.0	425	262	8.3	--	116	390	70	50	50	27	1	--	--
03023338	79-07-04	1520	24	18.0	322	--	--	--	78	--	--	--	--	--	46	--	--
	79-08-06	1455	12	23.0	340	185	7.7	.0	80	830	140	90	70	22	19	7700	180
	80-03-26	1300	38	4.5	179	115	7.4	5.0	48	360	70	30	30	21	12	--	--
	80-08-27	1430	4.3	20.5	357	210	8.0	--	110	800	30	110	90	23	21	--	--
03023400	79-07-05	0910	31	14.0	221	--	7.4	.0	74	650	210	40	<10	19	8	--	--
	79-08-06	1300	16	22.0	270	154	8.6	.0	76	400	100	20	<10	20	7	26000	570

Water quality at surface-water sites in Area 2 (continued).

STATION NUMBER	DATE OF SAMPLE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	TEMPER-ATURE (DEG C)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)	PH (UNITS)	ACIDITY (MG/L AS CACO3)	ALKA-LINITY FIELD (MG/L AS CACO3)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE)	IRON, DIS-SOLVED (UG/L AS FE)	MANGA-NESE, TOTAL RECOV-ERABLE (UG/L AS MN)	MANGA-NESE, DIS-SOLVED (UG/L AS MN)	SULFATE DIS-SOLVED (MG/L AS SO4)	SEDI-MENT, SUS-PENDED (MG/L)	IRON, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS FE)	MANGA-NESE, RECOV. FM BOT-TOM MA-TERIAL (UG/G)
03023400	80-03-25	1545	218	3.0	125	86	7.4	5.0	32	680	70	40	20	19	19	--	--
	80-08-27	1545	25	20.5	210	132	9.2	--	58	430	50	10	10	17	3	--	--
03024003	79-07-05	--	10	13.0	162	--	7.2	.0	60	540	160	30	<10	23	2	--	--
	79-08-09	1440	4.1	19.0	200	129	7.4	.0	62	230	60	<10	<10	18	5	41000	760
	80-03-25	1430	50	4.0	115	80	7.3	5.0	26	220	60	20	10	20	8	--	--
	80-08-25	1100	9.2	15.5	190	113	7.7	--	64	430	130	20	10	18	4	--	--
03024200	79-07-04	0930	4.3	13.0	148	--	7.1	.0	40	340	120	20	<10	15	3	--	--
	79-08-07	1530	.76	24.0	180	107	9.0	.0	56	210	20	20	<10	17	4	26000	470
	80-03-25	1130	49	3.0	75	54	6.5	5.0	16	520	300	30	30	14	14	--	--
	80-08-26	1115	5.0	17.0	115	84	8.1	--	62	270	60	10	0	14	1	--	--
03024210	79-07-05	1425	6.2	14.0	152	--	7.1	.0	34	520	120	30	20	14	2	--	--
	79-08-07	1705	9.0	18.5	115	73	7.6	.0	24	350	120	30	20	12	3	24000	360
	80-03-25	1000	79	3.0	75	43	6.3	5.0	10	320	70	40	40	13	10	--	--
	80-08-26	0930	6.5	16.5	130	81	7.4	--	44	330	180	40	50	13	2	--	--
03024300	79-07-05	1230	21	16.0	156	--	7.5	.0	58	660	90	120	<10	10	12	--	--
	79-08-09	1230	8.6	20.5	170	105	8.1	.0	64	280	20	50	<10	10	8	66000	950
	80-03-25	1230	116	3.5	100	66	6.7	5.0	22	310	60	30	20	16	7	--	--
	80-08-25	1500	22	22.0	140	94	8.9	--	51	330	90	40	10	9.5	3	--	--
03025200	79-07-05	1600	2.3	14.0	164	--	6.2	.0	22	400	60	50	20	14	5	--	--
	79-08-09	1035	1.3	17.0	180	114	6.9	.0	28	340	60	30	20	13	6	7800	280
	80-03-24	1515	23	7.0	96	56	6.8	5.0	10	540	30	40	20	15	22	--	--
	80-08-25	1245	4.4	16.0	138	82	7.2	--	20	230	50	20	30	14	5	--	--
03025505	79-07-05	1730	5.3	14.0	325	--	6.9	.0	28	520	100	80	40	16	6	--	--
	79-08-09	0850	3.5	18.0	300	213	8.1	.0	54	420	70	80	40	15	7	21000	1100
	80-03-24	1700	40	6.0	290	170	7.3	5.0	14	370	50	130	120	18	11	--	--
	80-08-25	1630	5.1	17.5	410	221	7.1	--	40	260	60	30	40	14	3	--	--
03025790	79-06-21	1730	9.8	18.0	273	--	4.6	.0	1	450	170	1800	1800	92	1	--	--
	79-08-10	1510	6.1	20.0	360	204	4.7	.0	0	550	130	2500	2500	120	--	11000	80
	80-03-25	1345	106	4.5	100	64	6.3	5.0	4	1500	810	480	470	30	11	--	--
	80-08-26	0845	15	16.0	217	156	5.2	10	2	580	240	1300	1300	70	1	--	--
03025810	79-06-15	0955	2.8	13.0	290	--	7.2	.0	27	510	220	150	130	32	3	--	--
	79-07-31	1015	3.1	19.0	200	133	6.9	.0	20	1700	150	150	90	30	1	9700	490
	80-03-24	1700	29	6.0	125	68	6.9	5.0	10	670	150	160	140	26	12	--	--
	80-08-26	1015	3.7	15.0	179	106	7.4	--	26	490	150	90	90	28	3	--	--
03026005	79-06-21	0825	--	14.5	240	--	7.3	.0	96	3200	240	330	300	38	234	--	--
	79-08-21	1045	2.2	18.5	395	106	7.0	.0	98	870	140	190	190	53	12	24000	480
	80-03-24	1230	4.1	6.0	125	73	6.6	5.0	14	150	10	10	10	25	4	--	--
	80-08-28	1130	.46	17.0	170	110	7.3	--	36	420	20	20	10	30	7	--	--
03026100	79-07-05	0930	10	10.5	195	--	6.8	.0	44	280	60	30	20	21	2	--	--
	79-08-09	1645	7.4	20.0	175	111	7.4	.0	46	230	50	20	<10	17	4	22000	400

Water quality at surface-water sites in Area 2 (continued).

