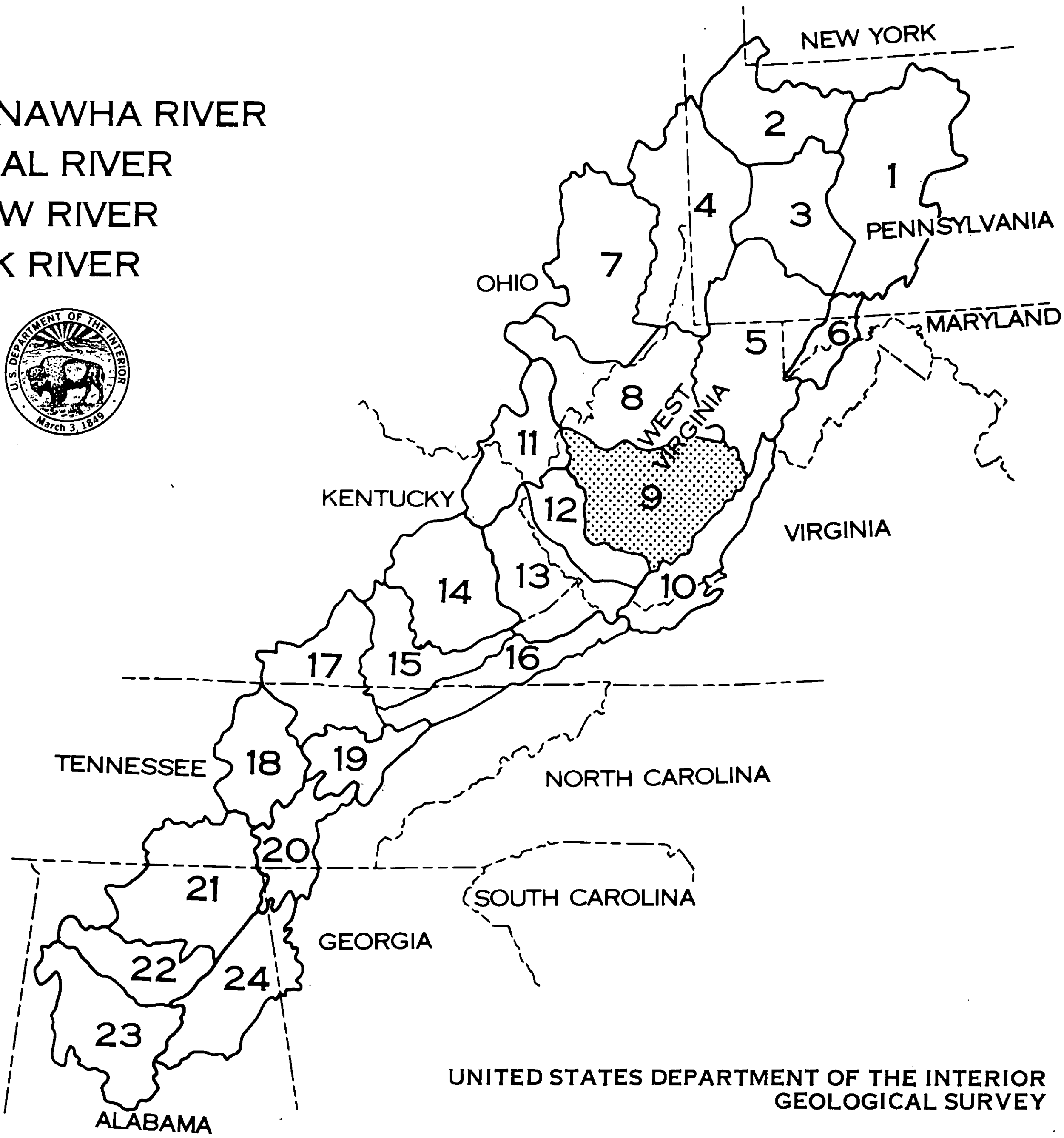
HYDROLOGY OF AREA 9, EASTERN COAL PROVINCE, WEST VIRGINIA

- KANAWHA RIVER
- COAL RIVER
- NEW RIVER
- ELK RIVER



UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 81-803

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BY
THEODORE A. EHLKE, GERALD S. RUNNER, AND SANFORD C. DOWNS

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CHARLESTON, WEST VIRGINIA
JANUARY 1982

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, *SECRETARY*

GEOLOGICAL SURVEY

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3416 Federal Building
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Charleston, West Virginia 25301

CONTENTS

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

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

Multiply inch-pound units	By	To obtain SI units
inches (in)	25.4	millimeters (mm)
inches per hour (in/h)	25.4	millimeters per hour (mm/h)
	2.54	centimeters per hour (cm/h)
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	cubic meters per second (m^3/s)
	3,785	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 per year [(tons/mi^2)/yr]	0.3503	metric tons per square kilometer per year [(t/km^2)/a]

HYDROLOGY OF AREA 9, EASTERN COAL PROVINCE, WEST VIRGINIA

BY THEODORE A. EHLKE, GERALD S. RUNNER, AND SANFORD C. DOWNS

Abstract

Area 9 is located in the Kanawha River basin and drains about 6,000 square miles in West Virginia. This report is intended to convey general hydrologic information to professionals such as hydrologists, consulting engineers, mine operators, and regulatory personnel. The report format consists of brief texts and supporting illustrations or tables on a series of hydrologic topics which together describe the hydrology of this area.

Area 9 is drained by the Kanawha, New, Pocatalico, Elk, Coal, and Gauley Rivers. The U.S. Geological Survey operates a network of 130 hydrologic data collection sites to monitor streamflow and quality-of-water conditions in the area.

Land use and land cover are strongly influenced by mountainous topography. More than 85 percent of the land cover is forest, largely because development is limited by the rugged terrain. Agricultural land use comprises 7 percent of the area, and is mostly confined to the floodplain along the Ohio and Kanawha Rivers, where land slopes are gentlest. Soils are generally shallow and are poorly drained because of sedimentary rock formations close to the surface.

Precipitation averages 43 inches in the area and is unevenly distributed, with the greatest rainfall occurring in mountainous areas and lesser amounts in the areas along the Ohio River and along the eastern boundary of the basin.

A variety of sedimentary rocks, mostly of Mississippian, Pennsylvanian, and Permian age crop out in Area 9. The major rock units from oldest to youngest include the Hinton, Princeton, and Bluestone Formations of Mississippian age; the Pottsville Group, Allegheny Formation, Conemaugh and Monongahela Groups of Pennsylvanian age; and the Dunkard Group of Permian age. The most important coal seams occur in the Pottsville, Conemaugh, and Monongahela Groups and in the Allegheny Formation. Most of the coal in Area 9 is produced from underground mines. In 1980, 469 deep mines and 255 surface mines operated in the area. Wells are the primary source of drinking water in rural areas. Most household wells have a specific capacity of less than 1 gallon per minute per foot of drawdown.

Many of the larger rivers in the area are controlled by a series of dams to lessen the chance of flooding and to maintain stage for navigation purposes. Locks on the Kanawha River at Winfield, Marmet and London and on the Ohio River and Gallipolis permit commercial traffic to operate from Point Pleasant to Kanawha Falls.

Specific conductance of surface waters in the area ranged from a mean of 60 μmhos/cm (micromhos per centimeter) at synoptic sites in the Gauley River basin to 499 μmhos/cm in the upper Kanawha River drainage. The median pH for all synoptic sites in the area was 6.9. Surface water pH was lowest in the Gauley River basin, primarily because of the low buffering capacity of the water and widespread mining activities. Sulfate concentrations ranged from 3.8 mg/L (milligrams per liter) to 880 mg/L and averaged 57 mg/L. The lowest concentrations were found in the headwaters of the Gauley River basin, where they were less than 10 mg/L. The highest concentrations were consistently found in the Coal River and upper Kanawha River drainages, usually exceeding 100 mg/L. Total iron concentrations ranged from 50 μg/L (micrograms per liter) to 260,000 μg/L in surface waters at synoptic sites, averaging 1,700 μg/L. The highest mean total iron concentration was found in the upper Kanawha River drainage (9,800 μg/L) and was more than ten times the mean concentration in the Elk River basin (590 μg/L). Dissolved manganese concentrations in surface water at synoptic sites averaged 165 μg/L. The mean dissolved manganese concentration ranged from 78 μg/L in the Elk River basin to 480 μg/L in the upper Kanawha River drainage. Most of the iron (95 percent) was transported in the suspended phase and most of the manganese (87 percent) was transported in the dissolved phase under the streamflow conditions (generally low to moderate flow) prevailing during the synoptic sampling periods in 1979 and 1980.

1.0 OBJECTIVE

Area 9 Report to Aid Permitting

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

This report provides general hydrologic information, using a brief text with an accompanying 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 information contained herein should be useful to surface-mine owners and operators, and consulting engineers in the preparation of permit applications, and regulatory authorities in appraising the adequacy of permit applications. The location of Area 9 within the State of West Virginia is shown on figure 1.1-1.

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 signed into law as Public Law 95-87, August 3, 1977.

This report broadly characterizes the hydrology of Area 9 as delineated in figure 1.1-1. 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 and data from other sources. It will provide a more detailed picture of the hydrology in the vicinity of the mine and the anticipated hydrologic consequences of the mining operation.

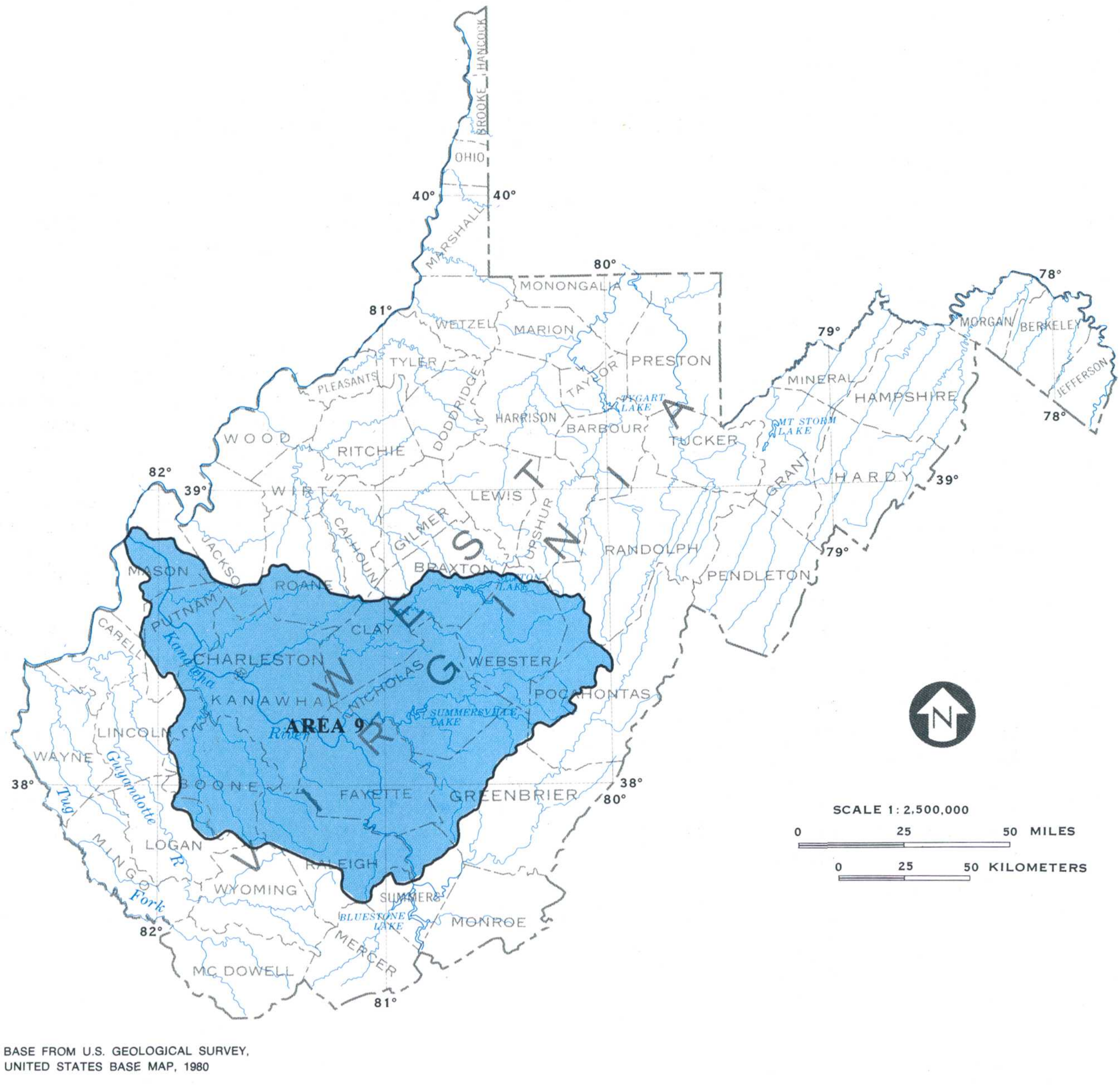


Figure 1.1-1 Area 9 location map

1.0 OBJECTIVE

2.0 GENERAL FEATURES
2.1 Surface Drainage

The Kanawha River Drains Area 9

The Kanawha River and five major river tributaries -- the Coal, Elk, Pocatalico, Gauley, and New, drain Area 9.

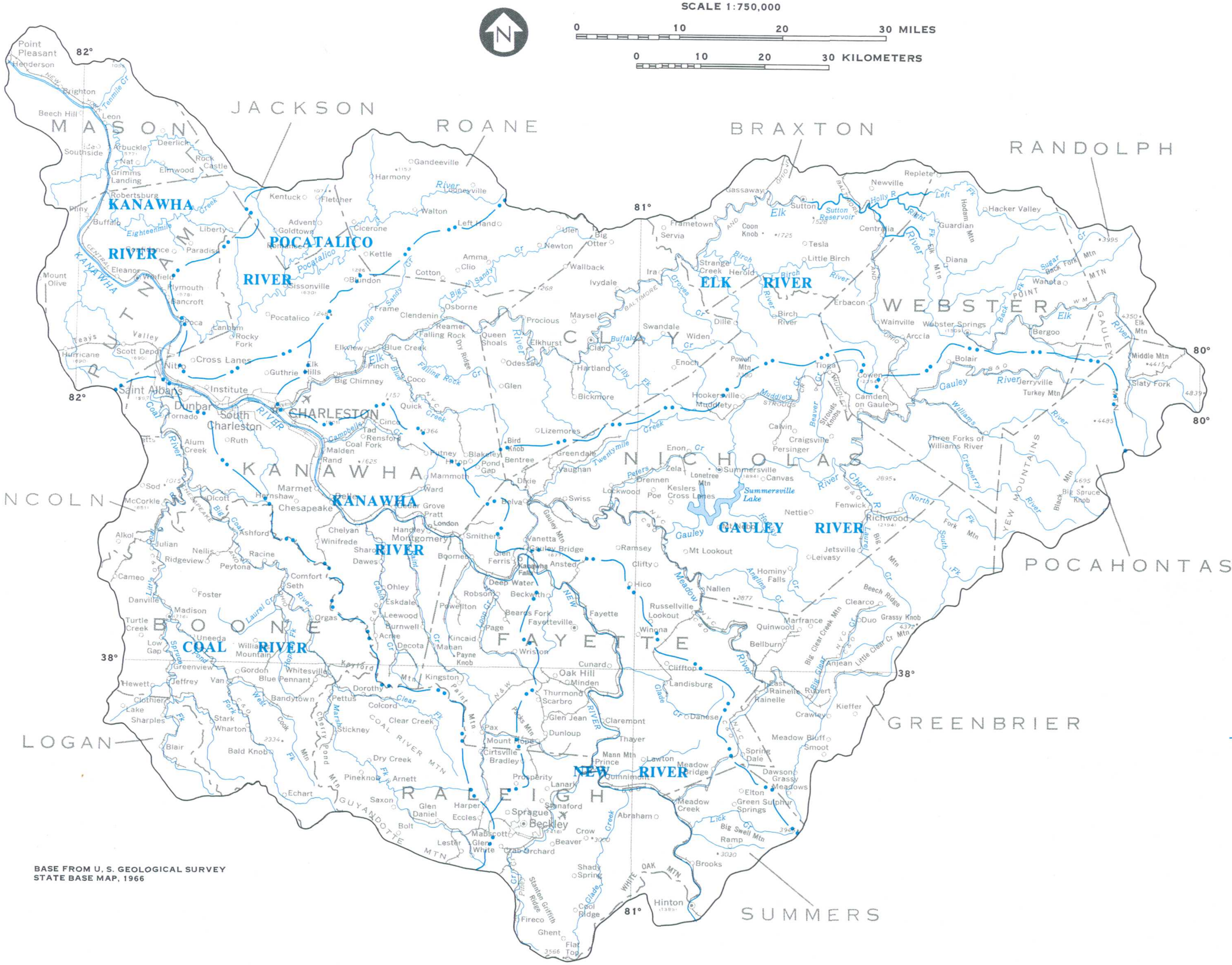
Area 9 has a surface area of about 6,000 mi^2 (square miles) consisting of the lower portion of the Kanawha River basin. The area is bordered by the Ohio River drainage to the west, the Little Kanawha and Monongahela River basins to the north, the Greenbrier River basin to the east, and the Guyandotte River basin to the south. The Kanawha River is the fourth largest tributary to the Ohio River and is the largest drainage basin within West Virginia.

Five major river tributaries to the Kanawha River--the Coal, Elk, Pocatalico, Gauley, and New, drain most of the area. In addition, the Area receives drainage from 6,300 mi^2 in North Carolina and Virginia by way of the New River. Much of this incoming drainage is encompassed in Area 10, the next area report in this series. The surface drainage network within Area 9 is shown in figure 2.1-1.

The Kanawha River is formed by the junction of the Gauley and New River at Gauley Bridge at mile 96.5, and flows northwestward into the Ohio River at Point Pleasant. The mainstream of the Kanawha flows through parts of Mason, Putnam, Kanawha, and Fayette Counties. Drainage from the Elk River enters the Kanawha River at Charleston, 57.4 miles upstream from Point Pleasant. The Coal River joins the Kanawha River at St. Albans, 45 miles upstream from Point Pleasant. The Pocatalico River, the furthest downstream of the major tributaries, joins the Kanawha River 39 miles upstream from Point Pleasant.

The Elk and Gauley Rivers drain 1,532 and 1,440 mi^2 respectively, which is most of the eastern part of Area 9. The New River drains 677 mi^2 within Area 9, and an additional 6,300 mi^2 in Virginia and North Carolina. The Kanawha River drains 520 mi^2 between Point Pleasant and Charleston, W. Va. The Coal River drains 899 mi^2 at the southern boundary of the basin. The Pocatalico River drains 359 mi^2 of gently sloping land extensively used for agricultural and industrial purposes near the Ohio River.

The Kanawha River is navigable from Point Pleasant upstream as far as Kanawha Falls, 94.5 miles upstream from the junction of the Kanawha with the Ohio River. A series of dams at London, Marmet, and Winfield on the Kanawha River and Gallipolis on the Ohio River divide this reach into four pools and maintain stage for navigation. Locks at London, Marmet, and Winfield are operated by the U.S. Army Corps of Engineers for boat traffic.



EXPLANATION

Drainage basin boundary

Figure 2.1-1 Surface-drainage basins

Consolidated Sedimentary Rocks of Permian, Pennsylvanian, and Mississippian Age Underlie Area

Rock units underlying Area 9 from oldest to youngest include the Hinton, Princeton and Bluestone Formations of Mississippian age; the Pottsville Group, the Allegheny Formation, the Conemaugh and Monongahela Groups of Pennsylvanian age; and the Dunkard Group of Permian age. These rock units consist of beds of sandstone, shale, limestone, and coal. Alluvial deposits in varying thicknesses occur along major river valleys. The most important coal beds occur in the Pottsville Group.

Area 9 is underlain by sedimentary rocks of Mississippian, Pennsylvanian, and Permian age as well as by older rock units which do not crop out in the area. Alluvial deposits occur along major river valleys. The oldest consolidated rock units which crop out in the area are the Hinton, Princeton, and Bluestone Formations of Mississippian age. These rocks crop out in a broad belt near the southeastern boundary of the area (fig. 2.2-1) and consist of beds of sandstone, varicolored (red, green, and gray) shale, and a few thin beds of limestone in the Hinton Formation. They do not contain commercial quantities of coal.

The Pottsville Group includes the Kanawha, New River, and Pocahontas Formations of Pennsylvanian age and consists of massive beds of sandstone separated by thinner beds of shale, siltstone, and coal. The Pottsville Group is 3,050-3,850 ft (feet) thick in southeastern West Virginia. As many as 69 coal beds have been reported in these rocks. The most important coal seams include the Sewell, Beckley, and Pocahontas No. 2 seams. Currently the Pocahontas No. 2 is the deepest coal seam mined in West Virginia.

The Allegheny Formation of Pennsylvanian age overlies the Pottsville Group and consists of beds of sandstone, siltstone, shale, limestone, and coal. The Freeport and Kittanning coal beds are the most important of seven coal beds reported in the formation.

The Conemaugh Group crops out in a narrow belt along the Elk River in Kanawha, Clay, and Roane Counties. The average thickness of the Conemaugh Group is about 530 feet in Area 9 and consists generally of non-marine deposits of shale, sandstone, limestone, coal, and underclay. The Bakerstown is the most important of the 22 coal seams reported in the Conemaugh Group.

The Monongahela Group crops out north of the Elk River and consists of varicolored shale, gray-brown sandstone, thin beds of limestone, coal, and underclay. The group has an average thickness of about 300 ft in the area. The Pittsburgh coal bed is the most important of several reported in the group.

The Dunkard Group of Permian age contains the youngest consolidated sedimentary rocks in Area 9 and crops out in the northwestern corner of the area in Jackson and Mason Counties. The Dunkard Group is about 450 ft thick and consists of beds of sandstone, limey shale, and thin beds of limestone, coal, and underclay. Fifteen coal beds, of which the most important is the Washington bed, have been reported in the group. Coal beds in the Dunkard Group are highly volatile bituminous coals that are mainly used for steam generation because of their low carbon content.

A more detailed description of geology of West Virginia is available from the West Virginia Geological and Economic Survey in Morgantown (Cardwell and others, 1968).

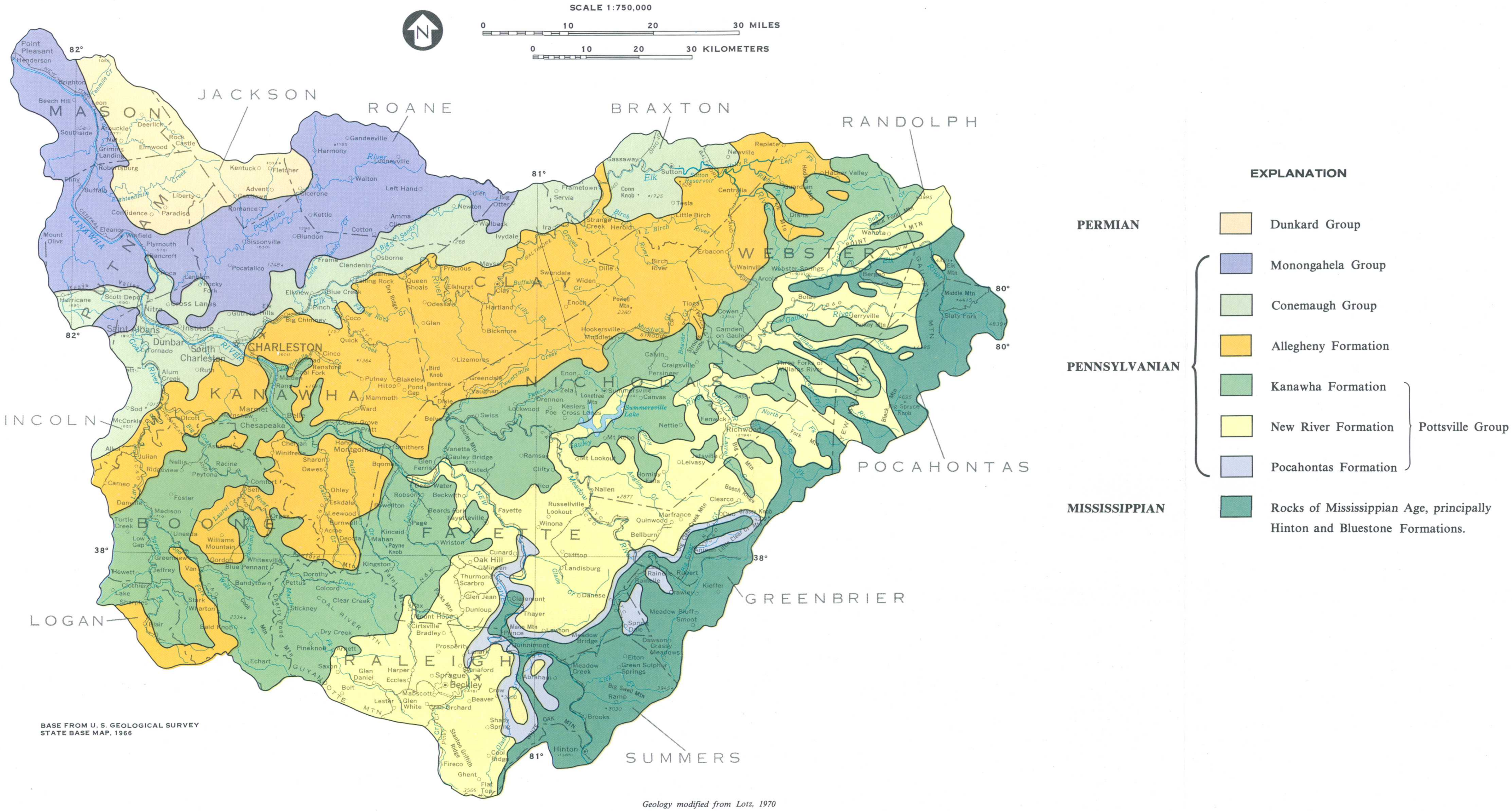


Figure 2.2-1 Generalized geologic map

Land Use and Land Cover is Primarily Forest in Area

The major land uses in Area 9 are forest (5,127 square miles), agriculture (426 square miles), and urban (152 square miles). Other land-use classifications such as rangeland, water, wetland, and barren land comprise about 4 percent (238 square miles) of the land area. Surface mines comprise about 1 percent of the area, or about 69 square miles.

Land use in Area 9 is strongly influenced by rugged topography; steep slopes dominate the terrain. Consequently, commercial and residential construction is concentrated in valley floors which are flat and subject to periodic flooding.

The major land use is forest. Approximately 5,127 mi^2 (square miles)(table 2.3-1 and fig. 2.3-1) or 85 percent of the area is forested. The counties with the greatest percentage of forest cover include Clay (96 percent), Webster (96 percent), Logan (93 percent), and Boone (92 percent). The least forest cover is found in Jackson County (72 percent), which lies in the flat land adjoining the Ohio River.

Agriculture, the second largest land use in the basin, occupies 426 mi^2 or 7 percent of the basin area and is highly variable among different counties within the basin. The greatest percentage of agricultural land use is in Jackson County (26 percent), whereas the least is in Boone (0.49 percent), and Logan (0.64 percent), counties which are more mountainous.

Urban or built-up land comprises the third largest land use in the basin. Because of the scarcity of suitable land, building is concentrated on valley floors near rivers and is subject to periodic flooding. Built-up land covers 152 mi^2 in the Kanawha basin, or 3 percent of the total land. Of this, 60 mi^2 or 39 percent of the total built-up land is found in Kanawha County.

Other land-use classifications such as rangeland, water, wetland, and barren land comprise about 5 percent of the basin area. Of these, surface mines are the largest single category and include about 69 mi^2 or 1 percent of the total basin area.

Land use has been described in previous studies. The U.S. Army Corps of Engineers prepared a detailed assessment of the Kanawha River basin (U.S. Army Corps of Engineers, 1971a, 1971b). The U.S. Geological Survey (USGS) has mapped land use at a scale of 1:250,000 based on color infrared aerial photography flown in 1973 (U.S. Geological Survey, 1976). The maps indicate 37 land-use classifications and consist of six types: topographic base, land use and land cover, census county subdivision, political units, hydrologic units, and federal land ownership. These maps are available for viewing at the West Virginia Geological and Economic Survey in Morgantown and can be purchased from the U.S. Geological Survey in Reston, Virginia. The West Virginia Geological and Economic Survey has prepared a statistical summary of land use based on the USGS maps (West Virginia Geological and Economic Survey, 1979). The bulletin shows acreages and percentage of land use for 26 categories by county.

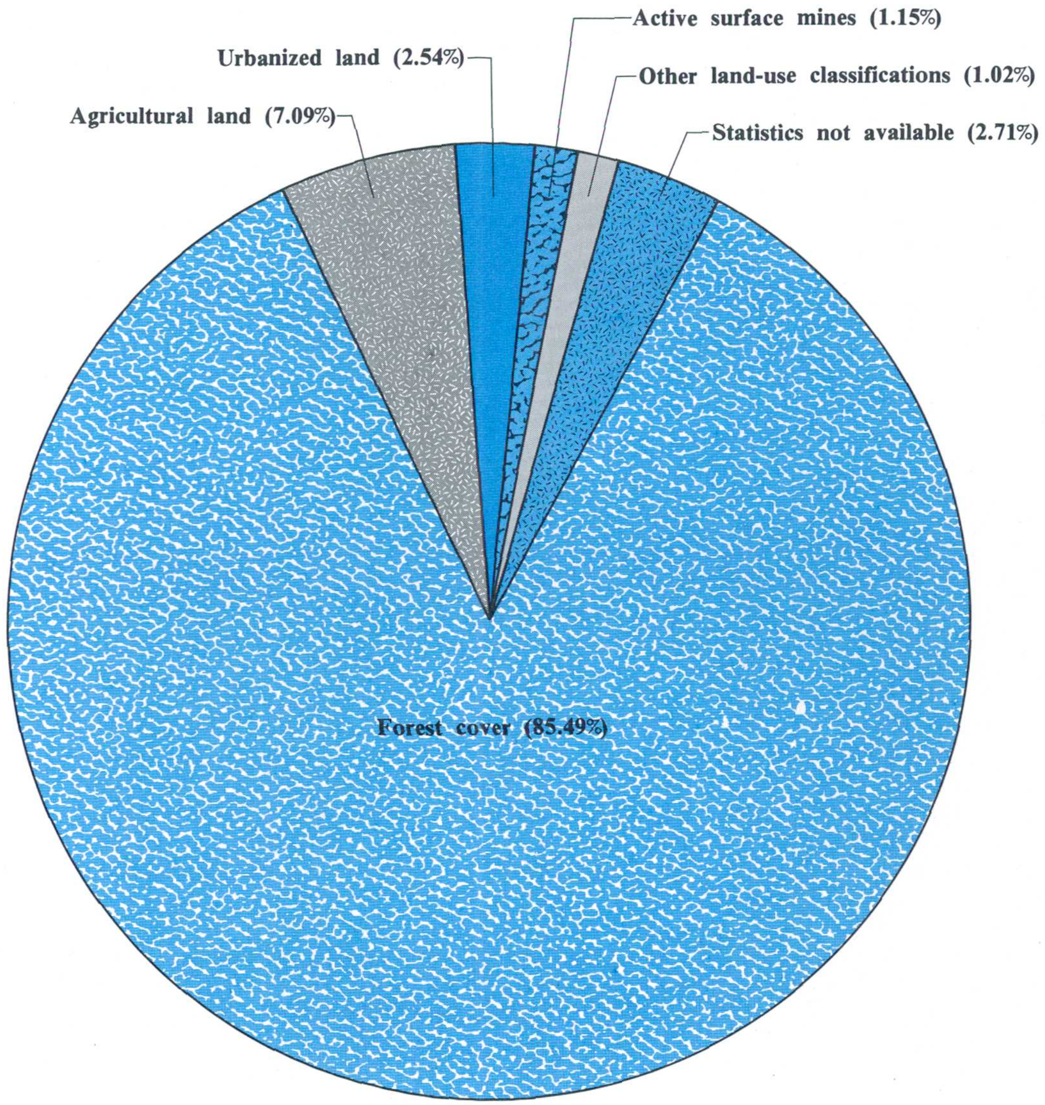


Figure 2.3.1 Land Use of Area 9, in percentage

Table 2.3-1 Summary of major land-use categories in Area 9.

County	Land within Area 9 (mi^2)	Forest Cover (mi^2)	Agricultural Land (mi^2)	Urbanized Land (mi^2)	Active Surface Mines (mi^2)	Other Land-Use Classifications (mi^2)
Braxton	242	213	23.7	2.6	0.07	1.0
Boone	481	446	2.4	9.7	13.10	10
Clay	339	327	11.4	2.5	.12	0.15
Fayette	663	595	34.1	19.0	11.01	8.88
Greenbrier	346	278	60.3	4.0	1.47	1.07
Jackson	75	54	20.0	1.4	0	.85
Lincoln	47	46	1.1	.2	0	0
Kanawha	907	812	18.2	59.9	2.81	17.2
Logan	58	54	0.4	1.8	1.04	.03
Mason	197	*	*	*	*	*
Nicholas	650	568	59.0	9.8	5.87	9.56
Pocahontas	214	189	23.2	.6	.33	.34
Putnam	295	234	45.7	11.2	0	4.15
Raleigh	504	423	39.0	22.0	24.02	3.0
Randolph	80	71	8.1	.6	7.54	.12
Roane	246	202	40.3	1.6	0	.19
Summers	119	102	19.1	1.4	.29	2.34
Webster	534	513	19.6	3.7	1.08	1.93

*Statistics not available.

Modified from West Virginia Geological and Economic Survey, 1979.

Soils in the Area are Mostly Shallow and Poorly Drained

Soils in most of Area 9 are shallow and poorly drained. Soils are grouped into four Land Resource Areas on the basis of distinct patterns of soils, slope, erosion characteristics, climate, vegetation, water resources, and land use.

Soils in Area 9 have been grouped into associations which are termed Land Resource Areas (LRA) by the U.S. Soil Conservation Service (U.S. Soil Conservation Service, 1979). A Land Resource Area is a geographic area of land characterized by a unique combination of soils, slope, erosion characteristics, climate, vegetation, water resources, and land use.

Soils in Area 9 are grouped into four Land Resource Areas: Eastern Allegheny Plateau and Mountains Association (LRA 127), Cumberland Plateau and Mountains Association (LRA 125), Central Allegheny Plateau Association (LRA 126), and Southern Appalachian Ridges and Valleys Association (LRA 128). The soil series associations within each Land Resource Area are shown in figure 2.4-1. A general summary of soil association drainage characteristics in Area 9 is given in table 2.4-1.

The Eastern Allegheny Plateau and Mountains Land Resource Area (LRA 127) is the largest Land Resource Area in Area 9. Soils in LRA 127 are mostly shallow and are underlain by impermeable shale, siltstone, sandstone, and limestone, and thus are usually poorly drained. Most soils are on moderate to steep slopes, and have a high erosion potential when vegetal cover is removed by construction, mining, and silvicultural and agricultural operations. Mean annual rainfall in LRA 127 ranges from 50 to 60 inches in the mountainous eastern portion. Because of the steep slopes and poor drainage, these soils are generally unsuited for cropland.

The Cumberland Plateau and Mountains Land Resource Area (LRA 125) comprises parts of the Coal and upper New River basins, that is, most of the center of Area 9. Most soils are shallow, and have a higher erosion potential where they occur on moderate to steep slopes. Drainage is generally poor due to the thin soil mantle and relatively impermeable sedimentary rock types close to the surface. Over 90 percent of LRA 125 is forested primarily because of the rugged terrain with steep, narrow valleys.

The Central Allegheny Plateau Land Resource Area (LRA 126) includes soils adjacent to the Ohio River in the Pocatalico and lower Coal River basins. Soils are moderately deep and are underlain by shale, siltstone, sandstone, and some limestone of Pennsylvanian and Permian age. Surface slopes are slight to moderate. More than half the area of LRA 126 is described as agricultural land. Very little mining is done in this area, as most of LRA 126 lies outside the boundary of the Eastern Coal Province.

The Southern Appalachian Ridges and Valleys Land Resource Area (LRA 128) includes soils in a very small area at the eastern boundary of Area 9. This area consists of valleys oriented northeastward and separated by steep ridges or mountains. Soils are mostly thin and are on very steep slopes. Much of LRA 128 lies within the rain shadow which occurs east of the Appalachian Mountains, so less rainfall occurs in this area than elsewhere throughout Area 9. The major soils in LRA 128 generally occur on steep slopes and are poorly suited as cropland.

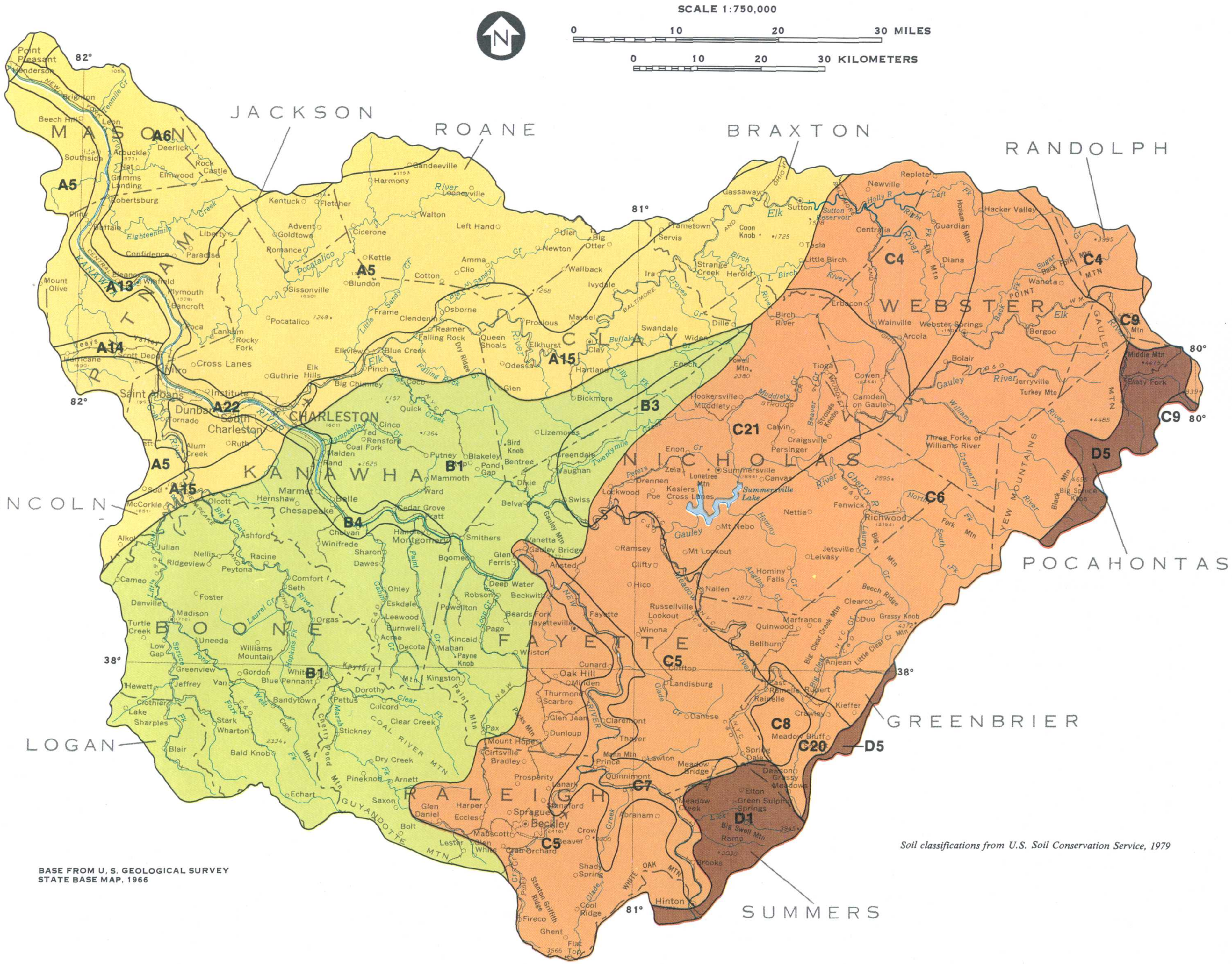


Figure 2.4-1 Classification of soils

Table 2.4.1 General summary of soil association drainage characteristics

EXPLANATION

Land Resource Area	Soil Associations*	Slope Range (percent)	Drainage
Cumberland Plateaus and Mountains (LRA-125)	Clymer-Dekalb-Jefferson **(B1)**	3-15 15-25 25+	Moderate Poor Poor
	Gilpin-Ernest-Buckhannon **(B3)**	3-15 15-25 25+	Poor Poor
	Kanawha **(B4)**	0-3	Moderate
Central Allegheny Plateau (LRA-126)	Gilpin-Upshur-Vandalia **(A5)**	3-15 15-25 25+	Poor Poor Poor
	Upshur-Gilpin-Vandalia **(A6)**	3-15 15-35 35+	Poor Poor Poor
	Lindside-Ashton **(A13)**	0-3	Poor
	Allegheny-Monongahela-Vincent **(A14)**	3-25	Moderate
	Clymer-Gilpin-Upshur **(A15)**	3-15 15-25 25+	Moderate Poor Poor
	Kanawha **(A22)**	0-3	Moderate
Eastern Allegheny Plateau and Mountains (LRA-127)	Gilpin-Dekalb-Buchanan **(C4)**	3-15 15-25 25+	Poor Poor Poor
	Dekalb-Gilpin-Ernist **(C5)**	3-15 15-35 35+	Poor Poor Poor
	Gilpin-Buchanon-Ernist **(C6)**	3-15 15-25 25+	Poor Poor Poor
	Dekalb-Rock outcrop **(C7)**	3-15 15-35 35+	Poor Poor Poor
	Calvin-Gilpin **(C8)**	3-15 15-25 25+	Poor Poor Poor
	Calvin-Belmont-Mackesville **(C9)**	3-15 15-25 25+	Poor Poor Poor
	Atkins **(C20)**	0-3	Poor
	Gilpin-Ernest-Buckhanon **(C21)**	3-15 15-25 25+	Poor Poor Poor
Southern Appalachian Ridges and Valleys (LRA-128)	Gilpin-Calvin-Berks **(D1)**	3-15 15-25 25+	Poor Poor Poor
	Calvin-Gilpin **(D5)**	3-15 15-25 25+	Poor Poor Poor

*Left to right order indicates predominant soil series composition of association; characters in parenthesis correspond to those in fig. 2.4-1.

Topography of the Area is Characterized by Rugged and Deeply Incised Terrain

Topography of Area 9 is characterized by rugged, deeply incised terrain where the Appalachian Mountains intersect Area 9 and by gentle slopes near the Ohio River. Overland slopes ranged from greater than 40 percent in the central part of the area to 20 to 30 percent near the eastern and western boundaries. The regional slope of the area gradually dips to the west. The deeply incised valleys form the drainage network of the major rivers--the Pocatalico, Coal, Elk, Gauley, Kanawha, and New Rivers.

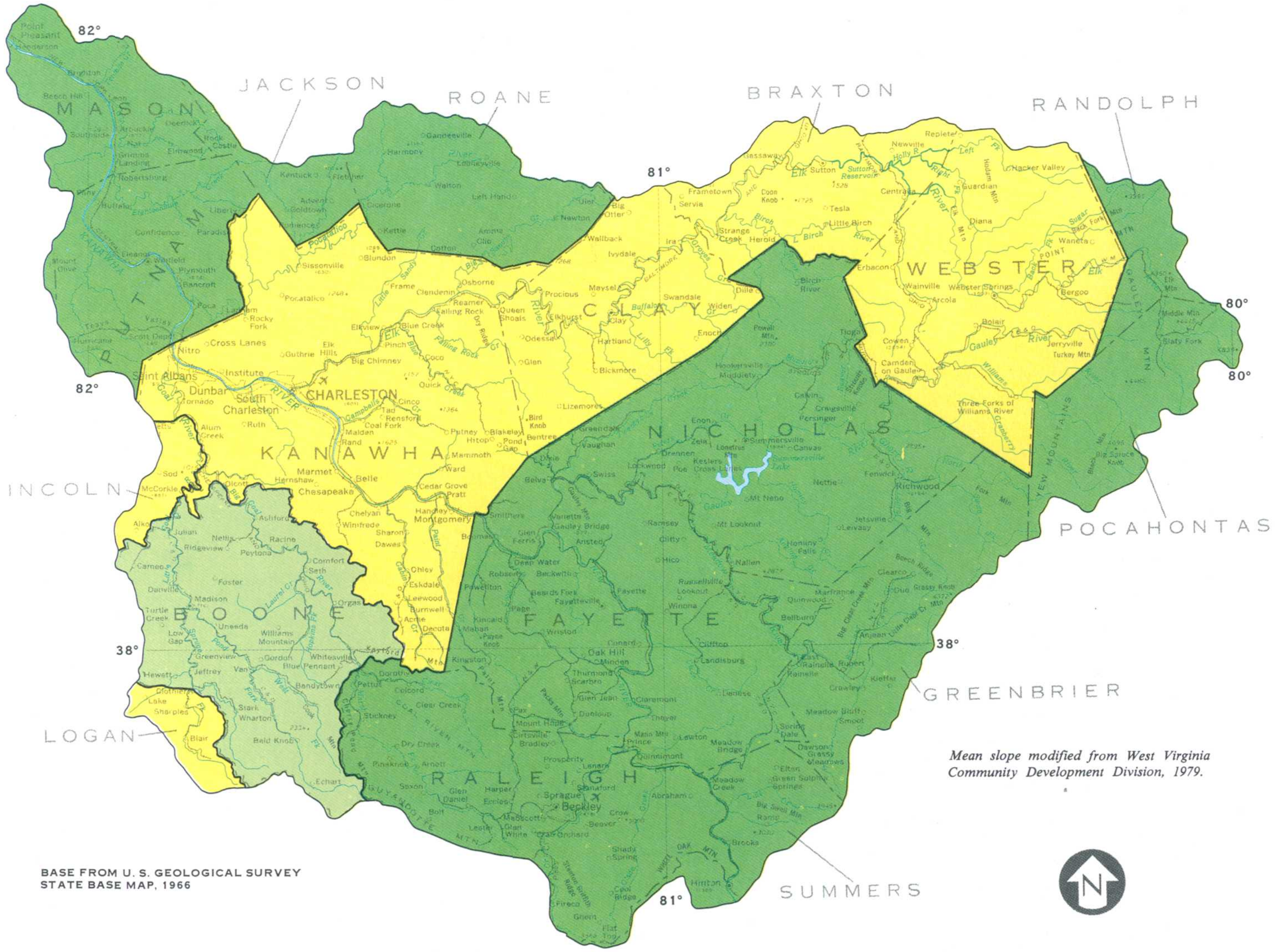
The topography of Area 9 is primarily mountainous, and is characterized by deep, steep-sided valleys and narrow winding ridges. Boone, Kanawha, Webster, Braxton, and Clay Counties are particularly mountainous with overland slopes generally exceeding 30 percent. The only relatively flat terrain (slopes less than 2.5 percent) is found in Mason County along the Ohio River, and in Putnam County near the Kanawha River. Land elevation (National Geodetic Vertical Datum of 1929) ranges from 4,695 feet near Big Spruce Knob at the eastern boundary of the area to 560 feet at Point Pleasant, the Kanawha River mouth.

Local relief ranges from 800 to over 1,500 feet in the eastern part of the area to 300 to 600 feet in the western part near the Ohio River. The single most impressive topographic feature of Area 9 is the New River gorge. This part of the New River valley follows a narrow, deeply trenched, irregular, winding course from the vicinity of Hinton to Gauley Bridge. The deeply incised and dissected valleys in the Appalachian Plateaus physiographic province form the drainage network of the major rivers--the Pocatalico, Coal, Kanawha, Elk, Gauley, and New Rivers which drain Area 9.

Overland slopes are gentlest (20 to 30 percent) near the Kanawha River valley in Mason, Putnam and Roane Counties, and at the eastern boundary adjacent to Greenbrier County (fig. 2.5-1). The greatest slopes are generally found on both sides of the mountainous spine of the Appalachians, which trend northeast in the center of the basin. Average overland slopes in Boone County generally exceed 40 percent.

Stream channel slopes are greatest in the areas of highest relief. Channel slopes were determined from elevation differences and the length of channel between points corresponding to 10 and 85 percent of the distance of stream channel upstream from the mouth, according to methods described by Benson (1962). Channel slopes of selected streams in Area 9 are shown in figure 2.5-2. The Elk, Coal, Cranberry, and Cherry Rivers have channel slopes that average from 60 to 100 ft/mi (feet per mile). The Kanawha River, which is divided into a series of four pools by dams at London, Marmet, and Winfield on the Kanawha River, and Gallipolis on the Ohio River, has an average channel slope of less than 1 ft/mi from Kanawha Falls to Point Pleasant.

The potential for erosion, earth slides, and excessive stream sedimentation is much greater when land slope exceeds 25 percent (West Virginia Community Development Division, 1979). Other than along the lower Kanawha River valley, most of Area 9 has overland slopes exceeding 25 percent, and thus is subject to excessive erosion and sedimentation.