STATION NUMBER	DATE OF SAMPLE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	TEMPER-ATURE (DEG C)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)	PH (UNITS)	ACIDITY (MG/L AS CACO3)	ALKA-LINITY FIELD (MG/L AS CACO3)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE)	IRON, DIS-SOLVED (UG/L AS FE)	MANGA-NESE, TOTAL RECOV-ERABLE (UG/L AS MN)	MANGA-NESE, DIS-SOLVED (UG/L AS MN)	SULFATE DIS-SOLVED (MG/L AS SO4)	SEDI-MENT, SUS-PENDED (MG/L)	IRON, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS FE)	MANGA-NESE, RECOV. FM BOT-TOM MA-TERIAL (UG/G)
03026100	80-03-24	1330	56	6.0	115	65	6.6	5.0	20	230	50	20	20	21	7	--	--
	80-08-25	0900	15	15.5	155	92	7.3	--	40	320	70	20	10	17	2	--	--
03026200	79-06-16	--	19	20.0	475	--	7.3	.0	34	300	40	2200	2200	170	5	--	--
	79-07-31	1100	12	19.0	640	449	6.7	.0	16	--	30	--	2100	180	1	23000	1200
	80-03-25	0930	105	4.0	330	198	6.8	5.0	4	1500	1000	1300	1300	94	9	--	--
	80-08-26	1400	18	19.5	598	434	7.3	--	16	250	10	2100	2000	180	1	--	--
03026300	79-06-16	0800	6.3	14.5	168	--	7.2	.0	24	830	20	90	20	46	10	--	--
	79-07-31	1320	5.8	19.0	190	125	7.2	.0	24	610	60	40	<10	180	14	12000	1700
	80-03-25	1130	39	3.5	130	76	7.4	5.0	20	650	90	100	80	29	5	--	--
	80-08-26	1145	3.2	17.0	191	114	7.7	--	32	510	40	30	20	38	8	--	--
03026500	79-06-13	0900	6.7	8.0	<50	--	6.4	.0	4	80	<10	30	30	7.8	1	--	--
	79-08-01	0915	13	17.0	30	28	6.9	.0	4	400	30	110	70	8.5	12	9600	140
	79-08-03	0940	--	--	--	--	--	--	--	--	--	--	--	--	--	52000	760
	80-03-26	0900	31	3.0	50	25	6.7	5.0	10	200	10	100	80	8.9	4	--	--
	80-08-20	0830	6.8	11.5	32	4	6.3	11	10	140	20	40	40	8.8	1	--	--
03027550	79-06-13	1425	4.1	13.5	61	--	6.9	.0	11	340	150	30	<10	10	3	--	--
	79-08-01	1445	2.5	22.5	71	46	7.5	.0	20	900	330	30	40	10	2	26000	530
	80-03-26	1020	35	2.5	50	37	6.8	5.0	--	640	40	40	20	11	19	--	--
	80-08-20	1310	10	16.0	60	33	8.1	--	15	550	150	40	40	10	14	--	--
03027610	79-06-13	1515	5.3	16.0	385	--	4.4	.0	<1	260	160	4100	4100	160	1	--	--
	80-03-26	0945	30	2.5	150	122	4.6	5.0	1	400	220	1300	1400	58	5	--	--
	80-08-20	1200	5.1	16.0	435	--	4.7	15	1	240	120	4100	4200	180	--	--	--
03027830	79-06-13	1015	22	9.0	104	--	7.4	.0	24	180	50	30	20	9.1	4	--	--
	79-08-01	1045	41	18.0	92	76	6.9	.0	14	1600	130	110	130	5.0	29	11000	310
	80-03-26	1110	109	3.0	65	52	6.9	5.0	16	240	30	40	20	9.6	3	--	
	80-08-20	0945	29	13.5	100	39	7.0	--	23	290	70	20	10	11	10	--	--
03027990	79-06-13	1115	11	9.5	95	--	7.6	.0	23	250	70	50	30	7.9	3	--	--
	79-08-01	1215	14	18.0	115	70	7.0	.0	8	880	140	140	130	16	14	9200	230
	80-03-26	1150	51	4.0	63	52	6.9	5.0	17	280	40	70	50	9.6	13	--	--
	80-08-20	1050	16	12.0	85	30	5.8	20	22	300	40	40	30	9.1	11	--	--
03028520	79-06-13	1315	5.6	12.0	67	--	7.5	.0	--	120	<10	20	<10	12	1	--	
	79-08-01	1700	3.3	22.5	76	48	7.2	.0	14	270	40	20	20	11	3	21000	220
	80-03-26	1345	45	3.5	55	48	6.9	5.0	14	210	10	40	30	13	4	--	--
	80-08-20	1530	7.6	16.0	62	36	7.2	--	13	300	30	10	10	11	1	--	--
03028595	79-06-13	1230	4.4	15.0	58	--	6.8	.0	--	260	50	100	100	10	4	--	--
	79-08-01	1600	3.8	25.5	70	55	7.5	.0	10	760	20	50	30	5.0	4	5100	320
	80-03-26	1240	28	3.5	50	38	6.5	10	8	190	40	180	180	12	4	--	--
	80-08-20	1430	4.7	18.5	70	36	6.4	10	16	310	40	80	80	10	1	--	--
03028800	79-06-13	1800	7.1	13.0	365	--	3.8	60	--	3500	3000	5900	5900	140	7	--	--
	79-08-01	1930	20	21.5	185	108	4.3	20	--	3300	480	1800	1900	61	24	25000	150

Water quality at surface-water sites in Area 2 (continued).