SCALE 1:1,000,000

0 10 20 30 MILES

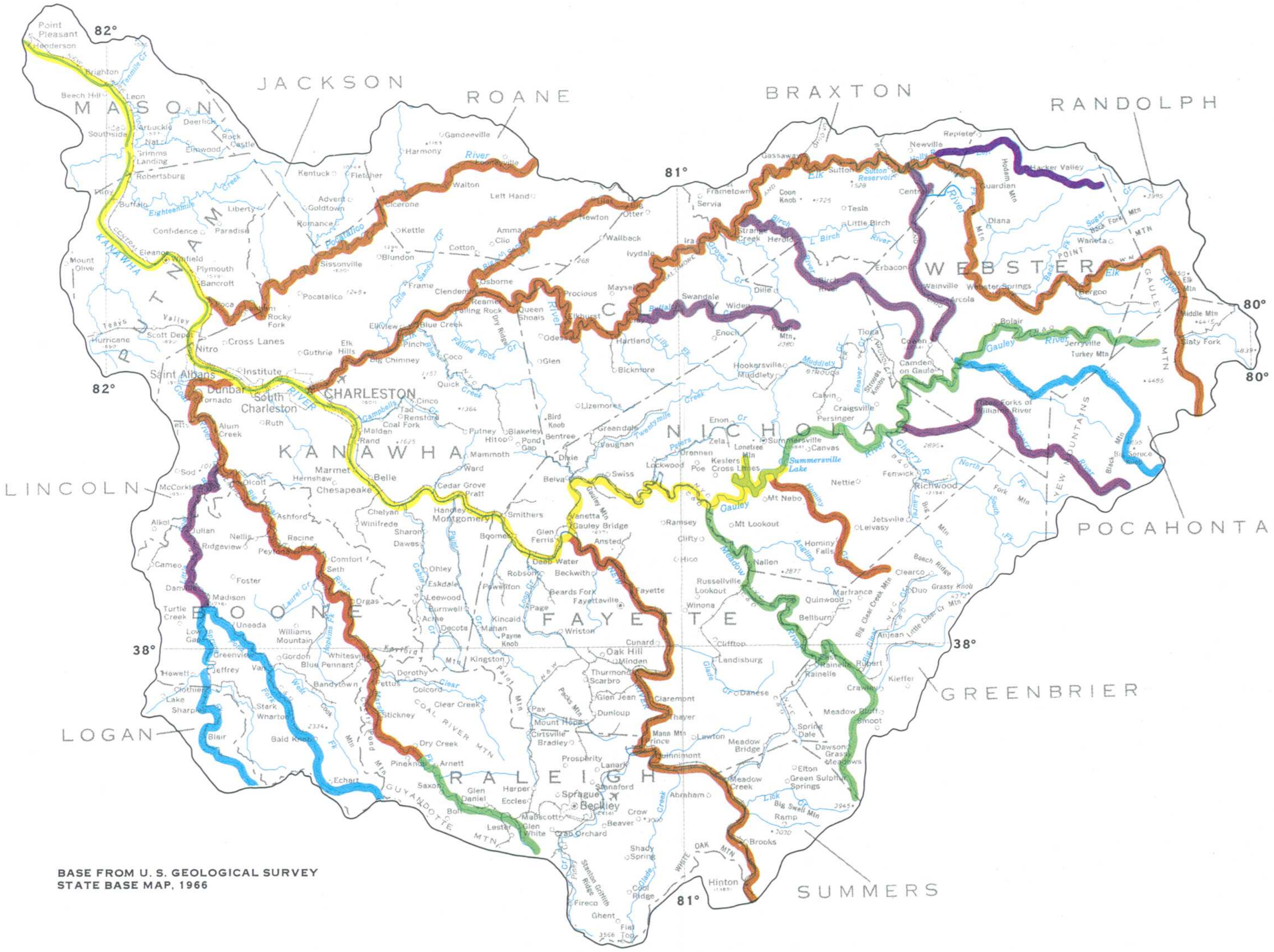
0 10 20 30 KILOMETERS

EXPLANATION

Mean overland slope in, percent

- 20-30
- 31-40
- Greater than 40

Figure 2.5-1 Mean overland slope, by county



EXPLANATION

Mean channel slope, in feet per mile

- Less than 1
- 1-20
- 21-40
- 41-60
- 61-80
- 81-100

Figure 2.5-2 Mean channel slope of major streams

Precipitation Averages Approximately 43 Inches Annually

Precipitation within Area 9 averages about 43 inches annually. Rainfall is greatest in mountainous areas and least near the Ohio River where land elevation is lower. Prevailing wind direction and surface topography are important factors affecting spatial rainfall distribution. Intense rainfalls exceeding 4 inches in a 24-hour period are frequent over small drainage areas, but are rare over the entire area.

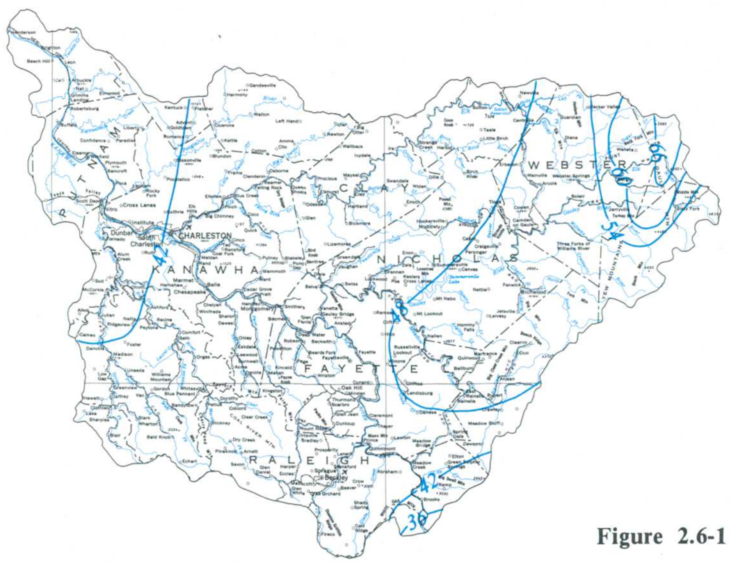
Mean annual rainfall in Area 9 averages 43 inches. Lowest rainfall occurs along the Ohio River, and along the southeastern boundary of the area. Greatest annual rainfall occurs in the mountain areas near the headwaters of the Elk and Gauley Rivers near the eastern boundary of the basin (fig. 2.6-1). Precipitation during the period April 1979 to March 1980 (fig. 2.6-2) was somewhat greater than the long-term average, particularly in the mountainous areas.

The rainfall distribution in Area 9 is influenced by the prevailing westerly wind direction and surface topography. As wind currents approach the mountains, they are subject to orographic lifting, which acts to trigger potential precipitation or to intensify precipitation which may already be occurring. As a result, average annual precipitation increases from the Ohio River eastward to higher elevations in the the Appalachian Mountains. On the other side of the mountains there is a well defined rain shadow.

Precipitation is generally greatest in midsummer and least in the fall and winter. Annual rainfall distribution for some larger cities is shown in figure 2.6-3. Intense rainfall events exceeding 4 inches in 24 hours are frequent for small drainage areas, but rarely occur over the entire Area 9. Isohyetals depicting 10-year, 24-hour rainfall are shown in figure 2.6-4. For most of the basin the 10-year, 24-hour rainfall is approximately 4 inches.

Annual snowfall distribution is more uneven than rainfall. Annual rainfall in Area 9 varies from about 42 to 66 inches. The mountainous areas near the eastern end of the basin receive 5 to 7 times more snowfall than the lower elevation areas near the Ohio River. At Charleston the snowfall averages 24 inches annually compared to about 200 inches at higher elevations in the Gauley River basin. Large accumulations of snow are rare due to frequent warm periods during the winter.

The average annual temperature for the area is approximately 52°F, with the highest values occurring in the area near the Ohio River and the lowest values in the mountainous region near the eastern boundary. Mean January temperature ranges from 31.4°F at Beckley to 34.5°F at Charleston (fig. 2.6-3). During the summer, the average daily maximum temperatures range from the upper 70's at higher elevations to the lower 80's at Charleston.



N

SCALE 1: 2,500,000

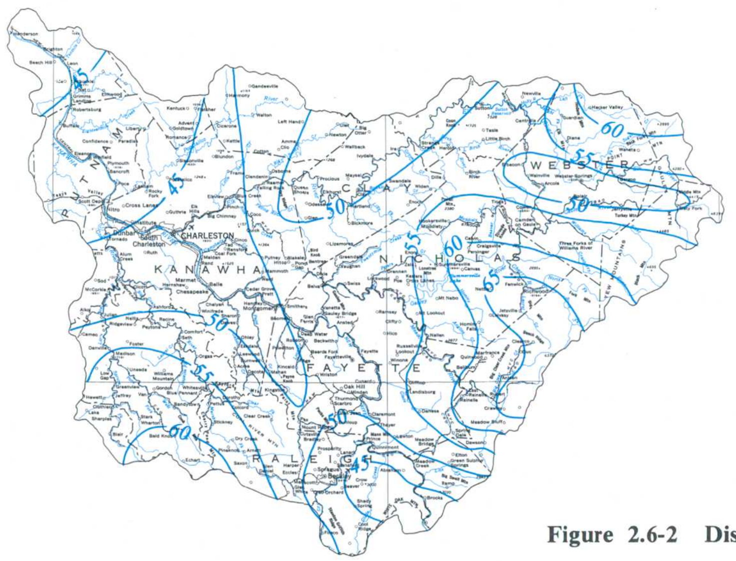
0 25 50 MILES

0 25 50 KILOMETERS

EXPLANATION

48 — Line of equal mean precipitation, in inches

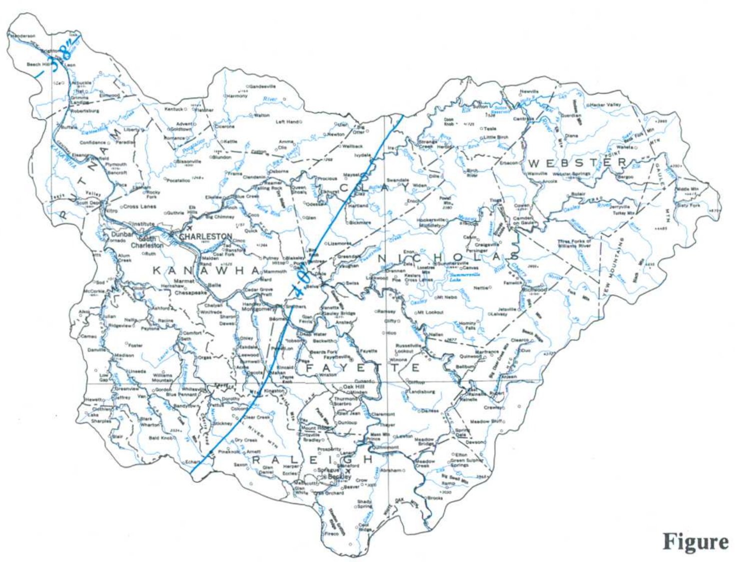
Figure 2.6-1 Distribution of annual precipitation for period 1931-1960



EXPLANATION

50 — Line of equal precipitation, in inches

Figure 2.6-2 Distribution of precipitation for period April 1979 - March 1980



EXPLANATION

4.0" — Line of equal 10-year, 24-hour rainfall

Figure 2.6-4 Rainfall isohyetals for 10-year, 24-hour event

Climatological data from the National Oceanic and Atmospheric Administration, 1977

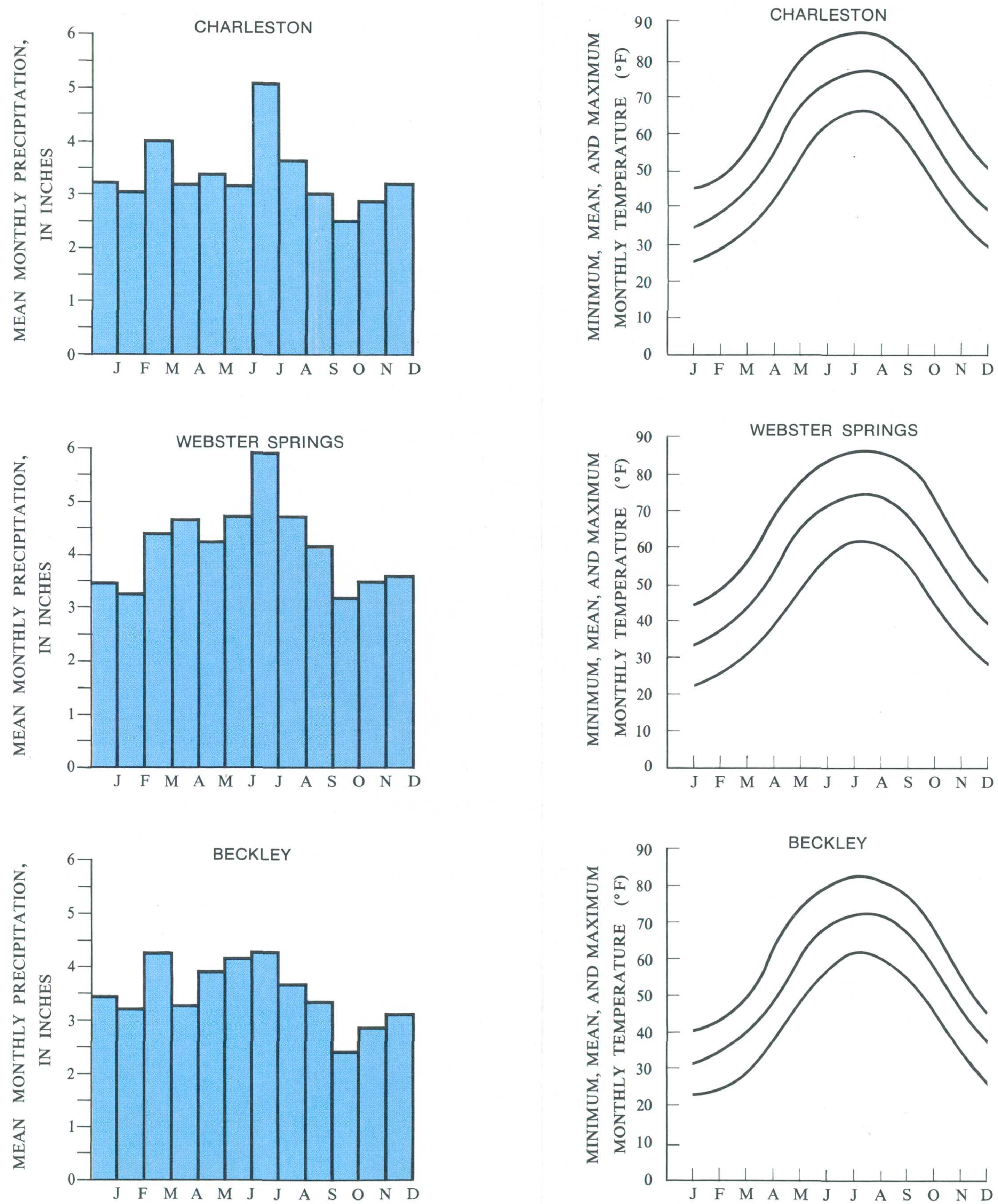


Fig. 2.6-3 Monthly precipitation and temperature for selected towns for period 1931-1973

Thirty Percent of the West Virginia Coal Output in 1978 and 1979 Produced From Area

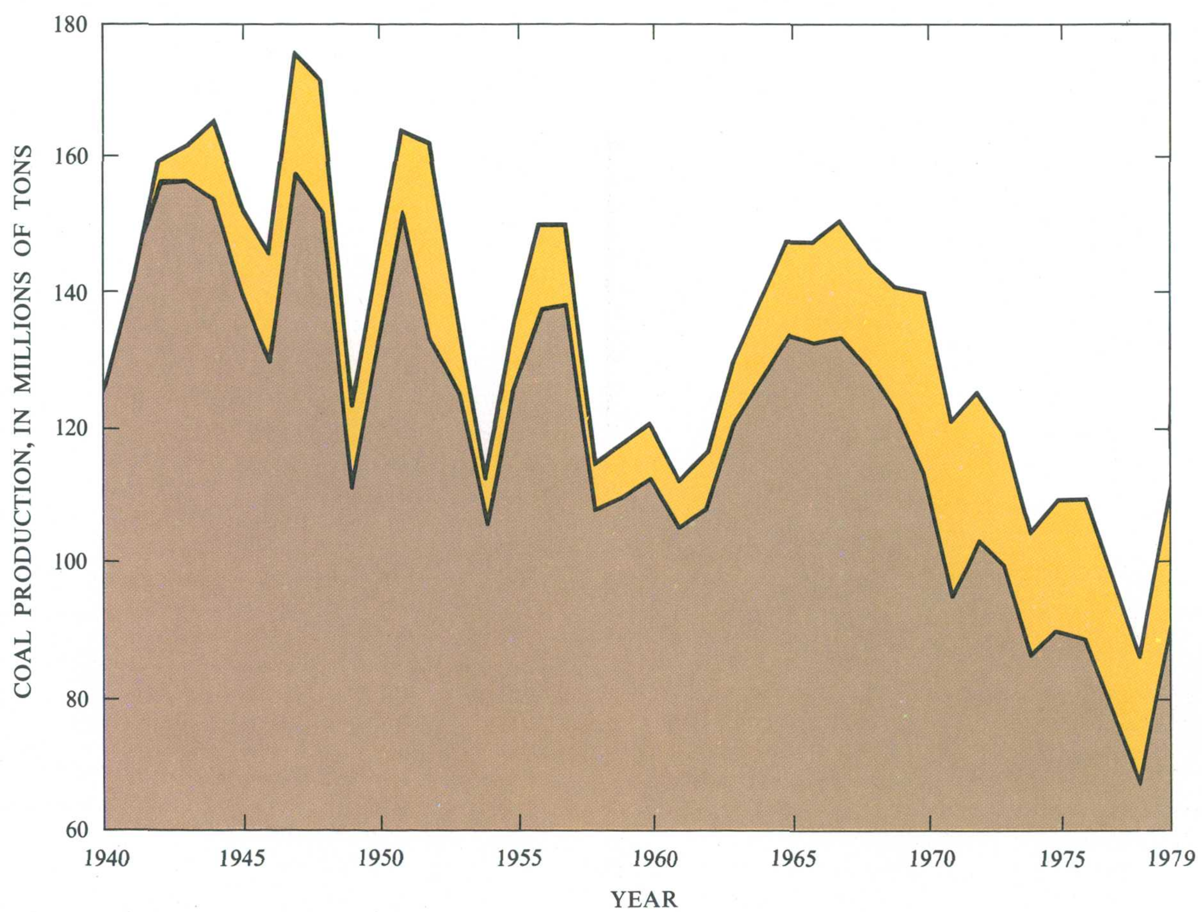
In 1978 and 1979, Area 9 produced nearly one-third of the West Virginia coal output. About 77 percent was produced by underground mining methods. In 1980, 255 surface and 469 underground coal mines operated within Area 9.

West Virginia produced 84.7 million tons of bituminous coal in 1978, which made it the nation's second largest producer. State coal production in 1979 increased to 112 million tons, but was less than the peak production of 174 million tons mined in 1947 (fig. 3.1-1) (Dugolinsky and Behling, 1980). About 25.6 and 32.7 million tons were produced during 1978 and 1979, respectively, by mines within Area 9. This represents about 30 percent of the West Virginia coal production for the respective periods. Most coal (77 percent) was produced by underground mining methods in 1978. Active coal mining operations in Area 9 consisted of 469 underground and 255 surface mines as of April 1, 1980 (West Virginia Department of Mines, 1980; Dugolinsky and Behling, 1980).

More than 62 coal seams in West Virginia are considered to be mineable (12 inches or more in thickness), but 75 percent of the production is from 8 seams (West Virginia Community Development Division, 1979). In Area 9 these highly productive seams include the lower Kittanning (No. 5 Block), Campbell Creek (No. 2 Gas), Sewell, and Winifrede.

Coal production is primarily centered in the mountainous terrain of the Appalachian Mountains in the central part of the area. The greatest total production during 1978 came from Boone, Kanawha, Nicholas, and Raleigh Counties (table 3.1-1).

Coals in Area 9 differ widely in carbon, ash, BTU, and sulfur content, and thus, serve different industrial uses. The coal-bearing rocks are divided into northern and southern fields separated by a "hinge line" of coal-poor rocks (fig. 3.1-2). Most coal produced in the northern coal field contains more than 1.5 percent sulfur, whereas coal produced from the southern field generally has less than 1.5 percent sulfur. High-sulfur coal is often burned in fossil-fuel electric power plants, but can also be used for conversion to other fuels. Low-sulfur coal is primarily used to produce coke which is utilized by the steel industry.



EXPLANATION

Surface mine production

Deep mine production

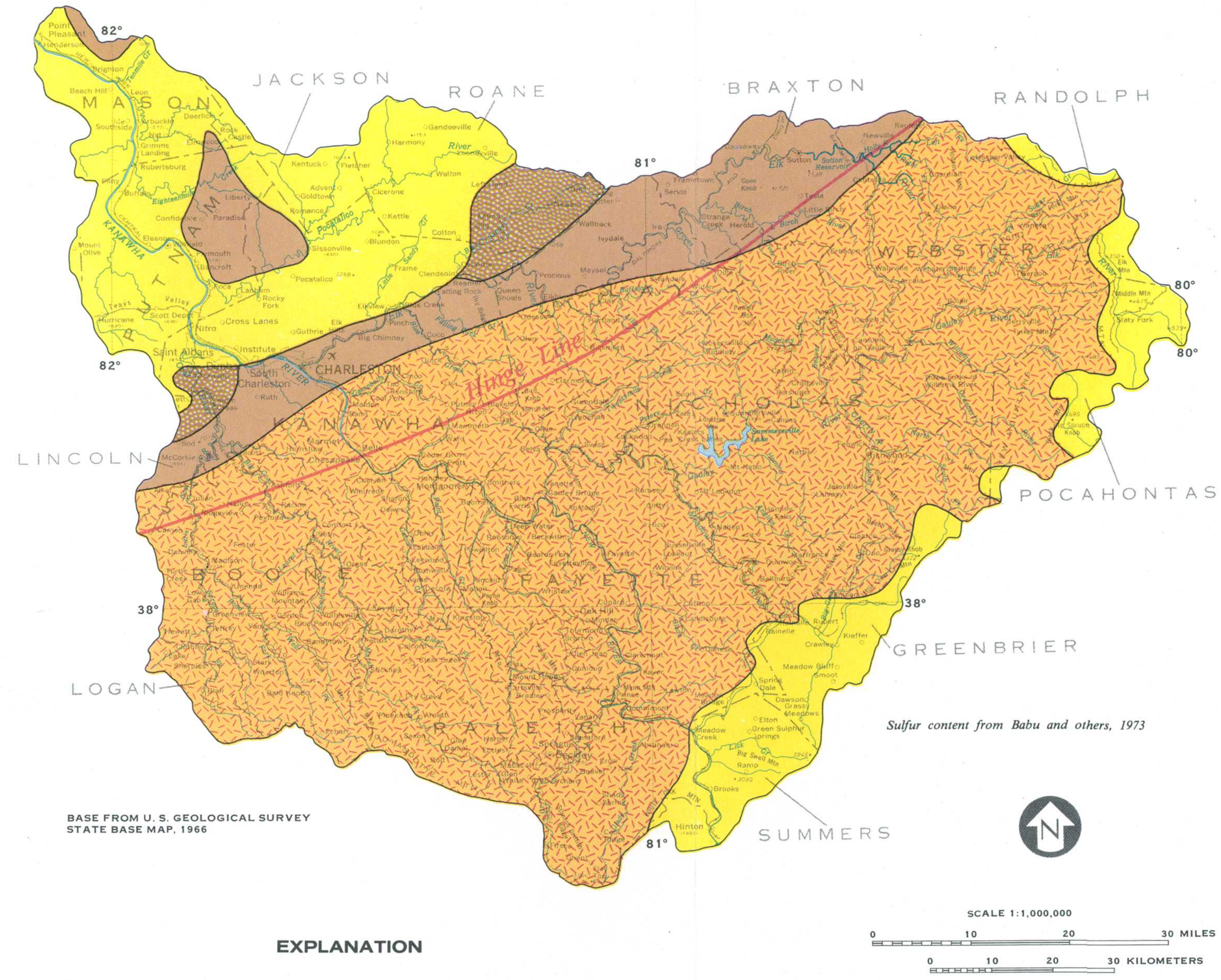
Total coal production

Figure 3.1-1 Bituminous coal production in West Virginia, 1940-79

Table 3.1-1 Area 9 coal production, in millions of tons, for 1978 and 1979

County	1978 Surface	1978 Underground	1979 Surface	1979 Underground
Boone	1,720,401	6,114,338	2,129,594	9,021,046
Clay	36,439	4,812	11,414	6,661
Fayette	646,164	1,019,744	780,547	1,195,054
Greenbrier	296,582	372,100	67,164	342,138
Kanawha	1,432,026	4,169,994	1,590,829	6,026,039
Logan	223,383	598,631	332,626	675,206
Nicholas	780,334	3,238,486	1,097,541	3,690,758
Raleigh	179,102	3,878,602	152,727	4,688,795
Randolph	211,899	87,250	115,375	165,608
Summers	0	11,024	0	0
Webster	344,224	111,620	138,842	170,393
	---	6,580	---	92,600
	---	156,322	---	265,534
Yearly total	25,630,057		32,756,541	

Production figures are for mines located within the boundary of Area 9.



EXPLANATION

Sulfur content of coal, in percent

Greater than 3

1.5 to 3

Less than 1.5

No data

Figure 3.1-2 Generalized sulfur content of the bituminous coals

Surface Mines in Area 9 Produced 6.4 Million Tons of Coal in 1979

During 1979, 255 surface mines operated in Area 9, and produced 6.4 million tons of coal. Most mines are located in Nicholas, Fayette, Kanawha, and Boone Counties. The number of surface mines in West Virginia has increased 228 percent between 1975 and 1978.

The number of surface coal mining operations in West Virginia has increased from 386 in January 1975 to 882 as of April 1980 (Welker and others, 1980). Of these, 255 or 29 percent operate within Area 9. In 1979 these mines produced 6.4 million tons, which was 20 percent of the area output (West Virginia Department of Mines, 1980). The greatest number of active surface mines (60) are located in Nicholas County. Other counties with substantial mining operations include Fayette (54 mines), Kanawha (34 mines), and Boone (31 mines). The number of active surface mines in counties within Area 9 is given in figure 3.2-1.

Surface mining is concentrated in a band about 40 miles wide trending northeast near the center of Area 9. The location of active mining sites is shown in figure 3.2-1. Mining is particularly intense in the Coal, the upper New, and parts of the Gauley River basins. Mines are particularly concentrated near Muddlety and Peters Creeks in Nicholas County, and near the Little Coal River in Boone County. Many mines are located adjacent to or near streams and rivers to permit transport of coal by river barge and railroad. Most coal moves from the mines by rail or truck to a terminal near the larger rivers, and by barge or rail to the final destination.

Mines, waste piles, and coal preparation plants, which are located close to streams and rivers increase the potential for serious water-quality impairment if improperly treated wastes are discharged. Besides the aesthetic aspects of the problem, the discharge of untreated or improperly treated wastes has resulted in numerous water-quality problems. Some water supplies have been degraded by excessive concentrations of iron, manganese, and sulfate to the extent that they no longer are potable (West Virginia Department of Natural Resources, 1975).

Surface mines are increasing in size as well as in number. In 1977, the average mining permit was for 76.6 acres, whereas in 1979 the mean new permit size was 99.6 acres. For the first quarter of 1980 the mean size of new permit applications was for 131.5 acres (West Virginia Department of Mines, 1980). According to land-use statistics, about 1 percent of the land in Area 9 (approximately 69 mi^2) has been surface mined in the past.

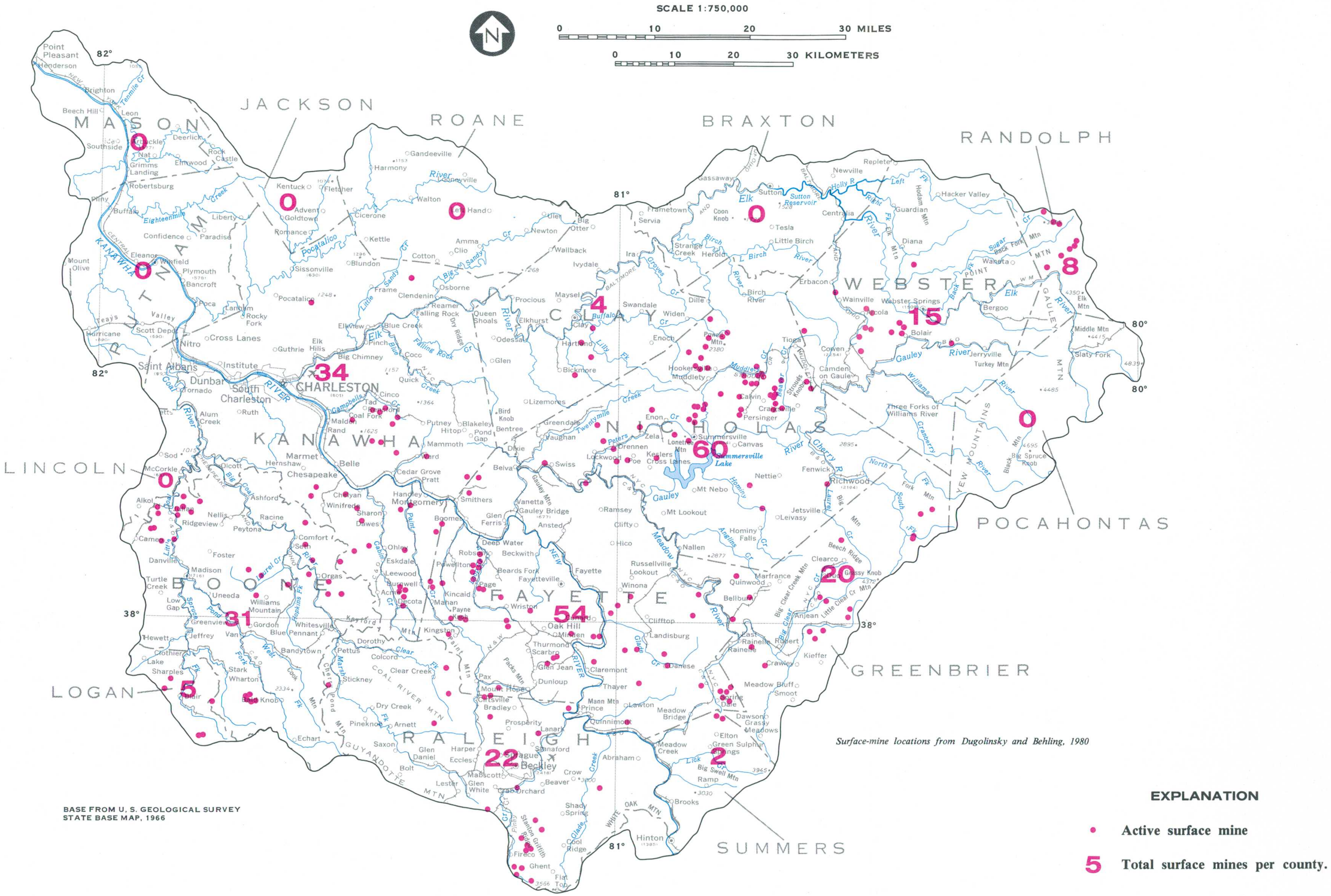


Figure 3.2-1 Active surface-mine sites

Underground Mines in Area 9 Produced 26.3 Million Tons of Coal in 1979

In 1979, the 469 underground coal mines operating in the area produced 26.3 million tons of coal. Most mines are located in Boone, Kanawha, Nicholas, and Raleigh Counties. About 22 percent of Area 9 has been previously mined by underground methods.

In 1979, 80 percent of the coal production from Area 9 (26.3 million tons) was produced by underground mines (West Virginia Department of Mines, 1980). In April 1980, 469 underground coal mines were operating in the area, which was over half of the total coal mines in the State. The approximate location of the mines is shown in figure 3.3-1.

Underground coal mines are concentrated in Boone (113 mines), Kanawha (93 mines), Nicholas (70 mines), and Raleigh (58 mines) Counties. The distribution of active underground mines in Area 9 is shown in table 3.3-1. Very few mines operate in the Kanawha River basin downstream from Charleston, and in areas near the northern boundary of Area 9. Less than 1 percent of the mines are located within the Pocatalico River basin, while 40 percent of the mines are located in the upper Kanawha and Coal River basins.

As is shown in figure 3.3-1, much of Area 9 (1,330 mi^2 or 22 percent) has been previously mined by underground methods. The mining is concentrated in the upper Kanawha, New, and Coal River basins, along the Kanawha, Coal, Elk, and New Rivers. Historically, mining has been most active near the large rivers, permitting the transport of coal by river barge.

Underground mining creates large quantities of spoil material which are discarded near mine portals. The location of some of the larger spoil areas is shown in figure 3.3-1 and is a general indicator of the extent of past mining activity. Drainage from these spoil areas can be acidic and may contain high concentrations of iron, manganese, sulfate, magnesium, aluminum, and calcium (Bader and others, 1980). Some spoil areas have caused stream blockage, resulting in temporary impoundment of water. Sudden collapse of such impoundments has caused severe flooding in downstream areas (Runner, 1974). The West Virginia Department of Reclamation considers rehabilitation of abandoned spoil areas a high priority and estimates that 52,900 acres are unreclaimed in West Virginia (West Virginia Department of Natural Resources, 1980b).

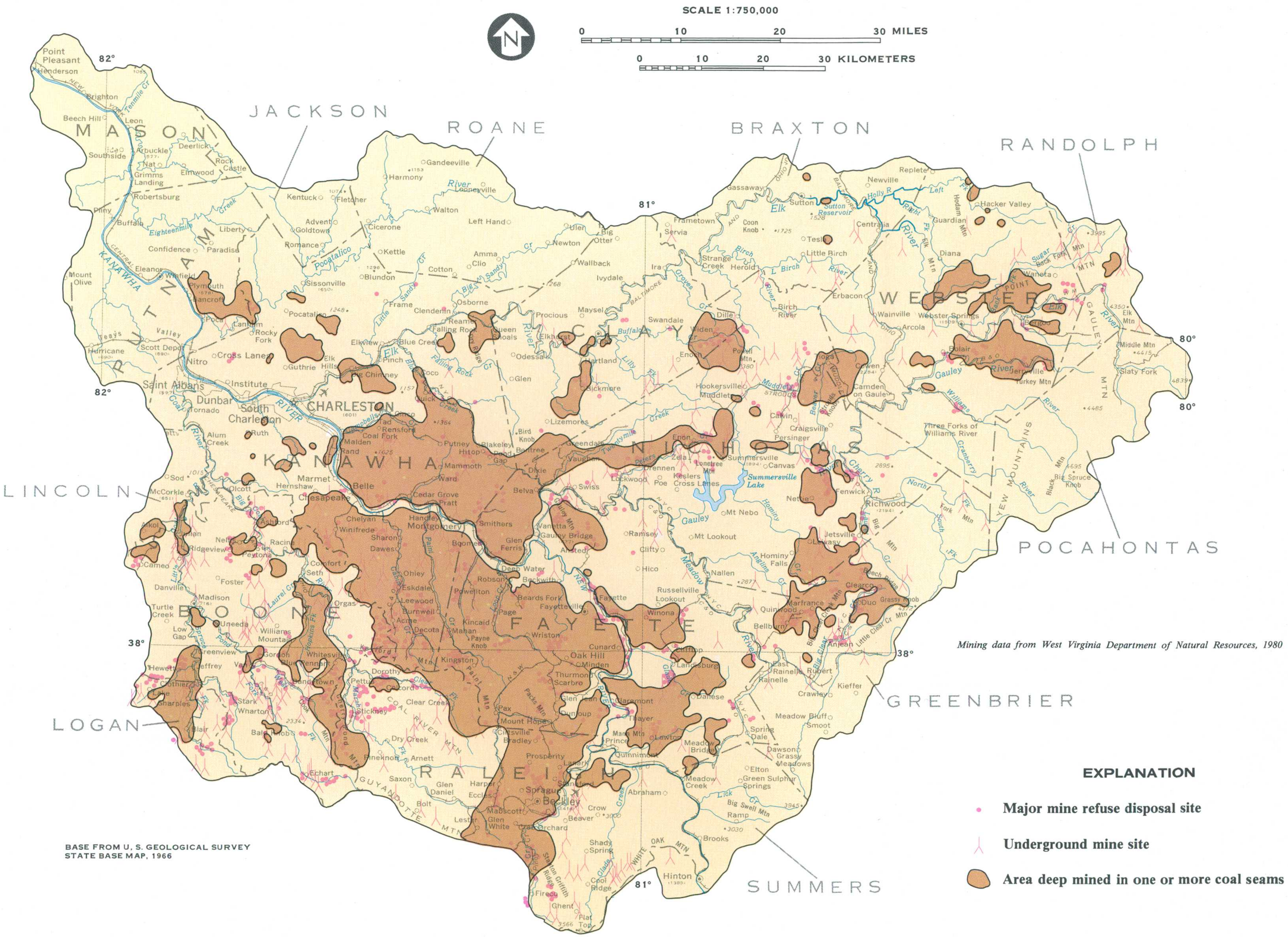


Figure 3.3-1 Active underground mines, mine refuse disposal sites, and mined out areas

Table 3.3-1 Distribution of active underground mines in Area 9.

County	Number of active mines as of 4-1-80
Boone	113
Braxton	3
Clay	10
Fayette	39
Greenbrier	25
Kanawha	93
Lincoln	2
Logan	19
Nicholas	70
Putnam	1
Raleigh	58
Randolph	11
Summers	2
Webster	23
Total	469

Hydrologic Data Available at 130 Surface-Water Locations

The streamflow and surface-water quality monitoring network in Area 9 consists of 130 continuous-record stations and miscellaneous measuring sites. Daily streamflow data are collected at 25 gaging stations, and intermittent streamflow data are collected at 105 sites. Surface-water quality is monitored on a daily basis at 2 stations, monthly at 23 stations and less frequently at 102 sites.

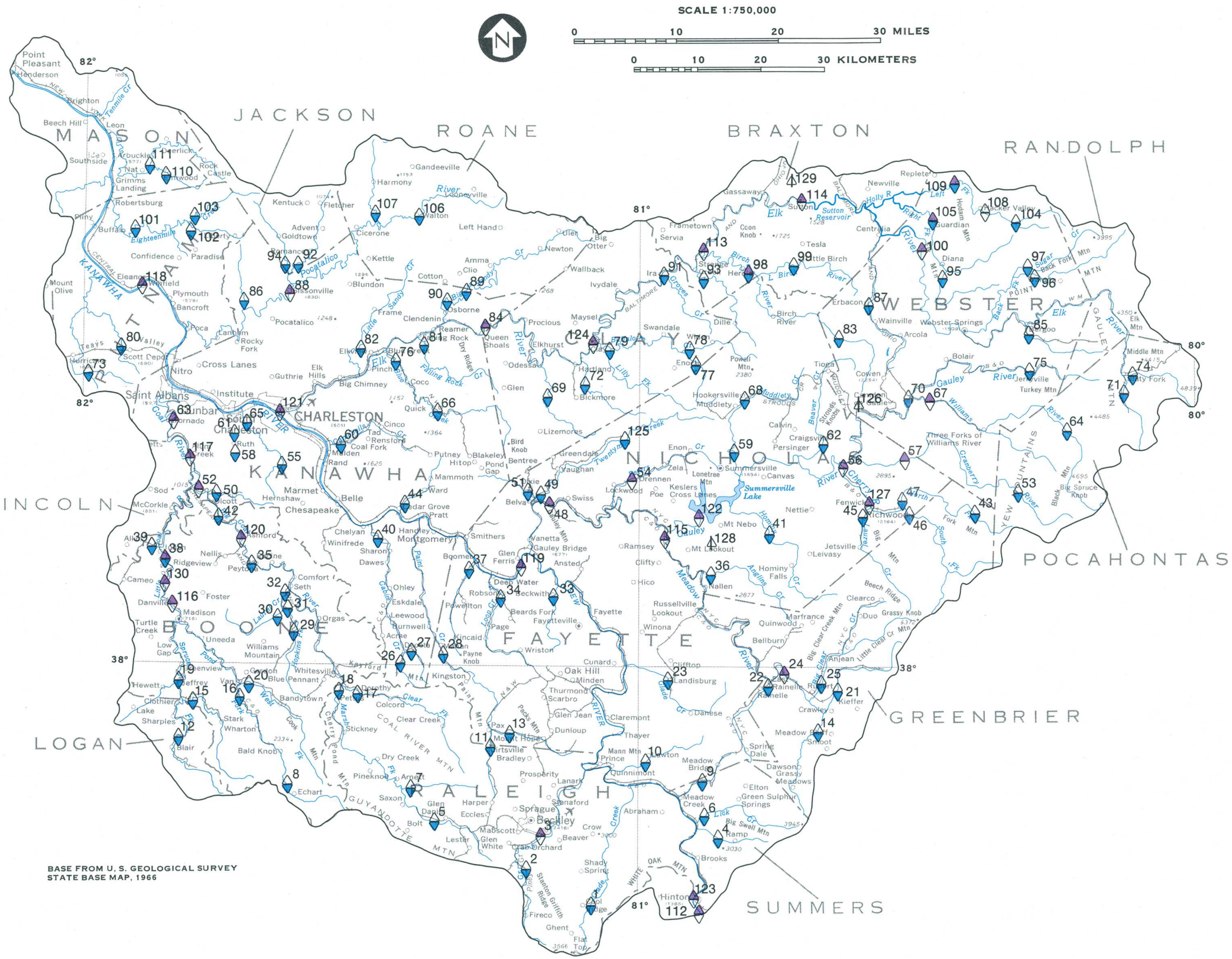
Surface-water quantity and quality data are collected at 130 stations and measuring sites in Area 9. Locations are given in figure 4.1-1. The data collection network provides information needed to describe the hydrology of the general area and aids mine owners and operators, consulting engineers, and regulatory authorities in evaluating the hydrologic consequences of mining.

Systematic collection of streamflow data is conducted on a daily basis at 25 gaging stations and intermittently at 105 sites. Several types of water-quality data are available at all locations. The most intensively sampled locations are referred to as trend and reference stations (sites 3 and 57, respectively, fig. 4.1-1 and section 7.0). Trend stations are intended to monitor regional water-quality changes in mining areas and are located in areas downstream from major mining operations. Reference stations are located in areas unaffected by mining.

Water-quality data were collected on an hourly and daily frequency at two stations and once monthly at 23 stations as indicated in figure 4.1-1. Specific conductance was measured hourly and suspended-sediment concentration once daily at sites 3 and 57. Water samples were collected at 23 stations on a monthly frequency for the determination of major dissolved constituents (calcium, magnesium, sodium, bicarbonate, chloride, and sulfate) and for dissolved and suspended concentrations of iron and manganese. Water temperature, pH, specific conductance, alkalinity, and acidity were measured on site whenever water samples were collected for laboratory analysis.

Intermittent streamflow and water-quality data were collected at 105 synoptic sites indicated in figure 4.1-1. Synoptic sites are ungaged sampling locations on small streams with drainage areas generally less than 50 square miles. Water sampling has been conducted at these sites during 1979 and 1980 under moderate to high streamflow conditions. Future sampling is planned for low flow. Water samples were collected for the determination of major dissolved constituents and selected dissolved and suspended trace element concentrations. Water samples were collected at synoptic sites (fig. 4.1-1) during storms for the determination of suspended-sediment concentrations. Certain physical and chemical properties of water, including water temperature, pH, specific conductance, alkalinity, and acidity were determined on site.

Data for all sites are available from computer storage through National Water Data Exchange (NAWDEX) and are published annually by the U.S. Geological Survey in "Water Resources Data for West Virginia."



EXPLANATION

- ▲24 Continuous record gaging station and number
- △12 Miscellaneous measurement site and number
- ▼44 Quality of water site and number, sampled on a less than monthly frequency
- ▽3 Quality of water site and number, sampled on monthly frequency
- 126 Inactive site and number

See Section 7.0 for detailed site description

Figure 4.1-1 Surface-water network

Streamflow Regulation and Geology Affect Low Flow in Area

Unfractured rocks in Area 9, because of their low permeability, do not maintain streamflow during drought periods. Streams having small drainage areas may go dry during droughts. Regulation affects low flow in most large rivers in the area.

Surface rocks in the area, where unfractured, store water poorly because of their low primary permeability. Thus ground-water discharge to many small streams is insufficient to maintain flow during drought periods, and many go dry. Low flow is affected by many factors, including stream diversion, regulation, size of drainage area, surface geology, precipitation patterns, wastewater discharge, and mining.

A commonly used streamflow characteristic is the 7-consecutive-day mean low flow at 10-year recurrence intervals ($M_{7,10}$). The probability that the actual low flow in any one year will be less than the calculated $M_{7,10}$ is equal to the reciprocal of the recurrence interval. Thus, the probability is 0.1 that the actual low-flow in any one year will be less than the calculated $M_{7,10}$.

Low-flow values for selected gaging stations are shown in figure 4.2.1-1. Low-flow estimates were calculated by fitting low-flow data points to a Log-Pearson type III frequency distribution (Hutchinson, 1975). Drainage areas for the sites range from 2.78 to 10,419 mi^2. Some of the data represent streamflow from non-concurrent time periods and thus, are not suitable for comparison between stations.

Streamflow regulation affects discharge in many large rivers throughout Area 9. The Kanawha River is controlled by dams to reduce the chance of flooding and to augment streamflow during low streamflow periods. Dams at London, Marmet, and Winfield provide lowhead power generation and control river stage for navigation. Bluestone Reservoir on the New River, Summersville on the Gauley, and Sutton on the Elk are multipurpose structures operated for flood control, recreation, and low-flow augmentation. Unregulated flow conditions no longer exist on many of the larger rivers in Area 9. Low flows in these streams are sustained for significantly longer periods of time.

Low-flow characteristics shown in figure 4.2.1-1 are dependent on homogeneous record for a minimum of 10 years. Any change in the regulation pattern would affect streamflow characteristics, including low flow. In that event, the $M_{7,10}$ values shown in figure 4.2.1-1 may not be applicable.

Low flows at many ungaged sites within the area cannot be estimated due to the effects of diversion, wastewater discharge, and drainage from mining operations.

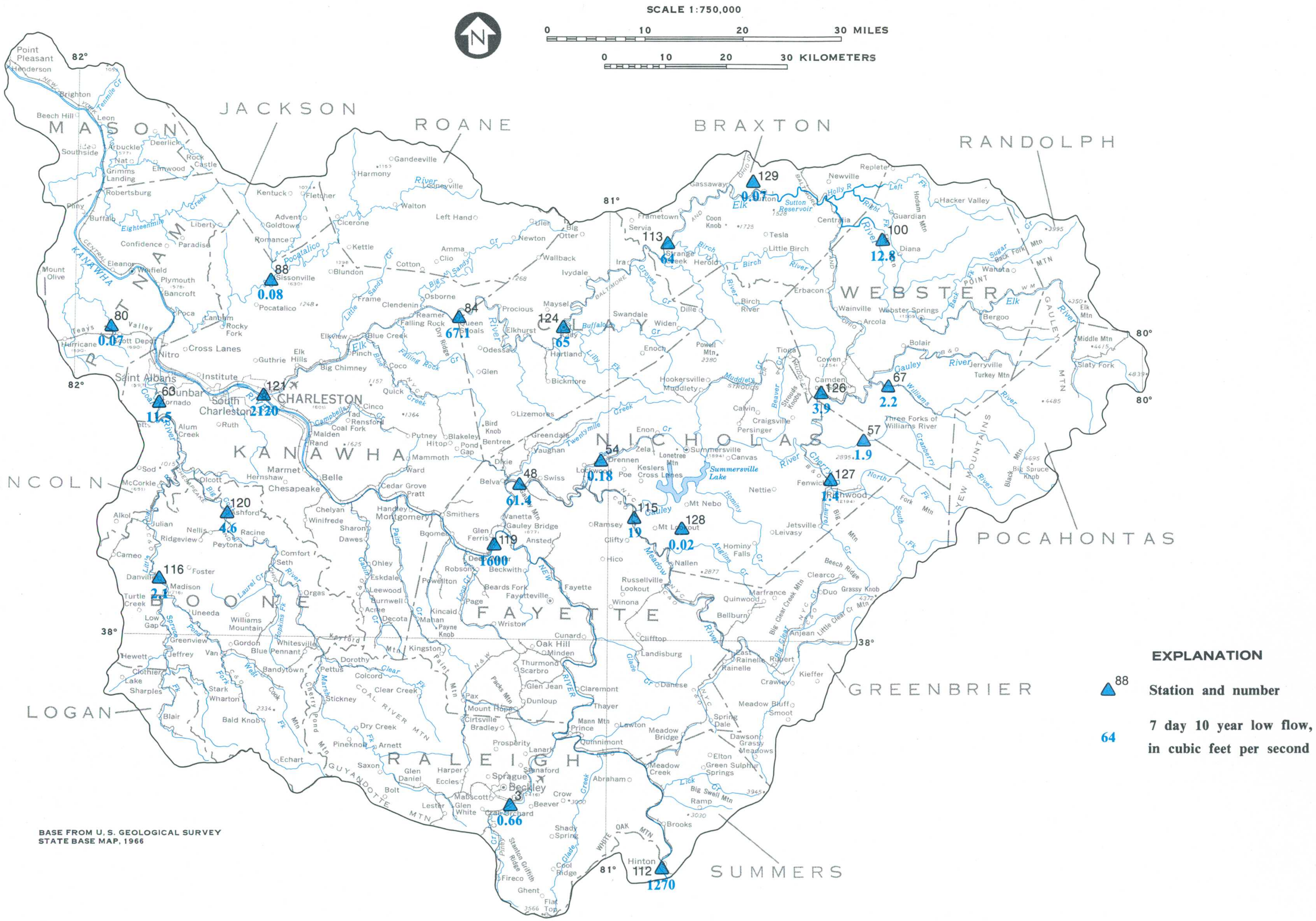


Figure 4.2.1-1 7-day, 10-year low flow for selected sites

Floods Vary with Drainage Area

Difference in drainage-area affects the magnitude and frequency of floods in Area 9.

Estimates of the magnitude and frequency of floods are needed for safe and economical design of hydraulic structures and flood-plain management. Flood frequencies are expressed as a probability of occurrence, or recurrence interval. The recurrence interval is the inverse of the probability of an event occurring in any one year. Thus, the 50-year recurrence interval flood would have a 2 percent chance of being exceeded in any one year.

Regression equations for estimating the magnitude and frequency of floods at ungaged sites in West Virginia were developed by Runner (1980).

The equations are of the following form:

$$Q_i = cA^b$$

where Q_i is the peak discharge in ft^3/s (cubic feet per second) at a given i year recurrence interval; c is the regression constant; A is the drainage area in mi^2 (square miles); and b is the regression coefficient.

The equations, developed for each of three geographical regions within the state (fig. 4.2.2-1), are applicable to basins with drainage areas ranging from 0.3 to 2,000 mi^2. The equations applicable to Area 9 for Q_{10}, Q_{50}, and Q_{100} are

Q_{10}

Drainage area 0.3 to 549 mi^2, $Q_{10} = 201A^{0.771}$

Drainage area 550 to 2000 mi^2, $Q_{10} = 149A^{0.818}$

Q_{50}

Drainage area 0.3 to 529 mi^2, $Q_{50} = 354A^{0.733}$

Drainage area 530 to 2000 mi^2, $Q_{50} = 249A^{0.789}$

Q_{100}

Drainage area 0.3 to 529 mi^2, $Q_{100} = 437A^{0.719}$

Drainage area 530 to 2000 mi^2, $Q_{100} = 303A^{0.777}$

Graphical solutions for estimating the 10-, 50-, and 100-year instantaneous peak discharges for basins in Area 9 are shown in figure 4.2.2-2. An example of discharge determinations for a given basin is also illustrated in figure 4.2.2-2. In the example, the Q_{10}, Q_{50}, and Q_{100} for a basin with a drainage area of 50 mi^2 are 4,100, 6,200, and 7,300 ft^3/s, respectively.

The graphs and equations presented here should not be used to estimate peak flows for sites draining urban basins, areas with significant regulation, or where drainage areas are less than 0.3 mi^2 or greater than 2,000 mi^2.