STATION NUMBER	DATE OF SAMPLE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	TEMPER-ATURE (DEG C)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)	PH (UNITS)	ACIDITY (MG/L AS CACO3)	ALKA-LINITY FIELD (MG/L AS CACO3)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE)	IRON, DIS-SOLVED (UG/L AS FE)	MANGA-NESE, TOTAL RECOV-ERABLE (UG/L AS MN)	MANGA-NESE, DIS-SOLVED (UG/L AS MN)	SULFATE DIS-SOLVED (MG/L AS SO4)	SEDI-MENT, SUS-PENDED (MG/L)	IRON, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS FE)	MANGA-NESE, RECOV. FM BOT-TOM MA-TERIAL (UG/G)
03028800	80-03-26	1440	39	3.0	110	78	4.2	15	0	1900	1700	1200	1200	40	3	--	--
	80-08-20	1745	3.9	16.0	460	270	3.4	5.0	0	1200	990	6700	6800	170	9	--	--
03028803	79-06-13	1650	24	17.0	230	--	6.1	.0	5	1500	540	1900	2100	73	11	--	--
	79-08-01	1830	56	23.0	270	117	6.7	.0	4	3100	110	1100	1100	51	40	28000	230
	80-03-26	1515	165	3.5	110	68	6.6	5.0	6	1000	510	610	610	31	10	--	--
	80-08-20	1700	30	19.0	215	113	6.3	1.0	7	500	50	1200	1300	56	16	--	--
03029120	79-06-14	1635	12	20.0	59	--	6.9	.0	8	290	50	100	70	120	2	--	--
	79-08-15	0845	14	18.5	50	43	7.1	.0	12	400	140	110	30	7.9	--	40000	1100
	80-03-25	0830	160	3.0	49	32	5.5	5.0	4	440	20	260	200	9.6	1	--	--
	80-08-20	0900	18	21.0	<50	28	6.9	--	15	280	130	80	90	9.8	4	--	--
03029140	79-06-15	1000	11	12.5	650	--	3.6	--	<1	8200	7300	3700	3900	280	7	--	--
	79-08-03	0755	21	16.5	360	206	4.4	25	--	3200	2200	2500	2400	130	9	58000	<10
	80-03-24	1245	56	3.0	247	146	5.3	10	6	2400	2100	1200	1300	79	11	--	--
	80-08-18	1400	8.1	16.0	520	391	4.5	--	0	6200	5900	3400	3500	240	31	--	--
03029144	79-06-15	1115	5.2	14.0	340	--	7.1	.0	16	190	30	1900	1900	120	1	--	--
	79-08-03	0940	9.6	17.0	300	212	6.8	.0	8	280	40	4000	4100	120	--	--	--
	80-03-24	1100	44	4.5	220	142	6.8	5.0	7	600	300	1600	1800	73	12	--	--
	80-08-18	1130	6.3	16.0	290	207	7.0	--	15	180	40	1700	1800	110	3	--	--
03029149	79-06-15	--	14	16.0	360	--	7.7	.0	36	400	<10	230	260	120	3	--	--
	79-08-03	1110	13	18.5	410	248	7.6	.0	40	940	50	290	240	130	17	40000	990
	80-03-24	1400	68	5.0	236	162	7.0	5.0	12	800	410	280	310	71	11	--	--
	80-08-18	1630	29	15.5	320	217	7.0	--	--	480	110	280	300	110	9	--	--
03029180	79-06-14	1545	17	18.0	71	--	7.5	.0	16	280	110	50	20	7.8	1	--	--
	79-08-14	1830	25	17.5	60	44	7.2	.0	12	480	120	80	50	7.8	5	19000	370
	80-03-25	0930	204	3.0	44	31	6.0	5.0	3	220	40	160	160	9.7	1	--	--
	80-08-20	1030	23	17.5	60	33	7.2	--	18	330	170	30	40	8.3	3	--	--
03029182	79-06-13	0950	72	9.0	66	--	6.8	.0	12	220	160	40	40	11	2	--	--
	79-08-02	1515	19	21.0	70	37	7.3	.0	16	780	210	50	40	8.0	5	8900	60
	80-03-27	1100	124	3.5	54	47	6.4	5.0	4	150	0	90	90	9.9	2	--	--
	80-08-21	0930	33	16.5	<50	32	7.2	--	16	460	150	70	70	8.9	8	--	--
03029188	79-06-14	1255	8.6	13.5	57	--	7.0	.0	8	180	70	30	40	9.1	1	--	--
	79-08-14	1625	12	17.0	50	38	7.0	.0	8	410	100	80	50	9.1	14	1000	710
	80-03-25	1100	69	3.5	49	37	5.8	5.0	2	130	10	130	130	10	1	--	--
	80-08-20	1330	9.9	17.5	<50	32	7.1	--	17	220	140	30	30	8.8	5	--	--
03029193	79-06-13	1120	3.9	13.0	88	--	7.3	.0	20	750	240	90	90	8.2	2	--	--
	79-08-02	1700	4.9	22.5	92	40	7.3	.0	16	1400	390	120	90	8.8	10	26000	20
	80-03-27	1330	30	5.0	61	47	6.2	5.0	4	230	80	220	230	10	20	--	--
	80-08-21	1300	8.6	19.0	60	35	7.2	--	17	1200	580	90	100	8.0	12	--	--
03029250	79-06-13	1350	9.7	13.0	80	--	7.4	.0	14	690	390	20	<10	11	11	--	--
	79-08-14	1230	7.9	15.5	90	55	7.3	.0	17	880	390	40	<10	8.1	6	11000	80