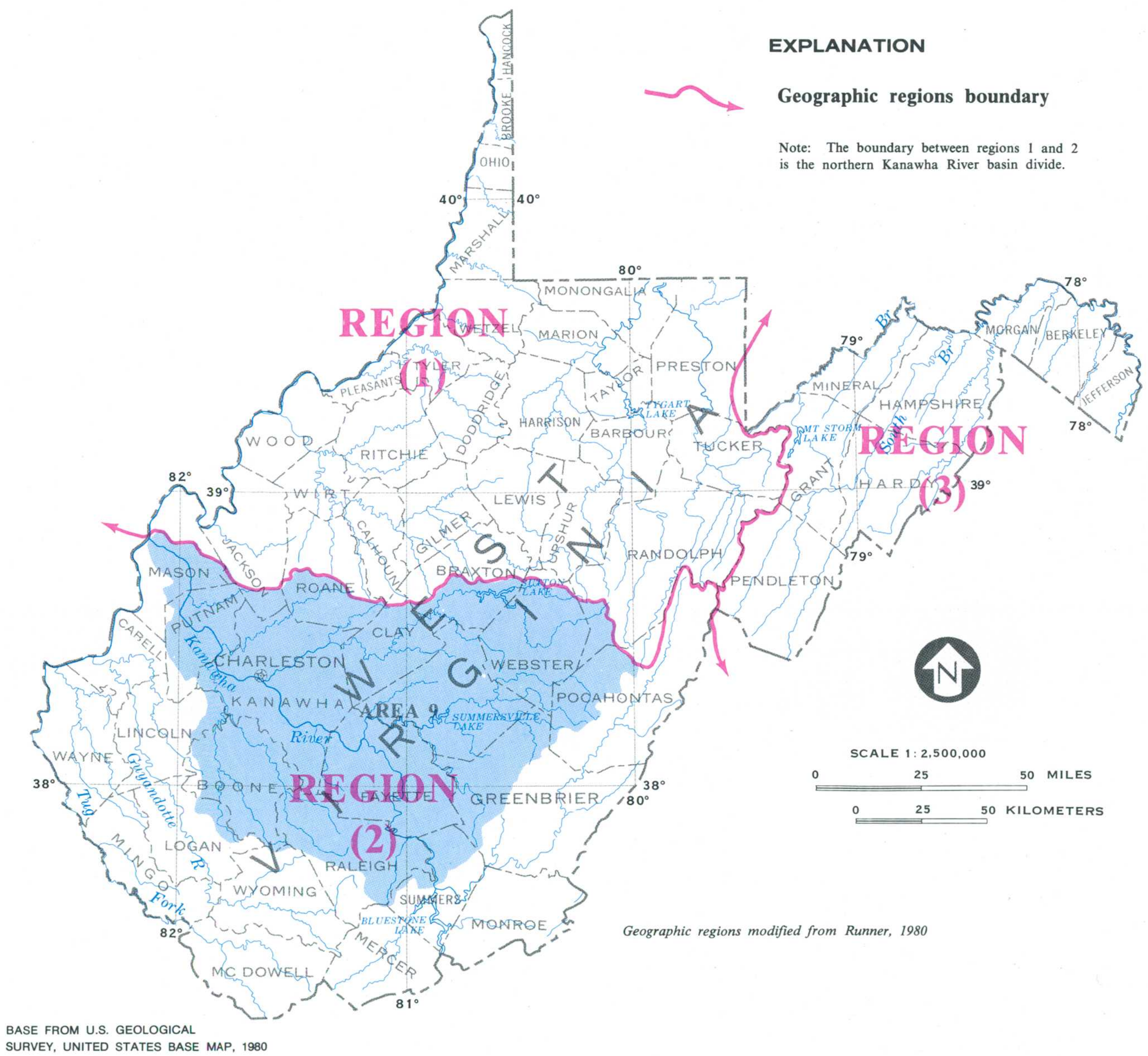


Figure 4.2.2-1 Relation of Area 9 to flood-frequency geographic regions in West Virginia

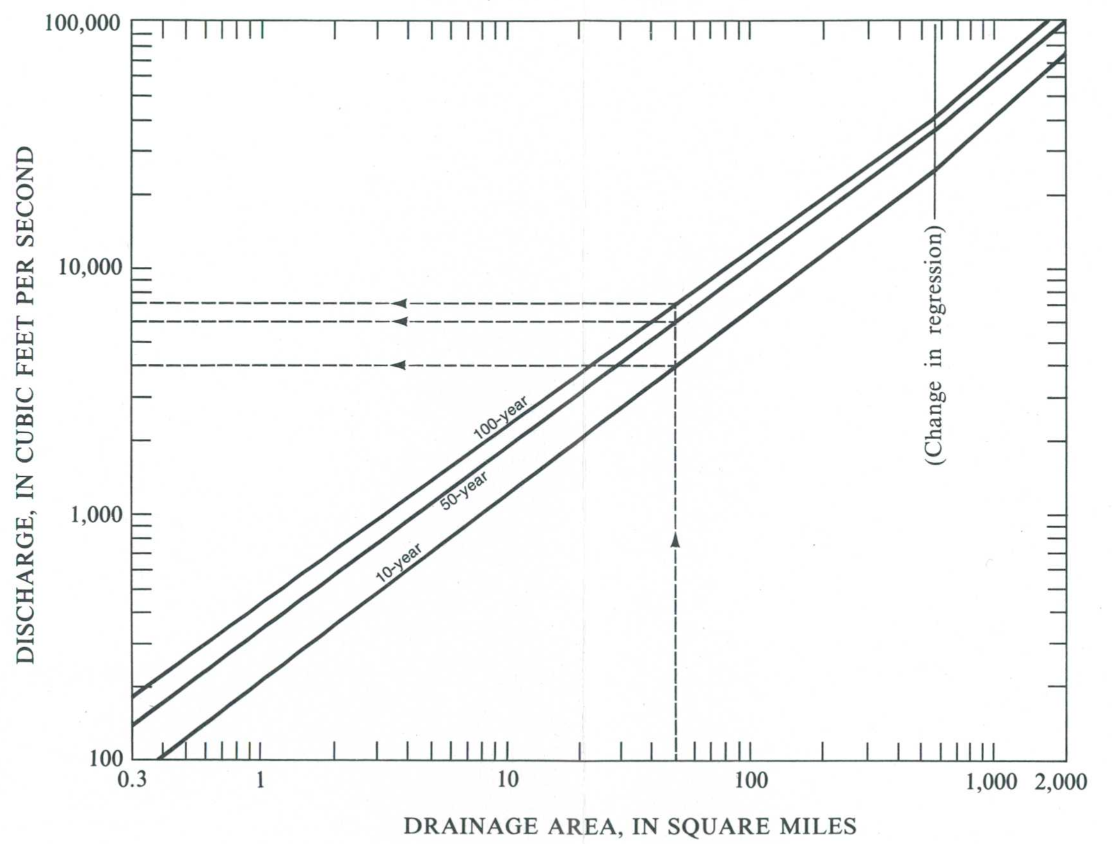


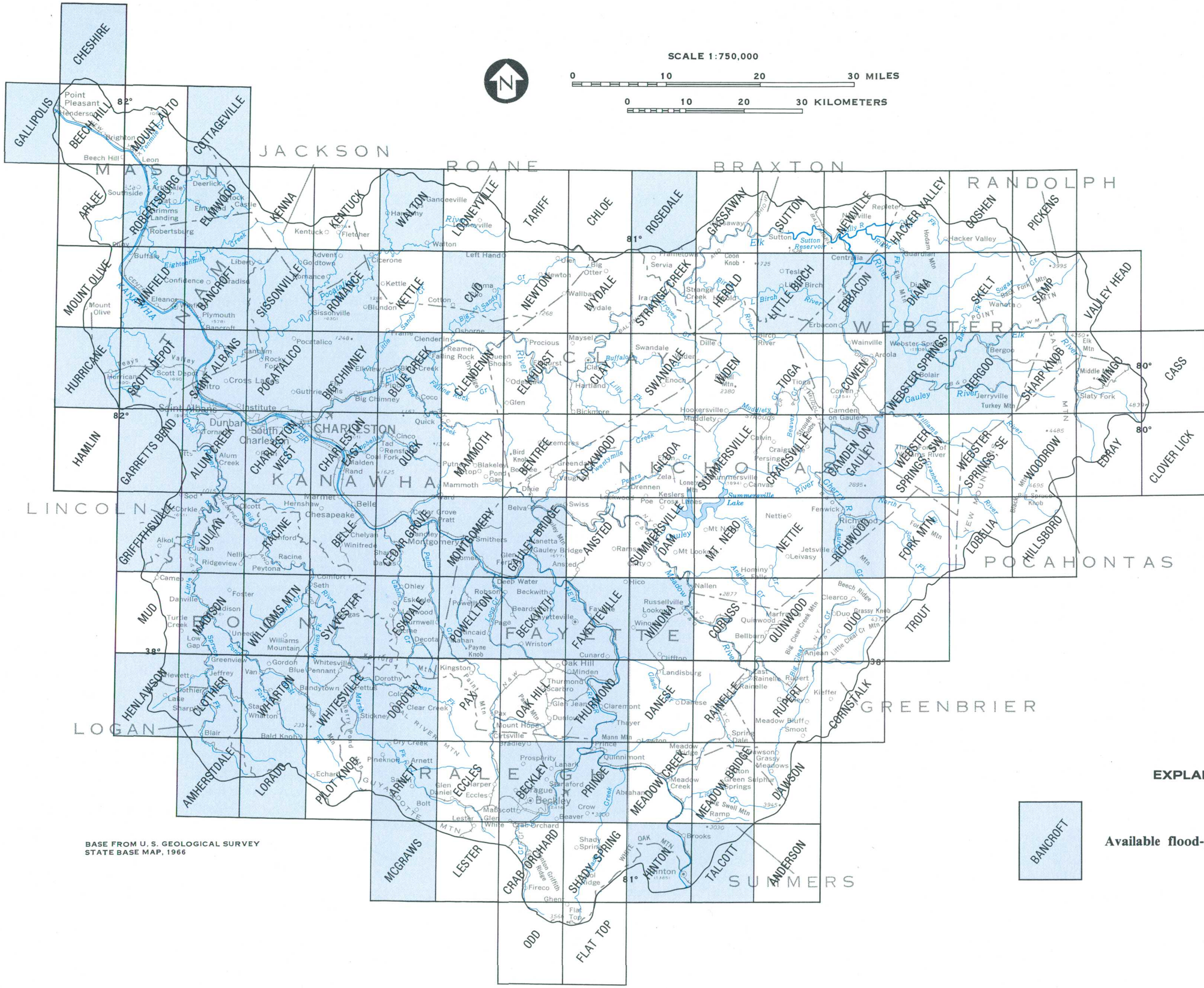
Figure 4.2.2-2 Relation of 10-year, 50-year and 100-year peak discharges to drainage area

Flood-Prone Maps Available for Area 9

The limits of the 100-year recurrence interval flood are delineated on 61 selected 7½-minute quadrangles in Area 9.

The National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973 established programs for investigating the extent of flooding in urban areas and rural communities. Flood-prone area maps prior to 1969 were for "approximate areas occasionally flooded." In 1969, the project was changed to delimit the approximate boundaries of the 100-year flood. In 1969 the U.S. Geological Survey began a mapping program to delineate flood-prone areas for all affected communities, recreational areas, and areas with the potential for development. Maps were produced using stage-frequency relations at gaging stations, profiles of high-water marks, and regional flood-frequency curves. Also shown on flood-prone maps are areas where U.S. Geological Survey hydrologic atlases are available, areas delineated in greater detail by other federal agencies, or inundated areas prior to reservoir construction. In general, the delineated areas are for natural stream conditions and give the user a quick way of identifying areas of potential flood hazards.

The locations for 61 flood-prone area maps in Area 9 are shown on figure 4.2.3-1. Completed 7½-minute flood-prone area maps are shown with the quadrangle name. The maps are open-file and available upon request from the U.S. Geological Survey District Office, 3416 Federal Building, Charleston, West Virginia 25301.



EXPLANATION

BANCROFT — Available flood-prone area map, scale 1:24,000

Figure 4.2.3-1 Maps of flood-prone areas

Streamflow Duration in Area 9 is Affected by Basin Physiography, Climate, Streamflow Regulation, and Coal Mining

Flow-duration curves indicate the percentage of time that specific discharges are exceeded during a given period. The shape of the curve is dependent upon many basin characteristics, including drainage area, climate, streamflow regulation, and land-use activities such as coal mining.

Streamflow-duration curves are cumulative-frequency curves that show the percentage of time that specific discharges are equaled or exceeded during a specified period of time. The curves are frequently used to demonstrate streamflow variability. For example, a discharge of about 500 ft^3/s (cubic feet per second)at Little Coal River at Danville (site 116, fig. 4.2.4-1) is expected to be equaled or exceeded about 20 percent of the time. Discharges at 20-30 percent flow duration generally correspond to the stream's mean flow. Streamflow occurring at or greater than 75 percent duration is generally considered low flow, while streamflow occurring at less than 10 percent duration is considered to be high flow. Streamflow-duration data for selected gaging stations in Area 9 (fig. 4.2.4-1) are summarized in table 4.2.4-1. Flow-duration data for regulated streams is presented separately according to unregulated and regulated periods of time. Some of the data for streams in table 4.2.4-1 represent streamflow from non-concurrent time periods and thus, are not suitable for comparison between stations.

The shape of flow-duration curves is generally dependent on drainage area, climate, topography, geology, and land use. A steep curve denotes highly variable streamflow derived mainly from direct surface runoff, whereas a flat curve, particularly in the low-flow portion, indicates streamflow derived from delayed surface runoff and ground-water storage. The flow-duration curve for the Little Coal River at Danville (fig. 4.2.4-1) is very steep and nearly linear from 0.10 to 99.7 percent duration. The curve typically reflects the limited contribution of ground water from storage in the geologic formations underlying the basin. The Little Coal River is unregulated and drains about 385 mi^2 of mountainous, deeply incised terrain with slopes generally exceeding 30 percent. The basin is also heavily mined.

Streamflow regulation affects streamflow variability by attenuating flood peaks and augmenting streamflow during periods of low precipitation. The effect of regulation on streamflow duration for the Gauley River above Belva (site 48) is also illustrated on figure 4.2.4-1. The flow-duration curve representing regulated streamflow conditions (1965 to present) is substantially flatter than the curve representing unregulated streamflow conditions (1928-1965). The flatter flow-duration curve at discharges greater than about 12,000 ft^3/s and less than about 30 ft^3/s typically reflects decreased high flow and increased low flow resulting from streamflow regulation. The shape of the low-flow portion of flow-duration curves for many small streams draining intensively mined basins in Area 9 is relatively flat. It similarly reflects low-flow augmentation by mine drainage contributed to streams during periods of low precipitation. The difference between the curves from the 3 to 99.5 percent durations reflects precipitation differences between unregulated and regulated time periods.

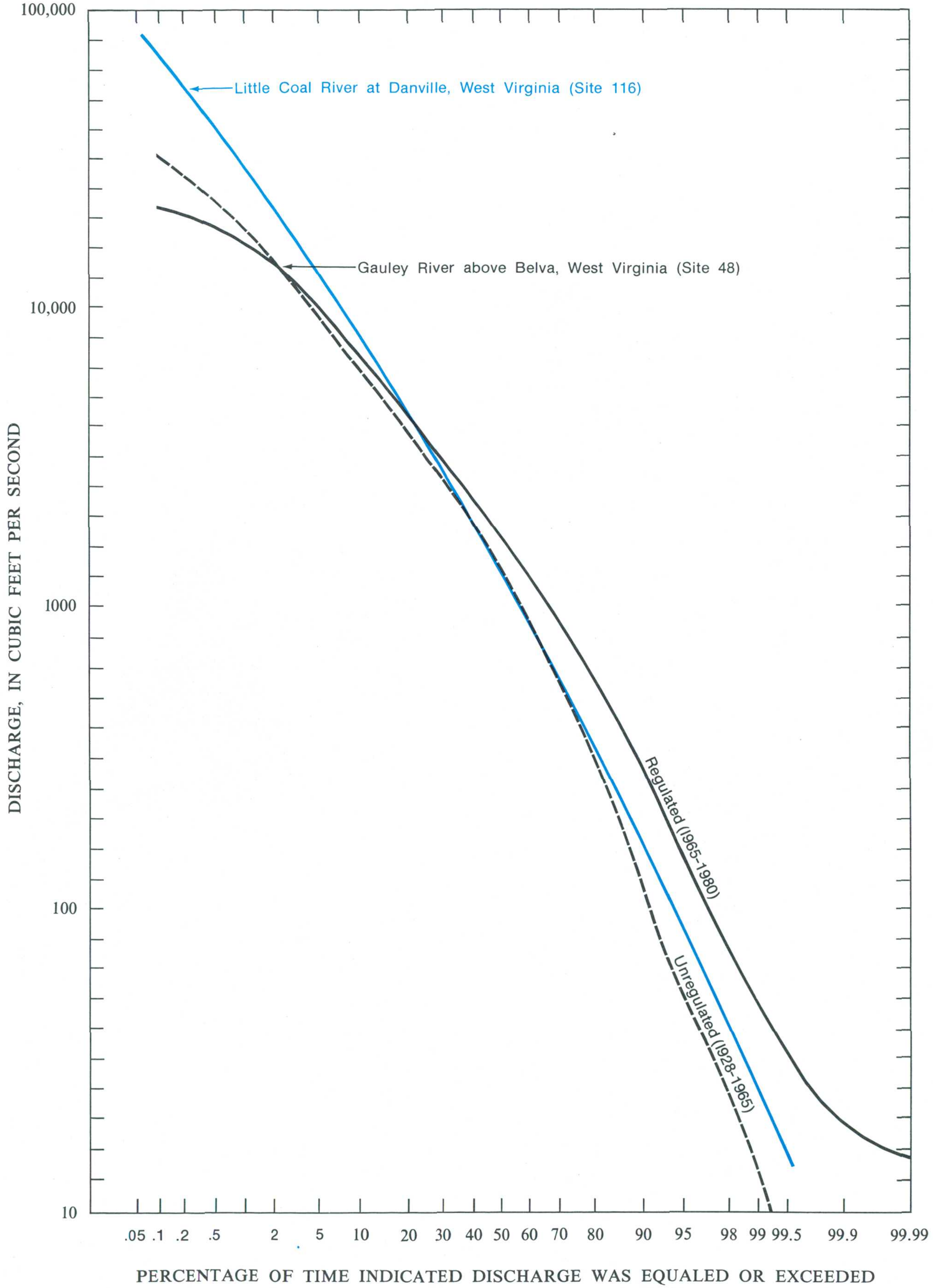


Figure 4.2.4-1 Representative flow-duration curves

Table 4.2.4-1. Flow duration for selected sites in Area 9.

Site Number	Station Name	Station Number	Years of Record	Daily Mean Discharge (ft/s) That Was Equaled or Exceeded For Indicated Percentage of Time						
				95	90	75	70	50	25	10
3	Piney Creek at Raleigh	03185000	30	2.2	3.7	9.1	12	30	73	140
35	Drawdy Cr. nr. Peytona	03198450	9	0.3	0.6	1.4	1.8	4.2	11	23
38	Little Coal River at Julian	03199400	5	35	50	100	120	260	630	1,300
48	Gauley River above Belva	03192000								
	Unregulated period		35	56	130	460	600	1,400	3,300	6,400
	Regulated by Summersville Lake		15	170	320	760	910	1,700	3,800	7,100
52	Big Coal River nr. Alum Creek	03198550	5	48	69	140	170	350	820	1,500
53	North Fork Cranberry River nr. Hillsboro	03187300	5	3.6	5	8.2	9.5	18	39	62
54	Peters Creek nr. Lockwood	03191500	27	1.3	2.7	7.2	9.6	25	71	160
57	Cranberry River nr. Richwood	03187500	19	9.6	19	52	64	130	270	520
63	Coal River at Tornado	03200500	27	50	100	290	350	700	1,500	2,800
67	Williams River at Dyer	03186500	51	9.7	20	67	86	180	400	770
80	Poplar Fork at Teays	03201410	13	0.2	0.4	1.2	1.6	3.8	9.4	23
84	Elk River at Queen Shoals	03197000								
	Unregulated period		31	37	91	320	410	960	2,400	4,800
	Regulated by Sutton Lake		20	140	220	450	550	1,100	2,800	5,600
88	Pocatalico River at Sissonville	03201000	55	0.8	2.2	14	21	73	260	740
98	Birch River at Herold	03196500	5	9.5	14	46	60	140	330	680
100	Elk River below Webster Springs	03194700	21	42	68	160	190	390	850	1,700
105	Right Fork Holly River at Guardian	03195100	5	5.2	7.9	19	23	43	110	230
109	Left Fork Holly River nr. Replete	03195250	5	6.6	9.9	24	28	51	130	260
112	New River at Hinton	03184500								
	Unregulated period		2	2,300	2,700	3,800	4,200	6,300	10,000	17,000
	Regulated by Claytor Lake		10	1,600	1,900	2,800	3,200	4,700	8,400	15,000
	Regulated by Bluestone Lake		31	1,600	1,900	2,800	3,200	5,300	9,900	17,000
113	Elk River nr. Frametown	03196600								
	Unregulated period		1	27	64	160	220	590	1,400	2,900
	Regulated by Sutton Lake		20	110	160	380	450	840	2,000	4,000
114	Elk River at Sutton	03195500								
	Unregulated period		21	28	58	200	260	590	1,400	2,600
	Regulated by Sutton Lake		20	83	110	270	350	640	1,400	3,000
115	Meadow River near Mt. Lookout	03190400	14	41	67	170	220	450	1,000	1,900
116	Little Coal River at Danville	03199000	51	8.7	16	40	52	140	410	850
119	Kanawha River at Kanawha Falls	03193000								
	Unregulated period		60	2,000	2,600	4,200	4,900	8,400	16,000	28,000
	Regulated by Claytor Lake		10	1,800	2,200	3,700	4,200	6,600	12,000	23,000
	Regulated by Bluestone Lake		16	1,700	2,200	3,600	4,200	7,300	15,000	27,000
	Regulated by Summersville Lake		15	2,500	3,100	4,800	5,400	8,400	16,000	28,000
120	Big Coal River at Ashford	03198500	60	15	24	61	76	210	610	1,300
121	Kanawha River at Charleston	03198000	42	2,300	2,900	4,900	5,600	9,300	19,000	33,000
124	Elk River at Clay	03196800								
	Unregulated period		1	32	69	170	260	650	1,700	3,800
	Regulated by Sutton Lake		19	130	190	400	480	980	2,500	5,000
126	Gauley River at Camden on Gauley	03187000	55	20	39	120	150	330	730	1,400
127	Cherry River at Fenwick	03189000	41	6.7	15	62	84	210	520	1,000
128	Collison Cr. nr. Nallen	03189650	11	0.1	0.1	0.4	0.7	2.1	5.3	11
129	Granny Creek at Sutton	03195600	11	0.2	0.4	1.0	1.4	3.5	10	23

Streamflow Varies with Seasonal Precipitation

Mean monthly streamflow is generally greatest in March and lowest in September or October. Annual distribution follows seasonal changes in precipitation and evapotranspiration. Regulation affects streamflow in many of the larger rivers.

Streamflow in unregulated streams typically varies greatly during the year, following the precipitation and evapotranspiration regime. The hydrograph for the Coal River at Tornado (site 63, fig. 4.2.5-1) is typical of unregulated rivers in the area. Monthly mean streamflow at site 63 for the period October 1, 1978 to September 30, 1979 was lowest in October (87.6 ft^3/s), which on the average is the driest period of the year.

The greatest mean monthly flows usually occur during March as a result of snowmelt runoff, increased precipitation, and relatively low evapotranspiration. Streamflow during spring and early summer is usually high as a result of increased thunderstorm activity. Streamflow recession during late summer and early fall results from evapotranspiration losses and decline of precipitation activity. During November and December, streamflow usually increases as evapotranspiration decreases and the winter rains begin.

Mean annual and mean monthly streamflow for selected streams in Area 9 (fig. 4.2.5-2) are given in table 4.2.5-1. As shown in the table, some of the larger rivers, the Elk, Gauley, New, and Kanawha, are affected by streamflow regulation. Streamflow regulation usually augments low-flow discharges during dry periods, and attenuates flood runoff and peak flows produced by significant precipitation events. Mean flows of regulated streams are generally less variable than those of unregulated streams and do not reflect natural streamflow characteristics in Area 9. Some of the data for streams in table 4.2.5-1 represent streamflow from non-concurrent time periods and thus, are not suitable for comparison between stations.

Figure 4.2.5-2 Streamflow measuring stations.

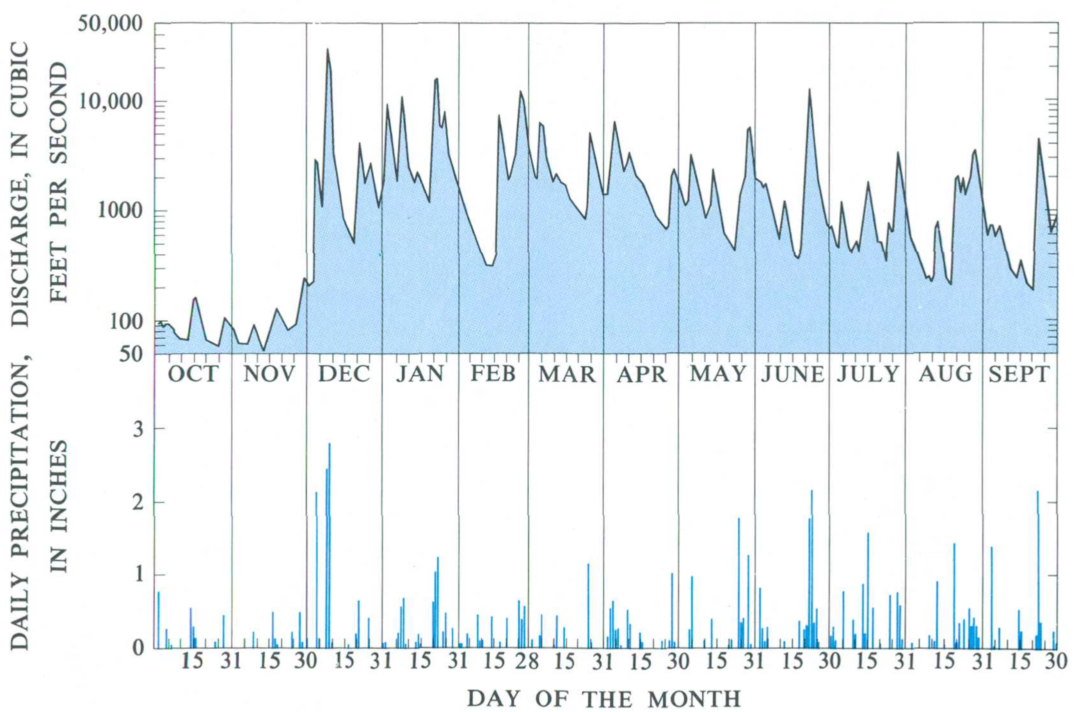


Figure 4.2.5-1 Streamflow and precipitation at site 63 for period October 1, 1978 to September 30, 1979

Table 4.2.5-1 Mean monthly and mean annual streamflow at selected stations in Area 9

Site Number	Station Name	Station Number	Years of Record	Regulated By:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean Annual
					Mean Monthly Discharge in Cubic Feet per Second												
3	Piney Creek at Raleigh	03185000	30	Unregulated	100	115	141	100	78.2	35.7	23.3	20.5	13.2	18.5	33.6	70.6	61.9
35	Drawdy Creek at Peytona	03198450	9	Unregulated	15	20	18.5	18	8.6	4.2	4.1	2.6	2.6	2.5	6.2	14.8	9.8
38	Little Coal R. at Julian	03199400	5	Unregulated	1,050	840	1,220	829	564	327	162	328	173	271	300	800	572
48	Gauley River above Belva	03192000	35	Unregulated	4,063	4,504	5,772	4,020	2,857	1,517	1,493	1,231	519	836	1,767	3,047	2,640
			15	Summersville Dam	4,126	3,862	5,202	2,917	3,147	1,736	1,601	1,598	1,380	2,666	3,462	4,044	2,980
52	Big Coal River nr. Alum Creek	03198550	5	Unregulated	1,570	1,120	1,420	1,100	670	345	180	310	193	350	404	1,060	725
53	North Fk. Cranberry River nr. Hillsboro	03187300	5	Unregulated	30.2	36.6	50.9	48.4	23.5	18.6	22.4	18.6	22	20.8	37.3	36.5	30.5
54	Peters Creek nr. Lockwood	03191500	27	Unregulated	96.2	114	135	94.2	68.6	31.3	33.1	30.9	12.8	12.9	39.6	79.1	62.3
57	Cranberry River nr. Richwood	03187500	19	Unregulated	308	339	421	320	258	114	122	85.7	94.8	103	203	288	220
63	Coal R. at Tornado	03200500	27	Unregulated	1,930	2,140	2,660	2,030	1,420	740	602	458	306	429	852	1,500	1,256
67	Williams River at Dyer	03186500	51	Unregulated	470	508	666	494	343	191	187	163	91.6	171	276	408	330
84	Elk River at at Queen Shoals	03197000	31	Unregulated	3,230	3,290	4,460	2,730	2,250	1,070	870	910	750	1,350	2,150	3,150	2,180
98	Birch River at Herold	03196500	5	Unregulated	492	400	464	410	288	185	116	61.1	106	157	182	435	275
100	Elk River below Webster Springs	03194700	21	Unregulated	930	986	1,430	1,060	691	412	351	317	249	405	679	961	703
105	Right Fk. Holly River at Guardian	03195100	5	Unregulated	135	130	187	125	112	79.3	47.9	30.1	24.5	81.4	83.3	134	97.4
109	Left Fk. Holly River nr. Replete	03195250	5	Unregulated	145	155	210	136	126	71.7	50.4	40.1	36.1	98.1	96.7	148	109
112	New River at Hinton	03184500	10	Claytor Lake	9,795	11,160	12,600	10,660	8,855	6,276	5,675	6,369	4,422	3,565	4,284	7,042	7,560
			31	Bluestone Dam Claytor Lake	10,220	13,050	16,560	12,690	9,547	6,185	3,850	3,450	3,120	4,240	5,630	8,520	8,090
113	Elk River nr. Frametown	03196600	22	Sutton Dam	2,870	2,980	4,060	2,390	1,970	1,040	688	775	609	1,090	1,960	2,700	1,926
115	Meadow River nr. Mt. Lookout	03190400	14	Unregulated	1,140	1,190	1,490	1,070	914	463	373	370	194	405	685	1,110	778
116	Little Coal River at Danville	03199000	51	Unregulated	570	690	865	630	383	204	162	112	62.2	69.8	143	390	355
119	Kanawha River at Kanawha Falls	03193000	61	Unregulated	19,070	21,930	24,350	19,340	14,520	10,180	7,542	6,455	5,225	6,461	8,473	12,580	13,000
			10	Claytor Lake	15,020	16,970	20,110	16,320	12,860	8,615	7,677	8,249	5,377	4,324	6,089	10,920	11,000
			16	Claytor Lake Bluestone Dam	15,480	21,200	26,410	19,840	12,310	7,430	5,476	4,233	3,430	4,454	7,103	12,620	11,700
			15	Claytor Lake Bluestone Dam Summersville Dam	17,800	18,801	24,200	17,610	15,820	10,090	6,426	6,381	5,349	8,889	11,230	14,930	13,100
120	Big Coal River at Ashford	03198500	60	Unregulated	873	1,000	1,250	905	548	272	228	165	90	119	227	567	517
121	Kanawha River at Charleston	03198000	10	Claytor Lake	19,000	21,500	26,400	21,100	15,400	10,100	9,070	9,150	5,920	4,730	7,410	13,900	13,600
			10	Claytor Lake Bluestone Dam	20,600	29,500	30,900	25,800	17,600	10,100	7,880	6,040	4,430	4,440	7,800	16,000	15,100
			14	Claytor Lake Bluestone Dam Sutton Dam Summersville Dam	22,600	23,700	29,900	21,200	19,400	11,900	7,600	7,600	6,460	10,700	13,900	19,100	16,200
126	Gauley River at Camden on Gauley	03187000	55	Unregulated	912	922	1,140	873	617	375	340	290	160	265	466	703	590
127	Cherry River at Fenwick	03189000	41	Unregulated	603	655	899	648	445	216	214	182	90.4	149	302	481	407
128	Collison Cr. nr. Nallen	03189650	11	Unregulated	6.8	8.3	8.0	5.9	4.6	2.0	3.0	2.8	0.64	2.4	3.8	8.3	4.7
129	Granny Creek at Sutton	03195600	11	Unregulated	15.5	15.6	14.4	17.2	8.1	5.5	2.8	3.2	3.7	4.4	8.9	15.3	9.6
130	Rock Cr. nr. Danville	03199300	2	Unregulated	51.3	36.4	31.8	40.2	20.8	20.5	21.8	12.8	16.6	10.2	15.3	16.4	24.5

Specific Conductance of Surface Water in the Area is Highest in Mined Areas

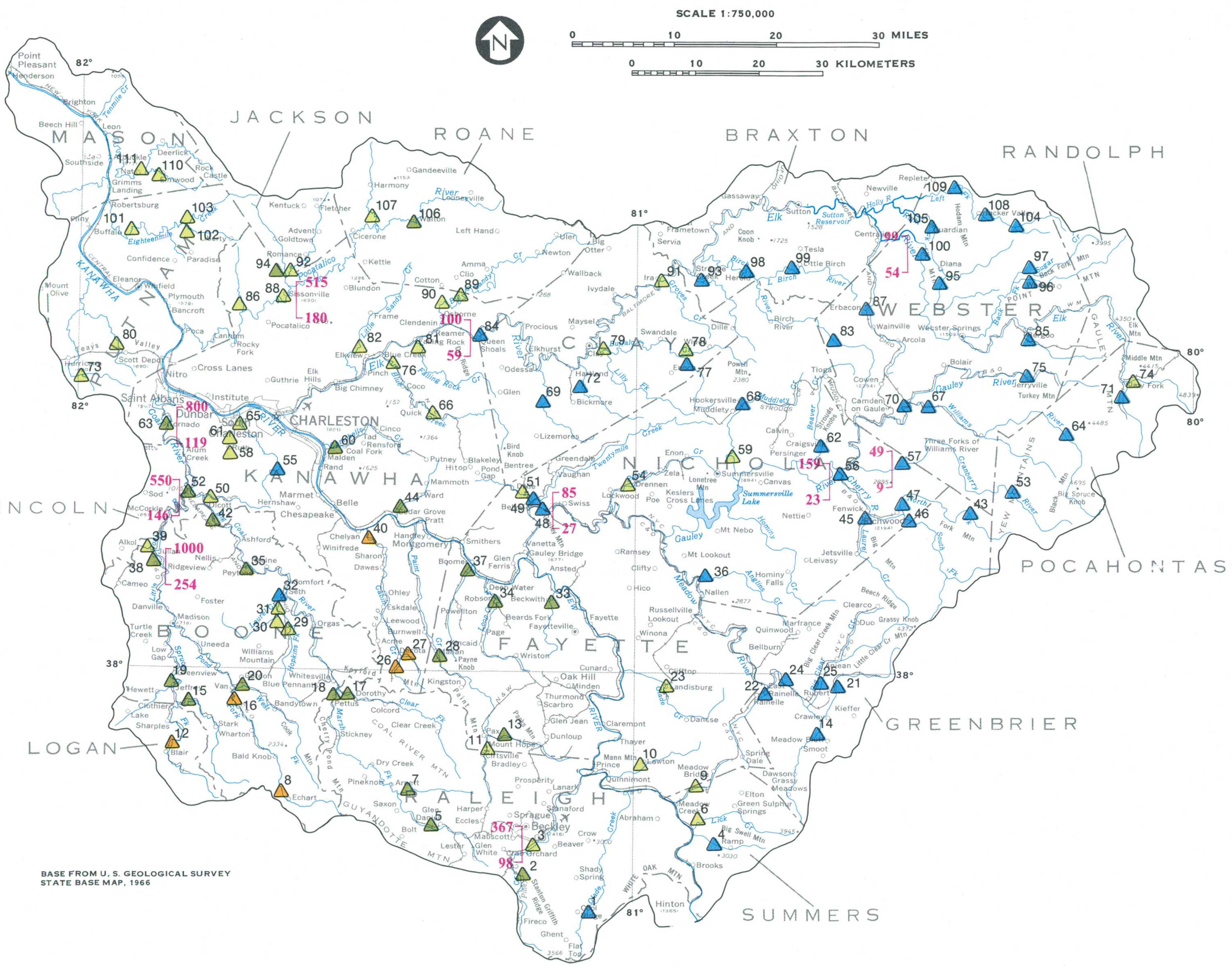
Mean specific conductance in surface water throughout Area 9 was 185 micromhos per centimeter. The lowest mean specific conductance was in the Gauley River basin.

Specific conductance is a measure of the ability of water to carry an electrical current, and by convention is reported at 25°C. Specific conductance is indicative of the quantity of ionized minerals in solution and is used as a general indicator of water-quality conditions.

Mean specific conductance in surface water at 102 synoptic sites throughout Area 9 was 185 μmhos/cm (micromhos per centimeter). Conductivity values for all surface-water monitoring sites are shown in figure 4.3.1-1. The mean specific conductance was lowest at synoptic sites in the Gauley River basin, 60 μmhos/cm. The headwaters of the Gauley River basin are relatively undisturbed and receive the area's greatest amount of rainfall, over 60 inches during the period from March 1979 to April 1980. The specific conductance of rainfall in the Gauley River basin averages less than 10 μmhos/cm and effectively dilutes more highly mineralized surface waters in the basin, except during extended periods of low precipitation.

The highest specific conductance values were observed at synoptic sites in the upper Kanawha and Coal River basins, averaging 499 and 344 μmhos/cm respectively. The higher average specific conductances observed in the upper Kanawha and Coal River basins reflect inflow of highly mineralized drainage from extensively and intensively mined areas in the basins. Mining operations can increase the specific conductance of surface water by the discharge of highly mineralized mine drainage from underground mine portals, spoil piles and by direct drainage from coal preparation plants. The average specifie conductance of 22 mine drains in southern West Virginia was reported to be 735 μmhos/cm (James W. Borchers, personal communication, 1981). The upper Kanawha and Coal River basins contain 40 percent of the active coal mines in Area 9.

The Pocatalico River basin has very little coal mining or industrial development, yet has fairly high average specific conductance in surface waters (182 μmhos/cm), which is probably the result of brackish ground-water seeps, agricultural practices, and lower rainfall. Salt deposits underlie much of the Pocatalico River basin and many wells have been drilled to recover brine. Numerous wells were improperly sealed or were uncased. Because the salt-water zones are under higher hydraulic head than the overlying fresh water, much of the shallow ground water has gradually become salty and has contaminated the surface water (Bain, 1970). Another source of high specific-conductance water is runoff from croplands where fertilizer and other agricultural chemicals have been used. Low rainfall in the Pocatalico River basin also contributes to generally higher stream specific conductances than elsewhere in Area 9.



EXPLANATION

Site location and number	Mean specific conductance, in micromhos per centimeter at 25°C
1	0-100
39	101-250
28	251-500
12	501-1000
367 – 98	Range of specific conductance, in micromhos per centimeter at 25°C *For period of record (selected sites only)*

See Section 7.0 for detailed site description

Figure 4.3.1-1 Specific conductance

Surface Water pH in the Area is Generally Neutral to Alkaline

Mining operations have a significant effect on stream pH in Area 9. The median pH of surface water at 102 synoptic sites throughout Area 9 was 6.9. Streams in the Gauley River basin were the most acidic, while streams in the Pocatalico and lower Kanawha River basins were the most alkaline.

pH is a measure of the hydrogen ion $[H^+]$ activity in water. It is expressed as the negative logarithm (base 10) of the hydrogen ion activity in moles per liter. Thus, a solution with $[H^+]$ of 1 x 10^{-7} M has a pH of 7. The pH of a solution can have any value from 0 to 14, with values less than 7.0 being acidic and values over 7.0 being alkaline. A value of 7.0 indicates neutral pH. Most natural waters have pH values ranging from 6.0 to 8.5 (Hem, 1970). In reality, neutral water (pH 7.0) is uncommon because the solution of minerals and gases in water affects the pH. Solution of atmospheric CO_2 in precipitation results in a pH of about 5.6, thus is acidic. The solution of $CaCO_3$ (limestone) in water raises the pH to alkaline conditions (pH >7.0).

The median pH of surface water at 102 sites throughout Area 9 was 6.9 and ranged from 4.3 to 8.6 units (fig. 4.3.2-1). In general, the median pH value measured during synoptic sampling periods at monthly water-quality stations approximated the median value for the period of record. Streams in the Gauley River basin were the most acidic (median pH was 6.4). The low pH of most streams in the Gauley River basin is probably the result of the low buffering capacity of most surface waters (the average alkalinity was 10 mg/L) in conjunction with mine drainage in the lower Gauley River basin.

Streams in the Pocatalico and lower New River basins were the most alkaline (median pH was 7.3) and were more highly buffered (average alkalinities were 53 and 42 mg/L, respectively).

Mining can have a significant effect on the pH of streams in Area 9. Iron pyrite, FeS_2, occurs naturally with coal, and along with other mining wastes is deposited in spoil piles near mining activities (see fig. 3.3-1 for location of some of the larger spoil piles). Once exposed to oxygen, moisture, and autotrophic bacteria, pyrite can be oxidized to sulfuric acid as follows:

$$FeS_2 + 7/2\,O_2 + H_2O \xrightarrow{\text{bacteria}} Fe^{+2} + 2H^+ + 2SO_4^{-2}$$

The same reaction occurs in the interior of active and abandoned mines, and where coal crops out. Drainage can be below pH 3.0 in extreme cases. The quantity of acid produced by autotrophic bacteria is largely dependent upon the percentage of sulfur in the coal and spoil material. Generally, the sulfur content of coals in Area 9 increases toward the north. Most coal produced near the southern boundary of Area 9 contains less than 1.5 percent sulfur. This may account for the higher pH values observed in the heavily mined Coal and New River basins. Some abandoned coal mines in southern West Virginia contain near neutral pH water and have been used as local domestic water supplies.

Drainage from active underground mines can also be alkaline. West Virginia mining regulations require a crushed limestone coating on interior mine surfaces to lessen the likelihood of coal-dust explosions. The solution of limestone ($CaCO_3$) neutralizes acid generated by pyrite oxidation by the overall reaction:

$$CaCO_3 + H_2O \rightleftharpoons Ca^{+2} + HCO_3^- + OH^-$$

and

$$HCO_3^- + H^+ \rightleftharpoons H_2CO_3$$

EXPLANATION

Site location and number	Median pH, in units
1	4.3-6.6
39	6.7-7.0
54	7.1-7.7
12	7.8-8.0
16	Greater than 8.0
8.6–6.2	Range of pH, in units *For period of record (selected sites only)*

See Section 7.0 for detailed site description

Figure 4.3.2-1 pH

Average Alkalinity of Surface Water Lowest in the Gauley and Elk River Basins

The mean alkalinity of surface water at 102 synoptic sites in Area 9 was 27 milligrams per liter. Mean alkalinity was lowest at synoptic sites in the Gauley and Elk River basins, and was greatest in the Pocatalico River basin. Geology, precipitation, and land use affect alkalinity in Area 9.

Alkalinity is the ability of water to resist pH change by addition of a strong acid. Alkalinity is thus a measure of the buffering capacity of water and is due to the presence of carbonate, bicarbonate, and hydroxyl ions. Surface water varies widely in alkalinity content in Area 9. Rainfall has almost no buffering capacity, whereas surface water draining limestone areas can have alkalinities exceeding 200 mg/L (milligrams per liter). Ground water generally has the highest alkalinities due to greater dissolved carbonate and bicarbonate content, and can exceed 400 mg/L in parts of Area 9.

The mean alkalinity of surface water at 102 sites throughout Area 9 was 27 mg/L and ranged from 0 to 260 mg/L (fig. 4.3.3-1). In general, alkalinity values measured during synoptic sampling periods at monthly water-quality stations approximated the mean value for the period of record. Streams in the Gauley and Elk River basins contained the lowest mean alkalinity values, an average of 10 and 12 mg/L, respectively, for all synoptic sites. Alkalinity in Area 9 is affected by a number of interrelated factors, including precipitation, geology and land use. Because rainfall has almost no alkalinity, it dilutes surface waters having higher alkalinity. Whatever alkalinity is present in surface water is largely acquired by solution of soil minerals, mainly limestone ($CaCO_3$) and dolomite ($CaMg[CO_3]_2$). The generally low alkalinity of surface water in the Gauley and Elk River basins illustrates the lack of carbonate minerals in those areas at shallow depths and effect of dilution by rainfall. According to Hem (1970), soils of humid, temperate regions may become depleted in calcium carbonate by leaching. The headwaters of the Gauley and Elk River basins received the area's greatest rainfall (generally over 60 inches during 1979-1980). This suggests that the more readily soluble minerals, including calcium carbonate, may have been leached from the shallow geologic strata to a greater degree in the Gauley and Elk River basins than in the western areas of the basin, which received less annual precipitation.

Streamflow derived mainly from runoff also tends to have low alkalinity values. The headwaters of all basins in Area 9 have steep slopes underlain by impermeable bedrock. This is evident from the nearly straight-line plots of many streamflow-duration curves (see fig. 4.2.4-1). Because the contact time of the surface rocks with the runoff is fairly short, less solution can occur, and the mineral content (thus the alkalinity) in headwater streams is very low. In general, mean alkalinity values in surface water increased toward the west in Area 9. Streams in the Pocatalico and lower Kanawha River basins contained the greatest mean alkalinity values, an average of 53 mg/L for all synoptic sites. This regional trend probably reflects the lesser precipitation and the greater abundance of carbonate minerals in this part of Area 9.

Land use practices can also affect alkalinity of surface water in Area 9. Mining regulations, which require the coating of interior mine surfaces with crushed limestone, effectively raise the alkalinity of mine discharges. However, drainage from abandoned mines, mine spoil areas, and coal preparation plants can have very low or no alkalinity. In agricultural areas, the addition of lime to soils may increase the alkalinity of surface drainage.

EXPLANATION

Site location and number	Mean alkalinity, in milligrams per liter
1	Less than 15
39	15-30
54	31-50
60	51-99
30	Greater than 99
41–7	Range of alkalinity, in milligrams per liter *For period of record (selected sites only)*

See Section 7.0 for detailed site description

Figure 4.3.3-1 Alkalinity

High Sulfate Concentrations Generally Associated with Underground Coal Mining

The mean sulfate concentration in surface water for 102 sites in Area 9 was 57 milligrams per liter. Streams in the Gauley River basin contained the lowest mean sulfate concentration, while streams in the Coal and upper Kanawha River basins contained the greatest mean sulfate concentration. The major source of sulfate in the Coal and upper Kanawha River basins is coal mine drainage, particularly from underground mining operations.

Sulfate is one of the best indicators of coal mine drainage and has long been used for that purpose. The principal sources of sulfate include the weathering of gypsum ($CaSO_4$) and the oxidation of various sulfides such as pyrite (FeS_2). Coal deposits in central and northern West Virginia, and in the northern edge of Area 9 average 1.5 percent sulfur or greater (fig. 4.3.4-1). Most other coal deposits in Area 9 average 0.5 to 1.0 percent sulfur. Mining can have a significant effect on the sulfate concentration of streams in Area 9. Iron pyrite, FeS_2, occurs naturally with coal, and along with other mining wastes is deposited in spoil piles near mining activities. Once exposed to oxygen, moisture, and autotrophic bacteria, particularly *Thiobacillus* and *Metallogenium*, pyrite can be oxidized to sulfuric acid as follows:

$$FeS_2 + 7/2\,O_2 + H_2O \xrightarrow{\text{bacteria}} Fe^{+2} + 2H^+ + 2SO_4^{-2}$$

The same reaction occurs in the interior of active and abandoned coal mines, and where coal crops out.

The mean sulfate concentration in surface water at 102 sites in Area 9 was 57 mg/L (milligrams per liter) and ranged from 3.8 to 880 mg/L (fig. 4.3.4-1). In general, the mean sulfate concentration measured during synoptic sampling periods at monthly water-quality stations approximated the mean value for the period of record. Samples in the Gauley River basin contained the lowest mean sulfate concentration, an average of 15 mg/L for all synoptic sites. Within the Gauley River basin, sulfate concentrations were lowest in the basin headwaters, 4-10 mg/L. Very little mining occurs in this area. Most mines in the Gauley River basin are located near Muddlety and Peters Creeks and along the Gauley River towards the basin outlet (fig. 3.2-1 and 3.3-1). The sulfate concentration in surface water downstream from these areas was generally greater (fig. 4.3.4-1).

Sulfate concentrations for all synoptic sites in the Elk and Pocatalico River basins averaged 18 and 21 mg/L, respectively. Neither basin is heavily mined. The Elk River basin makes up 26 percent of the land of Area 9, but contains only 12 percent of the active coal mines. The Pocatalico River basin has 6 percent of the land and less than 1 percent of the coal mines in Area 9.

Streams in the Coal and upper Kanawha River basins contained the greatest mean sulfate concentrations, 128 and 179 mg/L, respectively, for all synoptic data. Both areas have very dense concentrations of coal mines, particularly underground mines. Together, the Coal and upper Kanawha River basins comprise 24 percent of the land, and contain 40 percent of the active coal mines in Area 9. Most of the Coal and upper Kanawha River basins have been previously mined by underground methods in one or more coal seams (fig. 3.3-1). Underground coal mining and its resulting waste is probably responsible for most of the high sulfate concentrations in streams draining Area 9. A typical example is an area near Paint and Cabin Creeks in the upper Kanawha River basin. This 90 mi^2 area contains 50 major mine refuse piles and has been mined by underground methods in about 81 mi^2, and by surface methods in about 18 mi^2 (see inset, fig. 4.3.4-1). Four synoptic stream sites are located within the 90 mi^2 area and had mean sulfate concentrations ranging from 108 to 393 mg/L.