STATION NUMBER	DATE OF SAMPLE	TIME	STREAM-FLOW, INSTAN-TANEOUS (CFS)	TEMPER-ATURE (DEG C)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)	PH (UNITS)	ACIDITY (MG/L AS CACO3)	ALKA-LINITY FIELD (MG/L AS CACO3)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE)	IRON, DIS-SOLVED (UG/L AS FE)	MANGA-NESE, TOTAL RECOV-ERABLE (UG/L AS MN)	MANGA-NESE, DIS-SOLVED (UG/L AS MN)	SULFATE DIS-SOLVED (MG/L AS SO4)	SEDI-MENT, SUS-PENDED (MG/L)	IRON, RECOV. FM BOT-TOM MA-TERIAL (UG/G AS FE)	MANGA-NESE, RECOV. FM BOT-TOM MA-TERIAL (UG/G)
03029250	80-03-27	1430	55	5.0	64	37	6.6	5.0	2	240	80	90	90	12	4	--	--
	80-08-21	1500	11	18.0	70	41	7.6	--	18	520	330	30	30	11	4	--	--
03029400	79-06-13	1540	8.4	13.0	89	--	6.7	.0	4	180	60	180	200	24	1	--	--
	79-08-14	1100	5.5	15.0	120	78	6.8	.0	5	450	110	200	260	27	7	12000	370
	80-03-27	1600	30	5.0	74	55	6.0	5.0	2	240	90	200	200	17	1	--	--
	80-08-22	1000	6.2	16.0	85	57	6.9	--	12	290	150	140	160	23	7	--	--
03029510	79-06-13	1710	11	14.5	88	--	7.5	.0	18	180	80	40	<10	8.8	2	--	--
	79-08-14	0900	6.3	15.5	120	65	6.6	.0	32	630	180	100	70	10	12	10000	140
	80-03-28	0730	43	3.0	69	47	6.8	5.0	6	240	120	100	100	13	2	--	--
	80-08-22	0800	12	16.0	75	43	7.3	--	23	350	10	40	30	9.9	6	--	--
03029700	79-06-22	0950	18	16.5	800	--	3.2	--	<1	3700	3600	9500	9500	300	4	--	--
	79-08-13	1655	27	19.0	560	336	3.5	40	--	3500	2200	6000	970	190	10	99000	240
	80-03-28	0900	120	3.5	287	170	4.4	20	0	3200	2900	2700	2700	97	9	--	--
	80-08-22	1200	63	17.5	480	298	4.1	30	0	2700	2000	5500	5800	190	9	--	--
03030105	79-06-22	1155	24	17.0	1080	--	3.3	--	<1	28000	26000	13000	13000	490	41	--	--
	79-08-13	1340	25	17.5	1000	800	3.3	169	--	23000	22000	15000	1000	420	25	57000	90
	80-03-28	1030	78	4.5	547	357	3.7	65	0	11000	11000	6000	6200	210	9	--	--
	80-08-23	0800	25	15.5	900	670	3.7	144	0	18000	16000	12000	13000	410	14	--	--
03030365	79-06-22	1325	37	19.0	660	--	3.3	--	<1	2500	2500	3500	3700	200	4	--	--
	79-08-13	1510	37	18.5	500	266	3.4	45	--	2200	100	2900	890	160	5	28000	90
	80-03-28	1200	136	4.5	302	189	4.3	30	0	3100	3000	1800	1900	100	8	--	--
	80-08-23	0930	61	16.0	390	219	4.2	40	0	1200	1100	2500	2800	130	5	--	--
03030570	79-06-14	1710	11	17.0	375	--	7.2	.0	16	500	<10	2300	2400	140	20	--	--
	79-08-10	0940	10	18.5	390	284	6.6	.0	12	300	<10	1700	1700	140	17	25000	2000
	80-04-02	0800	119	5.5	200	146	6.5	5.0	4	1400	420	1200	1200	62	41	--	--
	80-08-22	1400	21	17.0	375	253	7.2	--	18	320	50	2100	2200	140	9	--	--
03030580	79-06-14	1440	8.6	15.0	1050	--	3.3	50	<1	7300	6800	15000	15000	600	11	--	--
	79-08-10	0855	6.6	18.5	1250	963	3.1	79	--	4000	3500	18000	18000	540	16	100000	480
	80-03-28	1630	22	6.5	933	653	3.8	60	0	6300	6100	12000	13000	400	9	--	--
	80-08-22	1600	13	18.0	1000	758	3.7	139	0	2700	2500	14000	15000	490	9	--	--
03030803	79-06-15	1500	6.2	20.0	475	--	7.3	.0	34	700	160	1100	1100	79	6	--	--
	79-08-09	1800	3.7	20.0	400	262	6.7	.0	44	700	100	1200	1200	87	11	82000	2000
	80-03-28	1330	22	5.5	241	144	7.3	5.0	16	780	480	520	530	47	9	--	--
	80-08-23	1100	12	17.5	270	170	7.3	--	83	460	190	570	590	49	8	--	--
03030900	79-06-15	1200	30	17.5	1400	--	5.3	.0	3	5800	3900	13000	14000	910	25	--	--
	79-08-09	1210	15	21.0	1800	1800	3.5	55	--	3900	2600	22000	22000	1100	19	89000	1100
	80-03-28	1500	103	6.5	1000	753	7.0	10	16	9500	8700	7200	7500	490	33	--	--
	80-08-26	0830	51	19.0	1300	1210	6.3	--	--	3400	910	12000	13000	820	24	--	--
03030948	79-06-15	1320	5.8	17.5	430	--	7.8	.0	48	700	50	120	70	110	9	--	--
	79-08-09	1455	2.2	21.0	482	286	6.7	.0	50	370	30	40	40	110	1	66000	2000
03030948	80-03-24	1530	33	6.0	210	117	7.1	.0	21	880	1200	180	150	45	12	--	--
	80-08-25	1630	3.9	21.5	340	224	8.0	--	46	390	90	40	40	70	2	--	--

Benthic invertebrate data, Area 2, August 1979.

Station reference No.	Number of individuals in taxon																	
	Hemi-ptera	Coleo-ptera	Dip-tera	Ephemer-optera	Trichop-tera	Plecop-tera	Mega-loptera	Odon-ata	Amphi-poda	Aca-rina	Deca-poda	Ara-neida	Unknown Order (Annelida)	Plesio-pora	Oligo-chaeta	Basomma-tophora	Nucu-loidea	Diversity index
1	2	2	8	3	28	19	13	0	0	0	0	0	0	0	0	0	0	2.3
2	0	6	10	20	17	13	1	0	1	0	0	0	0	0	0	0	0	2.4
3	0	4	6	8	33	17	0	0	0	0	0	0	0	0	0	0	0	2.1
4	3	2	10	31	20	8	1	0	0	0	0	0	0	0	0	0	0	2.2
6	2	1	4	5	57	25	1	2	0	0	0	0	0	0	0	0	0	1.7
7	0	0	9	9	22	9	2	2	0	0	0	0	0	0	0	0	0	2.2
8	0	17	23	3	45	7	1	1	0	0	0	0	0	0	0	0	0	2.0
9	0	0	11	1	31	17	13	0	0	0	0	0	0	0	0	0	0	2.0
10	1	0	17	13	3	15	0	3	0	0	0	0	0	0	0	0	0	2.1
11	0	0	3	0	4	0	0	0	0	0	0	0	1	0	0	0	0	1.4
13	1	4	9	3	4	11	4	5	0	0	0	0	0	0	0	0	0	2.7
14	2	2	7	1	4	4	0	0	0	0	0	0	0	0	0	0	0	2.3
15	1	0	1	4	1	7	0	2	0	0	0	0	0	0	0	0	0	2.1
16	0	2	10	10	17	26	3	0	0	0	0	0	0	0	0	0	0	2.2
17	2	0	15	3	72	17	2	1	0	0	0	0	0	0	0	0	0	1.6
18	0	0	1	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0.4
20	0	0	2	0	20	13	2	0	0	0	0	0	0	0	0	0	0	1.5
21	0	0	5	9	23	0	1	0	0	0	0	0	0	0	0	0	0	1.5
22	0	2	2	7	18	3	3	0	0	0	0	0	2	0	0	0	0	2.2
23	0	0	1	13	1	0	0	0	0	0	0	0	2	0	0	0	0	1.1
24	0	25	23	25	102	9	3	0	0	0	0	0	1	0	0	0	0	2.0
25	0	19	30	6	16	3	14	0	0	0	0	0	1	0	0	0	0	2.4
26	0	1	13	6	11	6	4	0	0	0	0	0	0	0	0	0	0	2.3
27	0	0	30	12	33	0	12	2	0	0	0	0	0	0	0	0	0	2.0
29	0	0	2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1.5
31	0	4	10	9	8	3	4	0	0	0	0	0	0	0	0	0	0	2.4
33	0	18	29	14	139	1	3	0	0	0	0	0	0	0	0	0	0	1.5
34	0	8	40	62	16	1	8	2	0	0	0	0	0	0	0	0	0	2.0
35	0	3	32	0	28	0	0	0	0	0	0	0	0	0	0	4	0	1.5
36	1	2	1	0	2	0	0	0	1	0	0	0	0	0	0	0	0	2.2
37	1	4	23	11	46	5	7	0	0	0	0	0	0	0	0	0	0	2.1
39	0	2	17	16	43	10	0	2	0	0	0	0	0	0	0	0	0	2.0
40	0	7	23	15	102	22	2	0	0	0	0	0	0	0	0	0	0	1.8
41	0	6	8	15	7	2	11	0	0	0	0	0	0	0	0	0	0	2.4
42	0	2	23	16	41	4	7	0	0	0	0	0	0	0	0	0	0	2.1
44	0	1	3	9	23	1	0	0	1	0	0	0	0	0	0	0	0	1.6
46	0	0	8	2	26	0	1	0	0	0	0	0	1	0	0	0	0	1.3
47	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.0
48	0	0	2	2	11	2	0	0	0	0	0	0	0	1	0	0	0	1.7
49	0	3	3	1	5	0	0	0	0	0	0	0	1	0	0	0	1	2.3
50	3	4	53	27	30	0	3	0	0	1	0	0	1	0	0	1	0	2.1

Benthic invertebrate data, Area 2, August 1979.