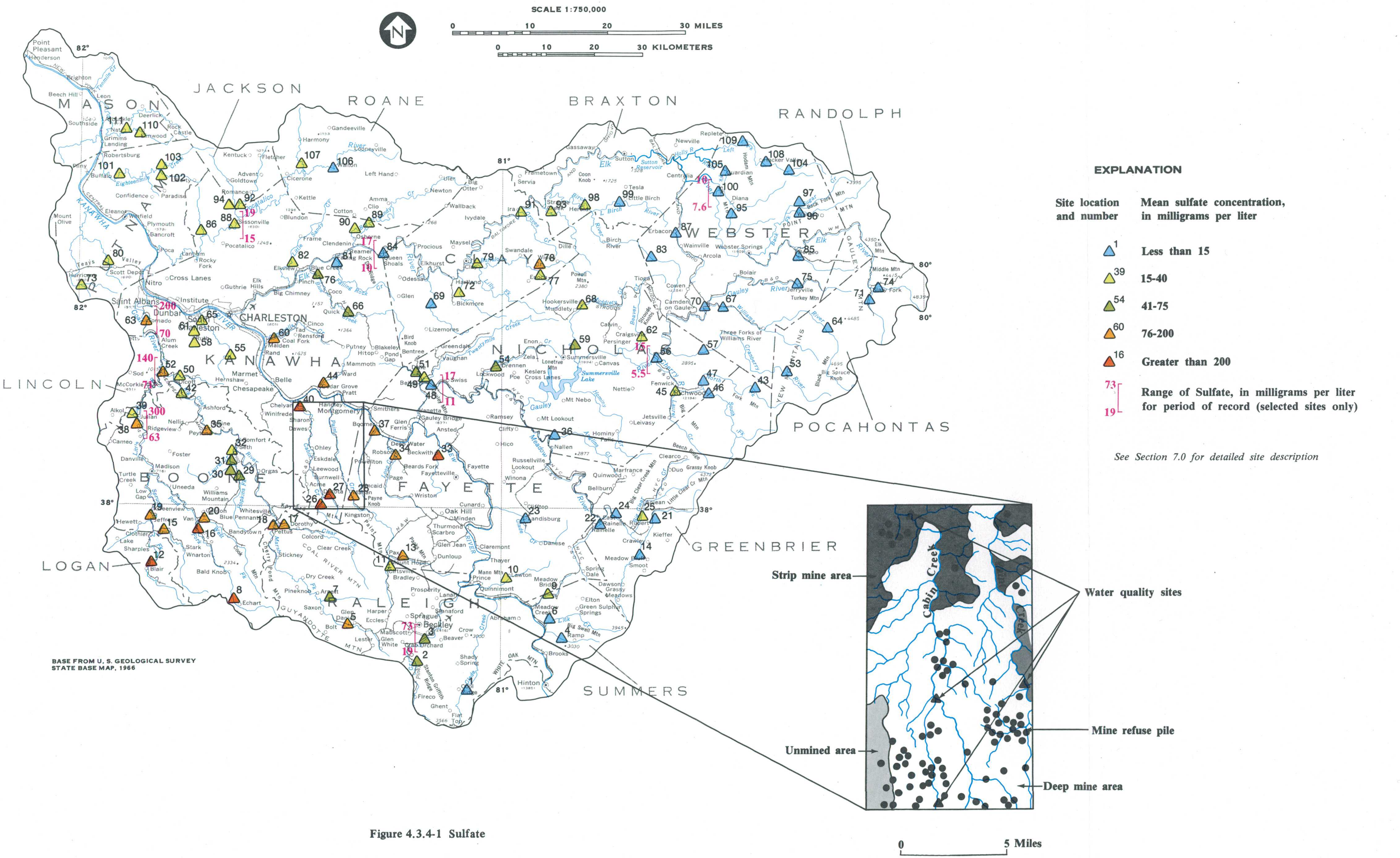


Figure 4.3.4-1 Sulfate

Iron Concentrations Generally are Highest in Old Mining Areas

Total iron concentrations in surface water averaged 1,700 micrograms per liter and ranged from 50 to 260,000 micrograms per liter at synoptic sites in Area 9. Streams in the Elk River basin contained the lowest mean total iron concentration, while streams in the upper Kanawha River basin had the highest total iron concentration. The highest total iron concentrations were observed at sites near long-established coal mining operations. The majority of iron was transported in the suspended phase.

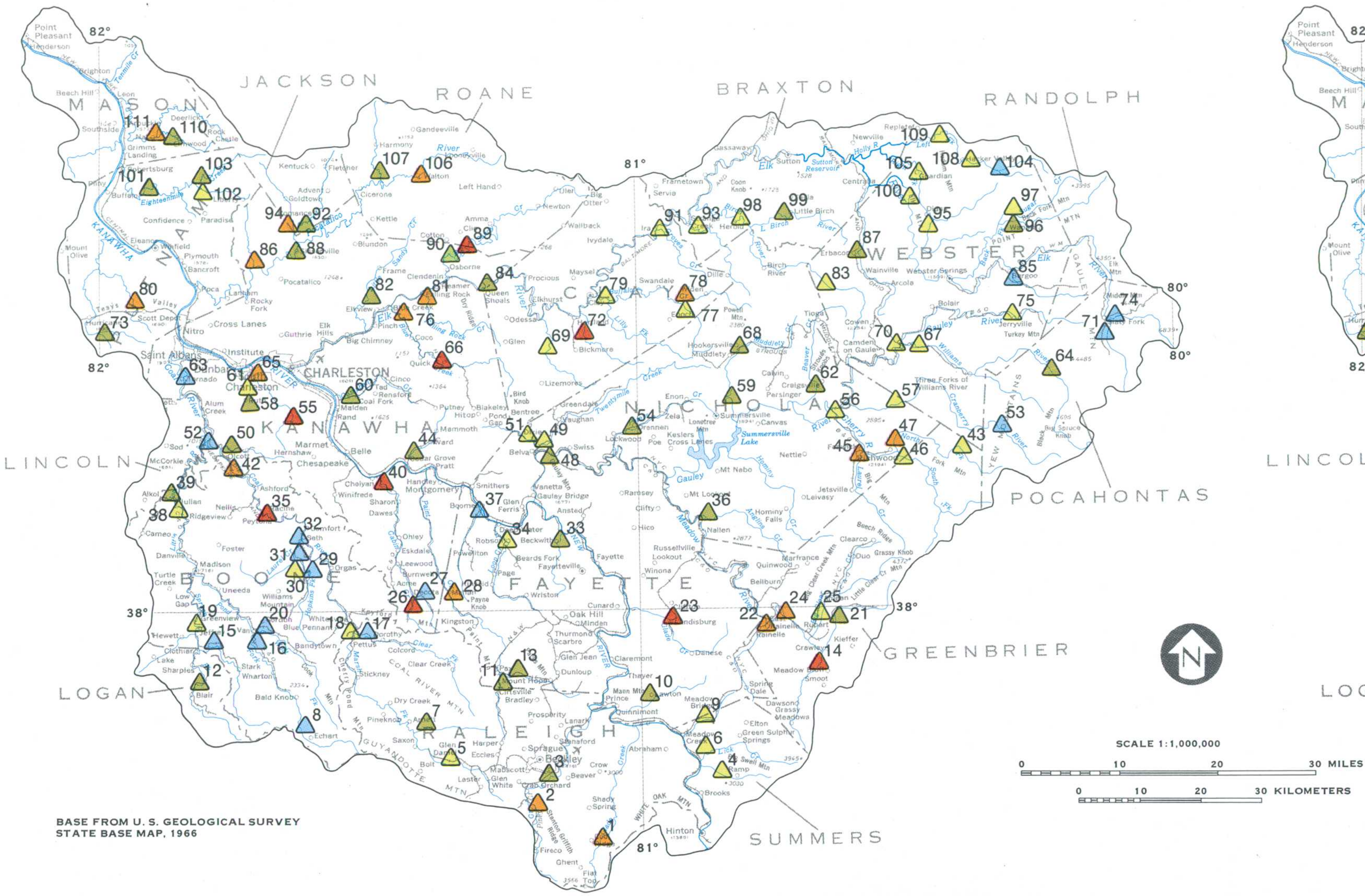
Iron is required to be monitored in mine-discharge effluents under present Federal mining regulations. In-stream water-quality standards for most of Area 9 allow a maximum of 1,000 μg/L (micrograms per liter) total iron (a summation of dissolved and suspended iron concentrations). A detailed explanation of West Virginia water-quality standards is available from the West Virginia State Water Resources Board (West Virginia State Water Resources Board, 1980). The limit of 1,000 μg/L is presently exceeded in many streams throughout Area 9.

The mean total iron concentration observed at 102 sites in Area 9 was 1,700 μg/L and ranged from 50 to 260,000 μg/L. Dissolved and total iron concentrations at water-quality monitoring stations are shown in figures 4.3.5-1 and 4.3.5-2, respectively. Generally, the mean total and dissolved iron concentrations which were measured during synoptic sampling periods at monthly water-quality stations approximated the mean value for the period of record. Streams in the Elk River basin contained the lowest mean total iron concentration, an average of 590 μg/L for all synoptic sites. By comparison, streams in the upper Kanawha River basin contained the greatest mean total iron concentration, an average of 9,800 μg/L for all synoptic sites, a difference of more than 10-fold.

Forty percent of the active coal mines in Area 9 are contained in the upper Kanawha River basin, which has been heavily mined for many years. Dissolved iron concentrations, however, did not vary appreciably among basins, ranging from a mean of 50 μg/L for all synoptic sites in the Coal River basin to 140 μg/L for all sites in the upper Kanawha River basin. In general, the concentrations of dissolved and total iron at selected monthly monitoring sites increased in a downstream direction (fig. 4.3.5-1 and 4.3.5-2). Most of the iron (95 percent) was transported in the suspended phase under the streamflow conditions (generally low to moderate flow) prevailing during the synoptic sampling periods in 1979 and 1980.

Iron is abundant in rocks of the Pottsville Group which underlies the area. It occurs as pyrite (FeS_2) intermixed with coal seams, and in shale and sandstone as oxides and hydroxides. The solubility of iron in water is dependent upon a complex redox (Eh) - pH relationship, and decreases as pH increases. For instance, the solubility of ferrous iron (Fe^{+2}) is about 100 times greater at pH 6.0 than at pH 8.0. Ferrous iron also becomes more soluble as Eh decreases, that is as the redox potential becomes less.

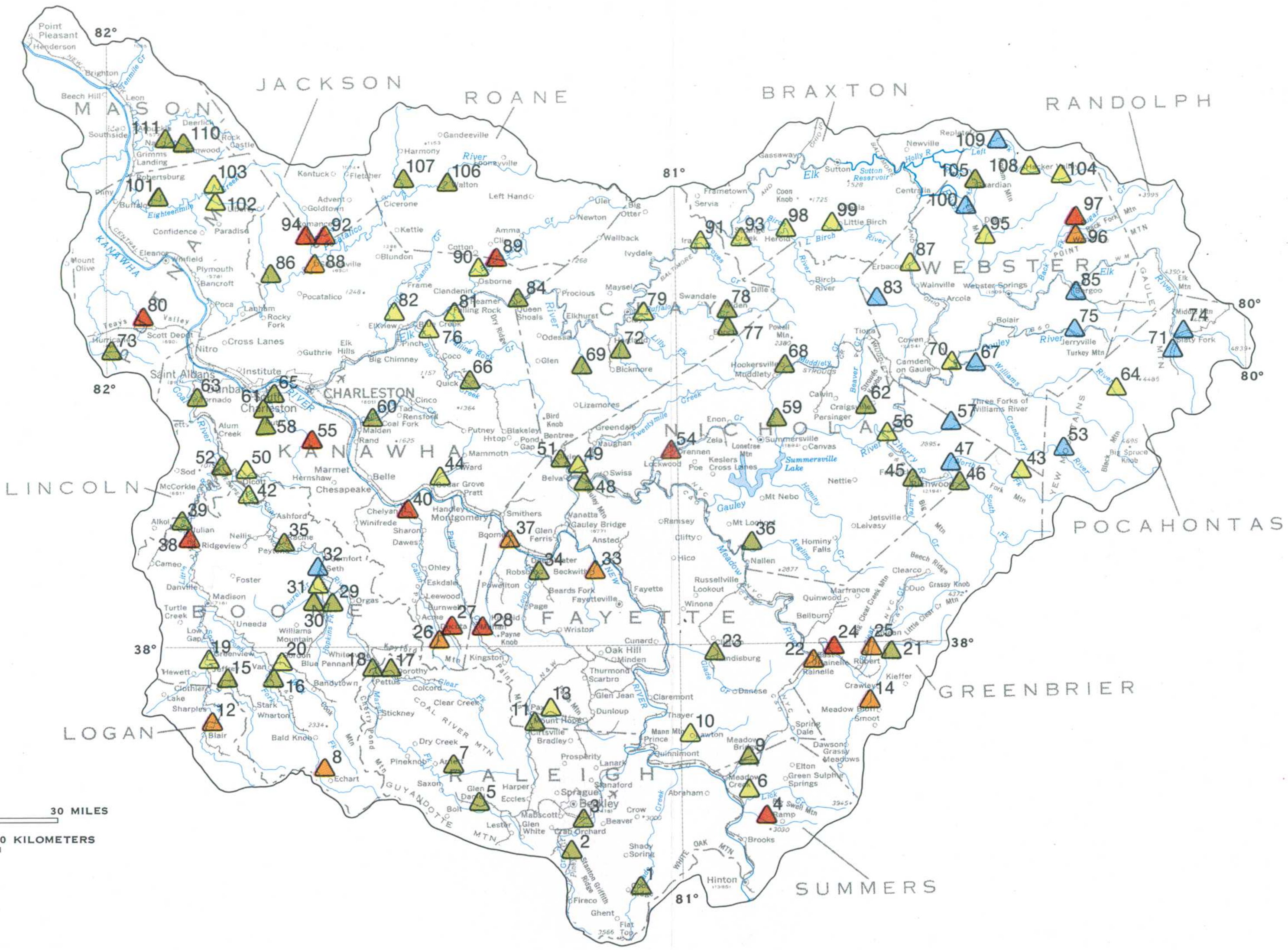
Mining operations typically increase the concentration of iron in surface water in several ways. Surface and underground coal mining generate large quantities of spoil material, which along with mined coal, is deposited on land surface in large piles. The spoil material and the mined coal have a greatly increased surface area compared with the original material, and their placement on land surface exposes the coal and spoil material to weathering by air and water. Autotrophic bacteria oxidize the reduced sulfur compounds (such as pyrite) to sulfuric acid which allows the solution of additional iron contained in the coal and spoil material. Under typical conditions, the drainage from spoil piles can contain concentrations of Fe^{+2} exceeding 1,000 mg/L (milligrams per liter) at a pH of 2.5 - 3.0. When the iron-rich drainage enters a stream, Fe^{+2} is quickly oxidized to ferric iron (Fe^{+3}), which is much less soluble, and precipitation occurs forming the yellowish-red deposits often observed in the stream channels near mining areas (fig. 4.3.5-3).



EXPLANATION

Site location and number	Mean concentration of dissolved iron, in micrograms per liter
74	Less than 20
25	20-49
7	50-119
94	120-200
55	Greater than 200

Figure 4.3.5-1 Dissolved iron



EXPLANATION

Site location and number	Mean concentration of total-recoverable iron, in micrograms per liter
32	Less than 200
19	200-499
72	500-1199
88	1200-2000
40	Greater than 2000

Figure 4.3.5-2 Total-recoverable iron

See Section 7.0 for detailed site description

Figure 4.3.5-3 Iron precipitate deposits ("Yellow Boy") in stream draining a mined area.

High Manganese Concentrations are Generally Associated with Old Mining Areas

The mean dissolved manganese concentration in surface water for 102 sites in Area 9 was 165 micrograms per liter. Streams in the Elk River basin contained the lowest mean dissolved manganese concentration, while streams in the upper Kanawha River basin contained the highest. Streams draining old underground coal mining areas generally had the highest dissolved manganese concentrations.

Manganese is a common trace element in surface and ground waters. Manganese is considered an essential trace element for plants and animals but is reportedly toxic at higher concentrations. For example, a mean concentration of 5,700 μg/L (micrograms per liter) was reportedly toxic to 50 percent of *Daphnia magna* (a freshwater crustacean) in a 3-week test (Biesinger and Christensen, 1972). The most important mechanism of toxic action is thought to be the poisoning of enzymes (Bowen, 1966). West Virginia in-stream water-quality standards for most of Area 9 limit manganese concentrations to a maximum of 1,000 μg/L in surface water (West Virginia State Water Resources Board, 1980).

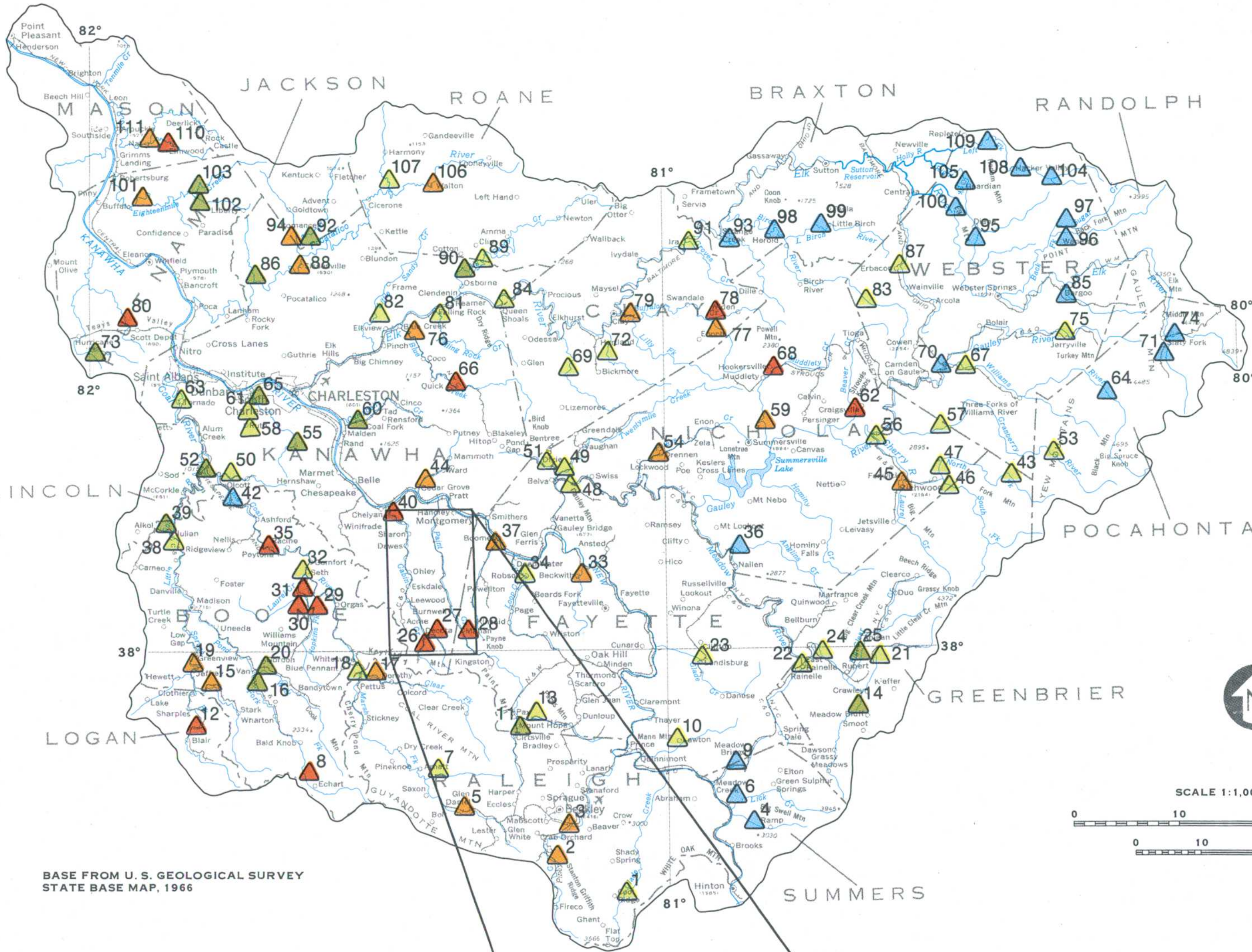
The mean concentration of dissolved manganese at 102 surface-water monitoring sites throughout Area 9 was 165 μg/L, slightly more than three times the maximum recommended concentration of manganese (50 μg/L) in drinking water (U.S. Environmental Protection Agency, 1979). Dissolved and total manganese concentrations at water-quality monitoring sites are shown in figures 4.3.6-1 and 4.3.6-2, respectively. Generally, the mean concentrations of manganese which were measured during synoptic sampling periods at monthly water-quality stations approximated the mean value for the period of record.

Streams in the Elk River basin contained the lowest mean dissolved manganese concentration (an average of 78 μg/L at 29 synoptic sites). Similarly, the mean concentrations of dissolved manganese at all synoptic sites in the Gauley and New River basins were 98 and 100 μg/L, respectively.

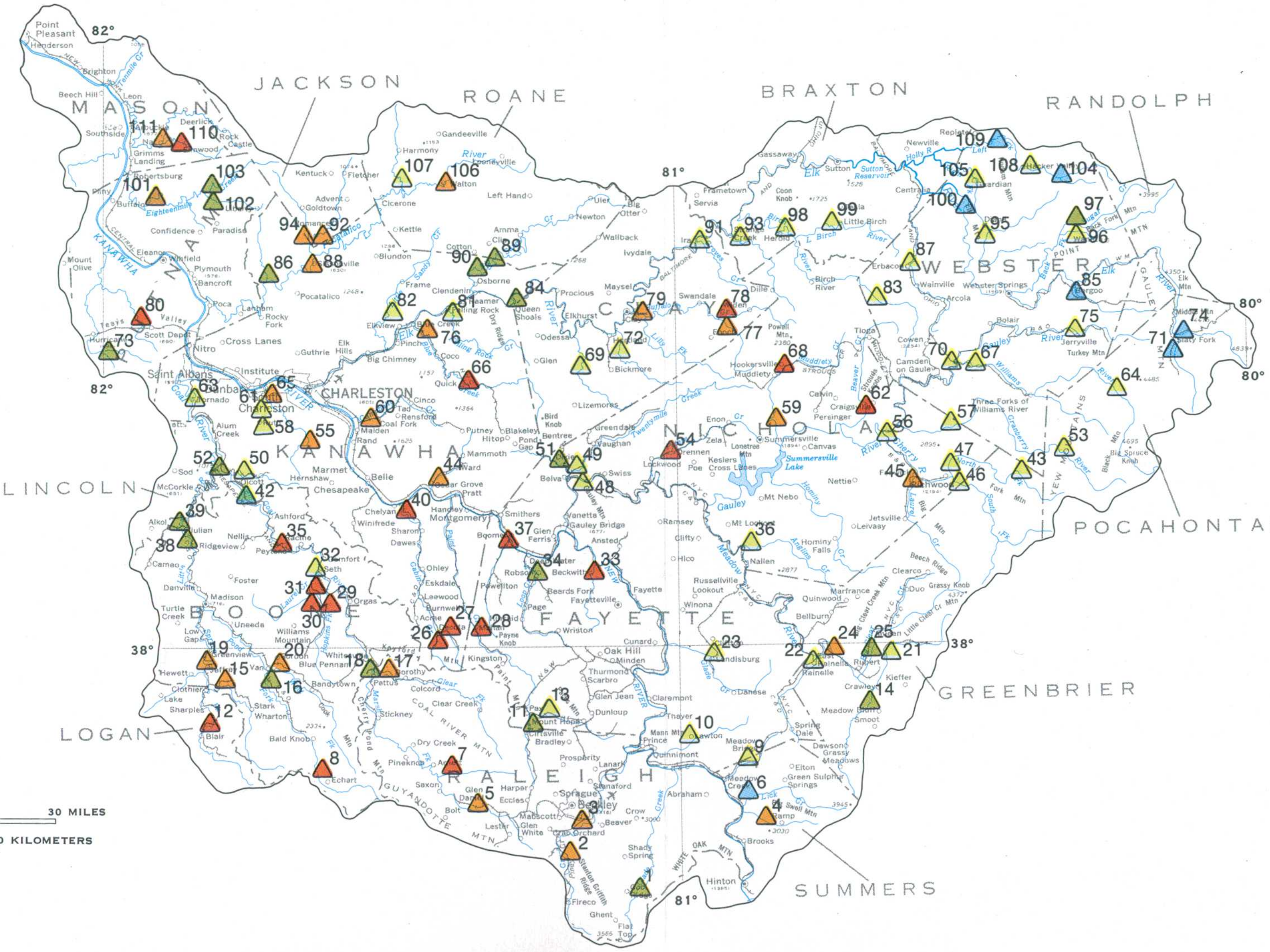
Streams in the upper Kanawha River basin contained the highest mean dissolved manganese concentration, an average of 480 μg/L at 11 synoptic sites. The same area contains 40 percent of the active underground coal mines in Area 9 and has been extensively mined in the past (see fig. 3.3-1). The Pocatalico River basin, by comparison, which has almost no present or past coal mining, had mean dissolved manganese concentrations at synoptic sites ranging from 53 to 163 μg/L.

Unlike many trace elements, such as iron, manganese is fairly soluble at neutral pH because of the formation of stable manganese complex ions (Hem, 1970). Most of the manganese (87 percent) was transported in the dissolved phase under the streamflow conditions (generally low to moderate flow) prevailing during the synoptic sampling periods in 1979 and 1980.

Old mining districts are responsible for much, although not all, of the high dissolved manganese concentrations in Area 9. Under typical conditions, the drainage from spoil piles can contain concentrations of manganese exceeding 1,000 μg/L. Manganese-rich drainage entering a stream can quickly oxidize and precipitate, forming a yellowish-red or brownish-black deposit often observed in the stream channels near mining areas (fig. 4.3.6-3). An example of high manganese in water is in an area near Paint and Cabin Creeks in the upper Kanawha River basin. This 90 mi^2 area contains 50 major mine refuse piles and has been mined by underground methods in about 81 mi^2, and by surface methods in about 18 mi^2 (see inset, fig. 4.3.6-1). One or more water samples from each of the synoptic sites located within the 90 mi^2 area yielded concentrations of over 1,000 μg/L dissolved manganese.