Station reference No.	Number of individuals in taxon																	Diversity index
	Hemi- ptera	Coleo- ptera	Dip- tera	Ephemer- optera	Trichop- tera	Plecop- tera	Mega- loptera	Odon- ata	Amphi- poda	Aca- rina	Deca- poda	Ara- neida	Unknown Order (Annelida)	Plesio- pora	Oligo- chaeta	Basomma- tophora	Nucu- loidea	
51	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0.0
52	0	0	8	23	6	7	0	0	0	0	0	0	0	0	0	0	0	1.8
53	0	1	3	3	0	21	0	0	0	0	1	0	0	0	0	0	0	1.3
55	0	0	4	4	21	1	0	0	0	0	1	0	0	0	0	0	0	1.5
56	0	1	1	0	0	0	2	0	0	0	1	0	0	0	1	0	0	0.0
57	5	0	1	11	0	0	0	0	0	0	1	0	0	0	0	0	0	1.4
58	1	0	3	0	0	4	0	0	0	0	1	1	0	0	0	0	0	2.0
61	0	0	1	5	33	3	0	0	0	0	1	0	0	0	0	0	0	1.2
62	1	0	4	2	3	0	0	0	0	0	1	0	0	0	0	0	0	2.1
63	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
64	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1.0
65	0	0	3	29	4	2	0	5	0	0	0	0	0	0	0	0	0	1.5
66	3	0	18	30	3	3	11	0	0	0	0	0	0	0	0	0	0	2.0
67	0	0	3	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1.4
68	12	0	3	2	6	5	0	2	0	0	0	0	0	0	0	0	0	2.3
69	0	2	5	2	0	0	3	1	0	0	0	0	0	0	0	0	0	2.1
70	0	0	1	12	1	0	1	0	0	0	0	0	0	0	0	0	0	1.0
71	1	2	4	41	0	6	0	1	0	0	0	0	0	0	0	0	0	1.3
72	3	0	9	12	9	7	1	0	0	0	0	0	0	0	0	1	0	2.4
73	0	2	7	6	6	10	0	0	0	0	0	0	0	0	0	0	0	2.2
74	1	0	10	28	7	8	0	5	0	0	1	0	0	0	0	0	0	2.2
76	0	0	11	16	9	10	6	0	0	0	0	0	0	0	0	0	0	2.3
77	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0.0
78	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0.0
79	25	0	3	0	2	0	19	0	0	0	0	0	0	0	0	0	0	1.5
81	0	0	2	26	11	0	0	0	0	0	0	0	0	0	0	0	0	1.1
82	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	---
83	0	1	6	29	4	0	0	0	0	0	0	0	0	0	0	0	0	1.2
84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	---
85	1	1	10	32	16	2	0	0	0	0	0	0	0	0	0	0	0	1.8

Benthic invertebrate data[1], Area 2, August 1980.

Station reference No.	Ephemer-optera	Odon-ata	Plecop-tera	Mega-loptera	Trichop-tera	Coleo-ptera	Dip-tera	Taxon Amphi-poda	Gastro-poda	Hiru-dinea	Oligo-chaeta	Anne-lida	Nema-toda	Hemip-tera	Deca-poda	Hydra-carina
1	P	-	P	P	P	-	P	-	-	-	-	-	-	P	P	-
2	P	-	P	-	P	P	P	-	-	-	P	-	-	P	P	P
3	P	-	P	-	P	P	-	-	-	-	P	-	-	P	P	-
4	P	P	P	P	P	-	P	-	-	-	P	-	-	-	P	-
6	P	-	P	P	P	P	-	-	-	-	-	-	-	-	P	-
7	P	-	P	-	P	P	P	-	-	-	P	-	-	P	-	-
8	P	P	P	P	P	P	P	-	-	-	-	-	-	-	P	-
9	P	P	-	-	P	P	P	-	-	-	-	-	-	P	P	-
10	-	-	P	P	P	-	P	-	-	-	-	-	-	P	-	-
11	P	-	P	-	P	-	P	-	P	-	P	-	-	-	-	P
14	P	P	P	-	P	P	P	-	-	-	-	-	-	-	P	-
15	P	-	P	P	P	-	P	-	P	-	-	-	-	-	-	-
16	P	P	P	-	P	P	P	-	-	-	-	-	-	-	P	-
17	P	-	P	P	P	-	P	-	-	-	-	-	-	P	P	-
18	P	-	-	-	P	-	P	-	-	-	P	-	-	-	-	-
20	P	-	P	-	P	P	P	-	-	-	-	-	-	P	P	-
21	P	P	P	P	P	-	-	-	-	-	-	-	-	-	P	-
22	P	P	-	-	P	P	P	P	-	-	P	-	-	-	-	-
23	P	-	P	-	P	P	-	-	-	-	-	-	-	-	P	P
24	P	-	P	P	-	P	P	-	-	-	-	-	-	P	-	-
25	P	-	-	P	P	-	P	-	-	-	-	-	-	-	-	-
26	P	-	-	-	P	P	P	-	-	-	-	-	-	-	-	-
27	P	-	P	-	P	-	P	-	P	-	-	-	-	-	P	-
29	P	-	P	-	-	P	-	-	-	-	-	-	-	-	-	-
31	P	-	P	-	-	P	-	-	-	-	-	-	-	P	-	-
33	P	-	P	-	-	P	P	-	-	-	-	-	-	P	-	-
34	P	-	P	P	P	-	-	-	-	-	-	-	-	P	-	-
35	P	-	P	-	P	P	P	-	-	-	P	-	-	P	-	-
36	P	-	P	-	-	P	-	-	-	-	-	-	-	-	-	-
37	P	-	P	P	-	P	P	-	-	-	-	-	-	-	-	-
39	P	-	P	-	-	P	P	-	-	-	P	-	-	-	-	-
40	P	-	P	-	P	P	-	-	P	-	P	-	-	-	-	-
41	P	P	P	-	P	P	P	-	-	-	-	-	-	P	-	-
42	P	-	P	-	P	P	-	-	-	-	P	-	-	-	-	P
44	P	-	P	-	-	P	-	-	-	-	P	-	-	-	-	-
46	P	-	P	-	P	-	-	-	-	-	P	-	-	-	-	-
47	-	-	-	-	-	P	-	-	-	-	P	-	-	-	P	-
48	P	P	-	P	-	P	P	-	-	-	-	-	-	P	P	-
49	-	-	P	-	P	P	P	-	-	-	-	-	-	P	-	-
50	P	-	P	-	P	P	P	-	-	-	P	-	-	P	-	-

Benthic invertebrate data[1], Area 2, August 1980 (continued).

Station reference No.	Ephemer-optera	Odon-ata	Plecop-tera	Mega-loptera	Trichop-tera	Coleo-ptera	Dip-tera	Taxon Amphi-poda	Gastro-poda	Hiru-dinea	Oligo-chaeta	Anne-lida	Nema-toda	Hemip-tera	Deca-poda	Hydra-carina
51	-	-	-	-	P	-	-	-	-	-	-	-	-	P	P	-
52	P	-	P	P	P	P	P	-	-	-	P	-	-	P	P	-
53	-	-	P	-	P	P	P	-	-	-	-	-	-	P	P	-
55	P	-	P	-	P	P	P	-	-	-	-	-	-	-	P	-
56	-	-	P	-	-	P	-	-	-	-	-	P	-	-	-	-
57	P	-	-	-	P	P	P	-	-	-	-	-	-	P	P	-
58	P	-	-	P	P	P	P	-	-	-	-	P	-	P	P	-
61	P	-	P	-	P	P	P	-	-	-	-	P	-	-	P	-
62	P	-	-	-	P	P	-	-	-	-	-	P	P	-	-	-
63	-	-	-	-	-	P	-	-	-	-	-	-	-	-	-	-
64	-	-	-	-	P	P	P	-	-	-	-	-	-	-	P	-
65	P	P	P	-	P	-	P	-	-	-	-	-	-	P	P	-
66	P	P	P	P	P	-	-	-	-	-	-	-	-	-	P	-
67	-	-	-	P	P	-	-	-	-	-	-	-	-	-	P	-
68	P	-	P	-	P	-	-	-	-	-	P	-	-	-	P	-
69	P	P	P	-	P	-	P	-	-	P	-	-	-	-	P	-
70	P	P	P	-	P	P	-	-	-	-	-	-	-	P	P	-
71	-	-	P	-	P	-	-	-	-	-	-	-	-	P	P	-
72	P	P	P	P	P	-	-	-	-	-	-	-	-	P	P	-
73	P	-	P	P	P	P	P	-	-	-	-	-	-	P	P	-
74	P	P	P	-	P	-	P	-	-	-	P	-	-	P	P	-
76	P	P	P	-	P	P	-	-	-	-	-	-	-	P	P	-
77	-	-	-	-	P	P	-	-	-	-	-	-	-	P	P	-
78	-	-	-	P	-	-	-	-	-	-	P	-	-	-	-	-
79	-	-	-	P	-	-	-	-	-	-	-	-	-	-	-	-
81	P	-	P	-	P	-	-	-	-	-	-	-	-	P	P	-
82	-	-	-	P	-	-	-	-	-	-	-	-	-	-	-	-
83	P	-	P	P	P	P	P	-	-	-	-	-	-	P	P	-
84	-	-	-	-	P	-	-	-	-	-	-	-	-	P	-	-
85	P	-	P	-	P	P	P	-	-	-	P	-	-	-	P	-

[1]P indicates taxon is present.

13.0 LIST OF REFERENCES

Berg, T. M., and others, 1981, Geologic map of Pennsylvania: Pennsylvania Geological Survey, 4th series, Map 1, (in press).

Bloyd, R. M., Jr., 1974, Summary appraisals of the nation's ground-water resources--Ohio region: U.S. Geological Survey Professional Paper 813-A, 41 p.

Britton, L. J., and Averett, R. C., 1974, Water-quality data of the Sacramento River, California, May 1972 to April 1973: U.S. Geological Survey Open-File Report, Menlo Park, California, U.S. Geological Survey, 30 p.

Buckwalter, T. F., Dodge, C. H., and Schiner, G. R., 1979, Selected water resources data, Clarion River and Redbank Creek basins, northwestern Pennsylvania, Part 2: U.S. Geological Survey Water-Resources Investigation 79-19, 135 p.

Buckwalter, T. F., and others, 1981, Water resources of the Clarion River and Redbank Creek basins: U.S. Geological Survey Water-Resources Investigations, (in press).

Commonwealth of Pennsylvania, 1980, Annual report on mining, oil and gas, and land reclamation and conservation activities: Department of Environmental Resources, 363 p.

Edmunds, W. E., and others, 1979, The Mississippian and Pennsylvanian (Carboniferous) systems in the United States--Pennsylvania and New York: U.S. Geological Survey Professional Paper 1110 B, 33 p.

Feltz, H. R., 1980, Significance of bottom material data in evaluating water quality: Contaminants and Sediments, Volume 1, Baker, R. A., editor, Ann Arbor, Ann Arbor Science Publishers, p. 271-287.

Fenneman, N. M., 1938, Physiography of eastern United States: McGraw Hill, New York, 714 p.

Flippo, H. N., Jr., 1977, Floods in Pennsylvania: Pennsylvania Department of Environmental Resources Water Resources Bulletin 13, 59 p.

1981, Technical manual of low-flow frequency models for streams in Pennsylvania: U.S. Geological Survey Water-Resources Investigations (in press).

Frimpter, M. H., 1974, Ground-water resources, Allegheny River basin and part of the Lake Erie basin, New York: Allegheny River Basin Regional Water Resources Planning Board Report ARB-2, 98 p.

Harvard University, 1970, Oxygenation of ferrous iron: Water Pollution Control Research Series 14010-06/69, Federal Water Quality Administration, 199 p.

Hem, J. D., 1970, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water-Supply Paper 1473, second edition, 362 p.

Herb, W. J., 1977, Channel characteristics as flood predictors for selected forested watersheds in Pennsylvania and Maryland: Unpublished M.S. thesis, Pennsylvania State University.

1981, Technical manual for estimating mean flow characteristics of Pennsylvania streams: Unpublished report on file in the Harrisburg, Pennsylvania office of the U.S. Geological Survey, Water Resources Division.

Howard, A. D., 1967, Drainage analysis in geologic interpretation, a summation: Bulletin American Association Petroleum Geologists 51, p. 2246-59.

Koester, H. E., and Miller, D. R., 1980, Ground-water quality and data on wells and springs in Pennsylvania, Volume I--Ohio and St. Lawrence River basins: U.S. Geological Survey Open-File Report 80-1119, p. 26-52.

Miller, C. R., 1951, Analysis of flow-duration, sediment-rating curve method of computing sediment yield: U.S. Department of the Interior, Bureau of Reclamation, 55 p.

National Climatic Center, 1977, Climate of Pennsylvania: Climatography of the United States No. 60, National Oceanic and Atmospheric Administration, 21 p.

Office of Resources Management, 1980, The state water plan, subbasins 14 and 16, Genesee and upper Allegheny River, Pennsylvania Department of Environmental Resources State Water Plan Bulletin 16, 202 p.

Office of Surface Mining, Reclamation, and Enforcement, 1979, Surface coal mining and reclamation operations, permanent regulatory program: Federal Register, v. 44, no. 50, book 3, 153 p.

Pennsylvania Topographic and Geologic Survey, 1929, Map of the coal fields of Pennsylvania: Commonwealth of Pennsylvania.

Porterfield, George, 1972, Computations of fluvial-sediment discharge: U.S. Geological Survey Techniques of Water Resources Investigations, Book 3, Chapter C3, 66 p.

Schiner, G. R., and Gallaher, J. T., 1979, Geology and ground-water resources of western Crawford County, Pennsylvania: Pennsylvania Geological Survey, 4th series, Water Resources Report 46, 103 p.

Schiner, G. R., and Kimmel, G. E., 1972, Mississippian stratigraphy of northwestern Pennsylvania: U.S. Geological Survey Bulletin 1331-1, 27 p.

Schumm, S. A., 1963, A tentative classification of river channels: U.S. Geological Survey Circular 477, 10 p.

Searcy, J. K., 1959, Flow-duration curves, manual of hydrology; Part 2, Low-flow techniques: U.S. Geological Survey Water-Supply Paper 1542-A, 33 p.

Skougstad, M. W., Fishman, M. J., Friedman, L. C., Erdman, D. E., and Duncan, S. S., (eds.), 1979, Methods for analysis of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 5, Chapter A1, 626 p.

Snedecor, G. W., 1957, Statistical methods, Fifth edition, Ames, Iowa State College Press, p. 174.

Soil Conservation Service, 1972, General soil map, Pennsylvania: Soil Conservation Service.

U.S. Department of Agriculture, 1977, The status of land disturbed by surface mining in the United States, basic statistics by State and county as of July 1, 1977: U.S. Department of Agriculture, 124 p.

U.S. Department of Commerce, 1973, Monthly normals of temperature, precipitation, and heating and cooling degree days 1941-70, Pennsylvania: National Oceanic and Atmospheric Administration, Environmental Data Service, Climatography of the United States, No. 81, 8 p.

U.S. Department of the Interior, 1968, Stream pollution by coal mine drainage upper Ohio River basin: Federal Water Pollution Control Administration, p. 110.

U.S. Environmental Protection Agency, 1977, National interim primary drinking water regulations: Environmental Protection Agency Report 570/9-76-003, 159 p.

U.S. Geological Survey, 1977, Water resources data for

Pennsylvania, Volume 3, Ohio and St. Lawrence River basins: U.S. Geological Survey Water-Data Report PA-76-3, Water year 1976, 262 p.

1978, Water resources data for Pennsylvania, Volume 3, Ohio and St. Lawrence River basins: U.S. Geological Survey Water-Data Report PA-77-3, Water year 1977, 272 p.

1979, Water resources data for Pennsylvania, Volume 3, Ohio and St. Lawrence River basins: U.S. Geological Survey Water-Data Report PA-78-3, Water year 1978, 310 p.

1980, Water resources data for Pennsylvania, Volume 3, Ohio and St. Lawrence River basins: U.S. Geological Survey Water-Data Report PA-79-3, Water year 1979, 386 p.

1981, Water resources data for Pennsylvania, Volume 3, Ohio and St. Lawrence River basins: U.S. Geological Survey Water-Data Report PA-80-3, Water year 1980, 304 p.

Wark, J. W., 1965, Sediment load of streams in the region, in Schneider, W. J., and others, Water resources of the Appalachian region, Pennsylvania to Alabama: U.S. Geological Survey Hydrologic Atlas HA-198.

Wilhm, J. L., and Dorris, J. C., 1968, Biological parameters for water quality criteria: BioScience, v. 18, no. 6, p. 477-480.

☆U.S. GOVERNMENT PRINTING OFFICE: 1983— 656-806