BASE FROM U. S. GEOLOGICAL SURVEY
STATE BASE MAP, 1966



EXPLANATION

Site location and number	Mean dissolved manganese concentration, in micrograms per liter
42	Less than 20
69	21-75
92	76-150
17	151-300
31	Greater than 300

Figure 4.3.6-1 Dissolved manganese

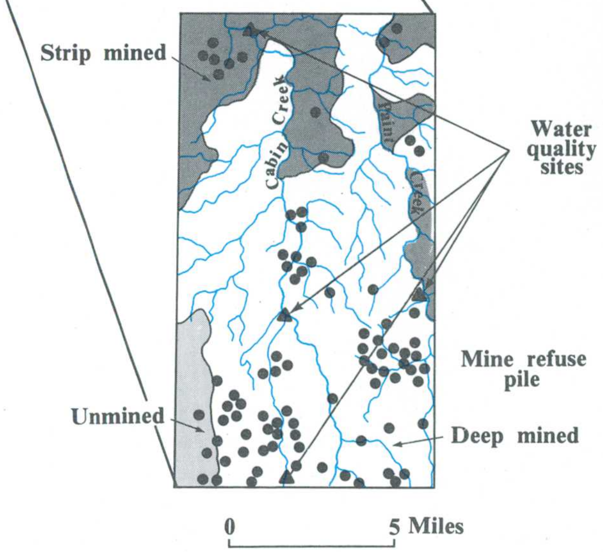


Figure 4.3.6-3 Manganese precipitate deposits in stream draining a mined area

EXPLANATION

Site location and number	Mean total-recoverable manganese concentration, in micrograms per liter
6	Less than 20
43	21-75
52	76-150
79	151-300
27	Greater than 300

Figure 4.3.6-2 Total-recoverable manganese

See Section 7.0 for detailed site description

4.0 SURFACE WATER--Continued
4.3 Quality of Surface Water-Continued
4.3.6 Manganese

Suspended-Sediment Concentrations Vary Widely in Area 9

The highest suspended-sediment concentration range observed at synoptic sites draining Area 9 was from 0 to 55,900 milligrams per liter; the lowest was from 7 to 351 milligrams per liter. The large variation between the ranges reflects the difference in land use between the basins.

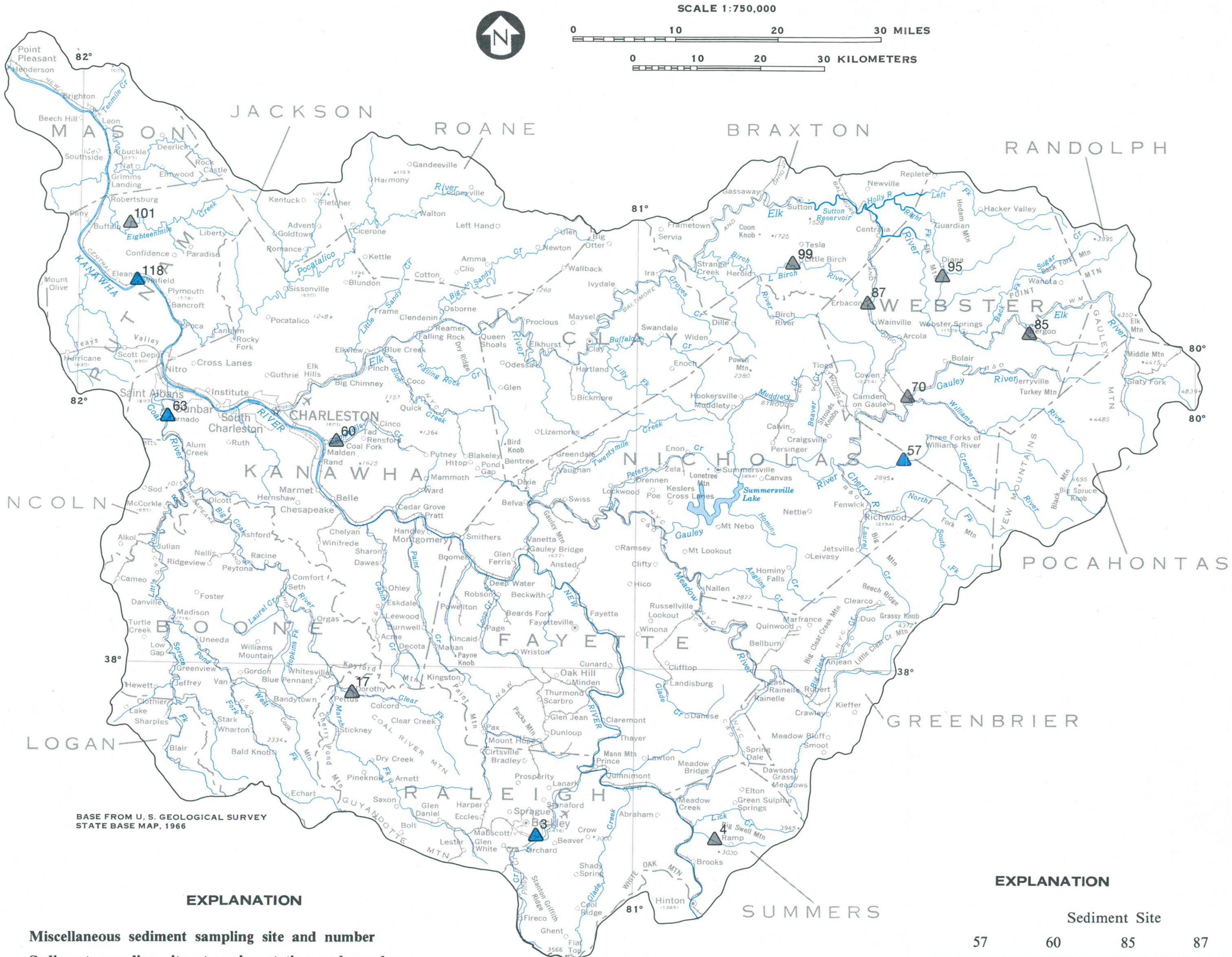
Land-use activities that drastically alter natural erosion and sediment yields include surface mining, road construction, silviculture, and agriculture. Based on results of studies made in Appalachia by the U.S. Environmental Protection Agency (1973), Collier and others (1964 and 1970) in Kentucky, and Eckhardt (1976) in Pennsylvania, sediment yields from active surface mining and road construction can range between 27,000 and 66,000 (tons/mi^2)/yr (tons per square mile per year). The same studies indicate that sediment yields from grasslands average 240 (tons/mi^2)/yr; forested lands average 24 (tons/mi^2)/yr; and harvested forest lands average 12,000 (tons/mi^2)/yr. In severely mined but unreclaimed areas, sediment yields can be as high as 300,000 (tons/mi^2)/yr (Hubbard, 1976).

Locations of selected sediment data collection sites in Area 9 are shown in figure 4.3.7-1. In the New River basin, suspended-sediment concentrations at synoptic sites ranged from 7 to 351 mg/L (milligrams per liter) at Laurel Creek at Sandstone (site 4) and from 0 to 7,850 mg/L at Piney Creek at Raleigh (site 3). In the Gauley River basin, suspended-sediment concentrations ranged from 0 to 361 mg/L at Cranberry River at Richwood (site 57) and from 5 to 4,660 mg/L at the Gauley River at Williams River (site 70). The large difference in maximum suspended-sediment concentrations between sites 57 and 70 reflect differences in land use between the basins. Site 57 drains a relatively undisturbed basin, whereas site 70 is downstream from many underground and surface coal mining operations.

Suspended-sediment concentrations at Campbells Creek downstream from Coal Fork (site 60), a small tributary to the Kanawha River, ranged from 16 to 15,700 mg/L. The major disturbance in the basin is extensive abandoned and active surface mining operations. In the Elk River basin, suspended-sediment concentrations in the Little Birch River at Little Birch (site 99) ranged from 0 to 55,900 mg/L, the greatest range observed in Area 9. Site 99 drains a basin with large areas with agriculture, logging, and coal mining operations. Suspended-sediment concentration ranges for other sites in the Elk River basin include Laurel Creek at Erbacon (site 87) with a range of 2 to 749 mg/L, Leatherwood Creek at Bergoo (site 85) with a range of 0 to 7,960 mg/L, and Grassy Creek at Diana (site 95) with a range of 6 to 2,900 mg/L. Sites 85 and 95 drain areas with large coal mining and logging operations.

Daily suspended-sediment data available for the Coal River at Tornado (site 63) for the period 1973-1979 have been published in annual U.S. Geological Survey reports. The data are summarized in table 4.3.7-1. Most of the sediment loads were transported during high flow periods. Suspended-sediment data at the Kanawha River at Winfield (site 118) has been collected on a monthly basis since 1974 as a part of the National Stream Quality Accounting Network (NASQAN). The range of suspended-sediment concentrations from 57 samples collected for particle-size distribution analysis at this site was from 7 to 1,820 mg/L. The particle-size analyses of the 57 samples indicate that on the average about 70 percent of transported sediment at this site is finer than 0.062 mm (millimeter); individual particle-size distribution samples ranged from 7 to 97 percent finer than 0.062 mm. In the Pocatalico River basin, suspended-sediment concentrations for 18 Mile Creek at White Star School (site 101) ranged from 93 to 5,780 mg/L. This site is unaffected by coal mining, but reflects high suspended-sediment contribution from road construction and agriculture.

The relationship between stream discharge and suspended-sediment yields for five selected sites in the area are shown in figure 4.3.7-2. Site 118 is the outflow site for most of Area 9, whereas sites 85 and 87 drain smaller basins affected by coal mining operations. Site 57 drains an undisturbed basin, and site



EXPLANATION

△4 **Miscellaneous sediment sampling site and number**

▲3 **Sediment sampling site at gaging station and number**

Figure 4.3.7-1 Suspended-sediment sampling sites

Table 4.3.7-1.--Maximum daily suspended-sediment concentrations and loads, and annual sediment yields at Coal River at Tornado (site 63)

Water Year	Maximum Daily Sediment Concentration (mg/L)	Maximum Daily Sediment Load (tons/day)	Annual Sediment Yield (tons mi^2)
1973	4,000	105,000	557*
1974	2,220	106,000	787
1975	4,000	106,000	567
1976	1,030	18,000	168
1977	2,600	124,000	520
1978	3,480	263,000	830
1979	1,850	116,000	904

*Partial year

EXPLANATION

	Sediment Site 57	60	85	87	118
Period of Record	1979-80	1979-80	1979-80	1979-80	1974-79
Suspended-sediment concentration range, in milligrams per liter	0-36	16-15,700	0-7,960	2-749	7-1,820
Drainage area, in square miles	81.2	32.6	19.2	36.5	11,809

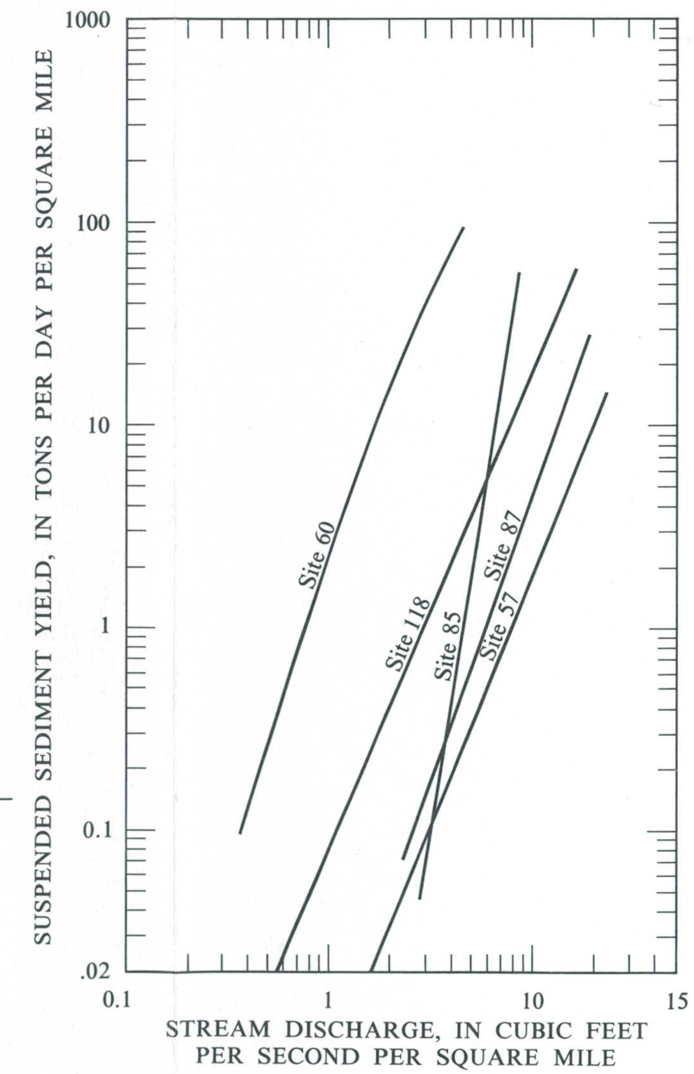


Figure 4.3.7-2 Relationship between stream discharge and suspended sediment at selected sites

60 drains an extensively mined basin. The sediment yield curves shown in figure 4.3.7-2 are useful for estimating the yields and loads leaving the respective basins and may also be used to compare yields between basins. A comparison of the sediment yield curves for sites 57 and 60 shows that drastic increases in sediment production can result from coal mining operations. The illustration indicates that estimated sediment yields at site 60 average about 240 times greater than those for site 57 for the same unit area discharge range, 2 to 10 (ft^3/s)/mi^2 (cubic feet per second per square mile).

Iron Transported Primarily by Suspended Sediment Throughout Area 9

Suspended sediment is the major transport mechanism of iron in surface waters throughout Area 9. Most of the iron is transported during peak streamflows which occur on several days each year.

Suspended sediment is the major transport mechanism for iron in Area 9 because of the low solubility of iron in surface water. Chemical analyses of water samples collected throughout Area 9 indicate the predominance of iron in the particulate (suspended) phase. Typically less than 10 percent of the total quantity of iron is present in the dissolved phase in most surface waters. The remaining fraction of iron is transported sorbed to suspended sand, silt, clay, and organic material.

The transport of iron is largely a function of the surface area of particles in suspension. Surface area per unit weight of sediment increases as particle size decreases, which means that the finer size fractions of sediment (silt and clay fractions) can potentially transport a greater quantity of sorbed iron per unit weight of sediment than can the coarse fractions of suspended sediment (Feltz, 1980). Using data for the synoptic sampling period of August 18-22, 1980, a least squares fit of the suspended sediment and total iron concentrations leads to the relationship shown in figure 4.3.8-1 which can be summarized by the regression equation as follows:

$$[Fe] = 56.6[S]^{0.82}$$

$$r^2 = 0.88$$

Where [Fe] is the concentration of total iron in μg/L (micrograms per liter),

[S] is the concentration of suspended-sediment in mg/L (milligrams per liter), and

r^2 is the proportion of the total variation explained by the regression equation.

The relation shown in figure 4.3.8-1 may be used to estimate total iron loads leaving the basins in Area 9. Although significant quantities of iron can be transported at very low concentrations of suspended sediment, the majority of the total iron load is transported with suspended sediment during a few peak streamflow periods each year. Daily sediment loads in the Coal River (site 63) are summarized in figure 4.3.8-2. The illustration indicates that the majority of the annual suspended-sediment load (560,300 of 778,439 tons) at site 63 was transported during 17 days of high streamflow ranging from 3,840 to 29,900 ft^3/s (cubic feet per second) during 1979. During a 202-day period of low streamflow ranging from 51 to 1,910 ft^3/s, less than 1 percent of the total annual suspended-sediment discharge occurred. It is estimated that about 12,966 tons of iron was transported in suspension by the Coal River in 1979, most of it (68 percent) on 17 days during 1979.

Suspended sediment in the Kanawha River (site 121) consists primarily of fine material. During the period of 1974-1980, most suspended sediment (70 percent) consisted of particles finer than 0.062 mm (millimeter) in diameter. During 1974-1980 about 80 tons per day or about 29,200 tons per year of iron were transported in suspension in the Kanawha River at site 121. A significant part of that load of iron may have been derived from sources within the Coal River basin.

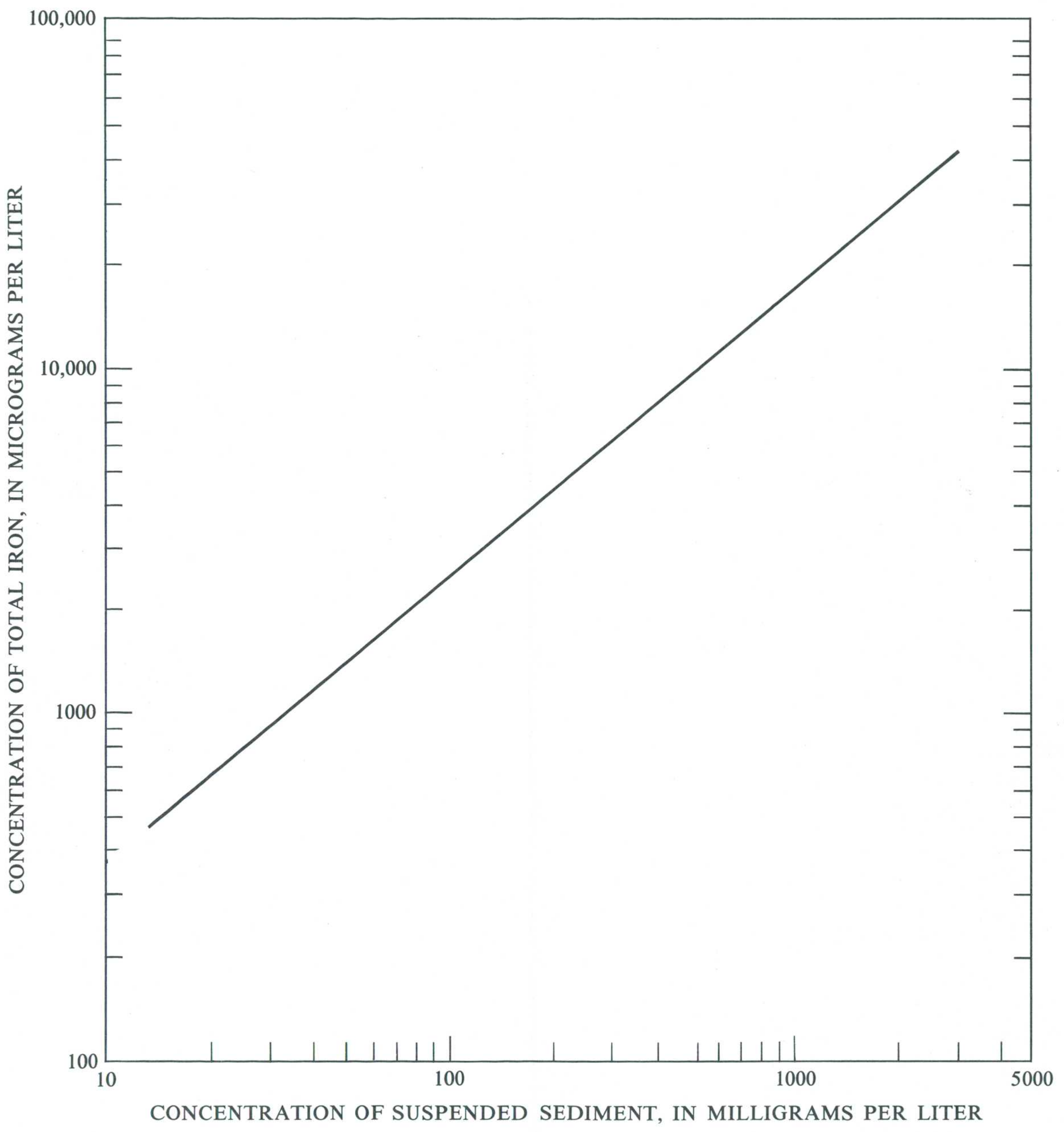


Figure 4.3.8-1 Relationship of suspended-sediment concentration to total iron-concentration

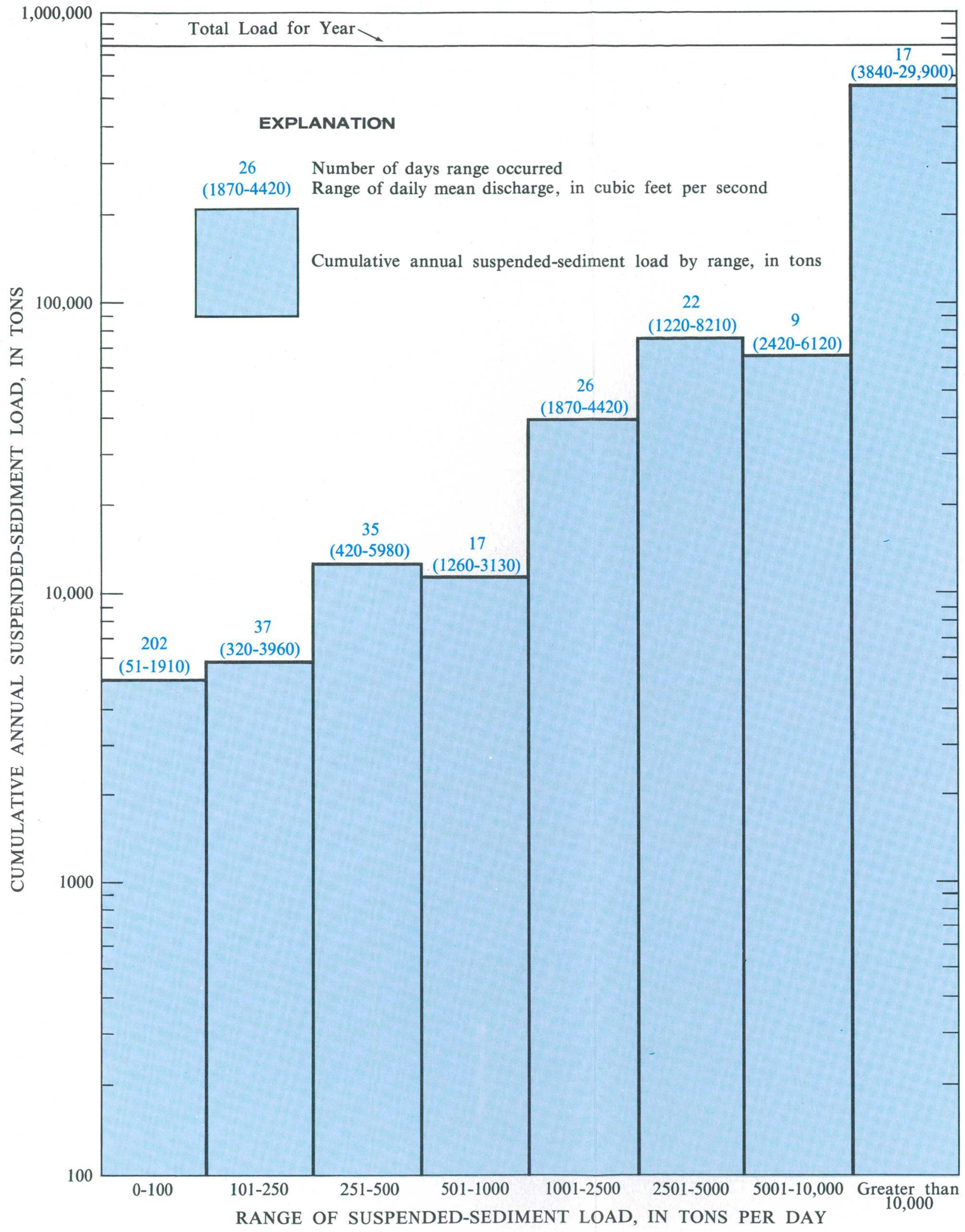


Figure 4.3.8-2 Distribution of cumulative suspended-sediment discharge for the Coal River at Tornado (site 63), October 1, 1978 to September 30, 1979

5.0 AVAILABILITY OF GROUND WATER

Secondary Permeability is Generally More Significant than Primary Permeability.

Movement of ground water is largely by secondary permeability throughout the area; that is, through fractures, joints, and bedding plane separations. Wells which penetrate few fractures generally have specific capacities less than 1 gallon per minute per foot of drawdown. Alluvial deposits along the larger rivers are good sources of water where they are of sufficient thickness.

Permeability is a measure of the degree to which liquids move through rock formations. Primary permeability is the movement through natural pore spaces between rock grains. Surficial rocks in the area are largely sandstone, siltstone, and shale which were cemented together by the deposition of carbonates or silicates in pore spaces between rock grains. The primary permeability is generally low throughout the area (Wyrick and Borchers, 1981).

Secondary permeability is the movement of liquids through rock fractures, and is generally more significant in the area than primary permeability. The deposition of cementing material reduces the ability of rocks to flex, making them more brittle and subject to fracturing. When rocks are eroded from a valley, the walls and valley floor are subjected to unequal stresses which are relieved by a series of rock fractures termed "stress-relief fractures" (fig. 5.0-1). These fractures are interconnected and become a major means of ground-water movement and storage (Wyrick and Borchers, 1981).

The yield to wells in Area 9 is highly variable and depends largely on the number of water-bearing openings (fractures, joints, and bedding plane separations) penetrated by the well. The yields of selected household wells in Area 9, expressed in terms of specific capacity, are given in table 5.0-1. The well locations are shown in figure 5.0-2.

The specific capacity of a well is defined as the yield in (gal/min)/ft (gallons per minute per foot) of water-level drawdown. Specific capacities are useful for comparing the ability of wells to yield water regardless of well diameter, pump size, and pumping rate. Because the occurrence of water-bearing openings in rocks is variable, wells drilled within a few feet from each other can have widely different specific capacities. Wells penetrating few openings generally have specific capacities less than 1.0 (gal/min)ft.

Well depth and topography are also important factors affecting well yields. Generally, well yield increases with well depth. Clark and others (1976) determined that valley wells, on the average, yielded twice as much water as hillside wells and much more than hilltop wells. Wells near the axis of an anticline yielded the most water while wells near the axis of a syncline yielded the least.

Some of the best yielding wells are located in alluvial terrain along valley floors, particularly along the lower reaches of the Kanawha River. The thickness of the alluvium is variable, but in the vicinity of Charleston it is about 50 feet. Alluvial deposits along the New, Gauley, and Elk Rivers are also of sufficient thickness in places to be considered aquifers. In other areas alluvial deposits are either nonexistent or too thin to be considered a major source of water.

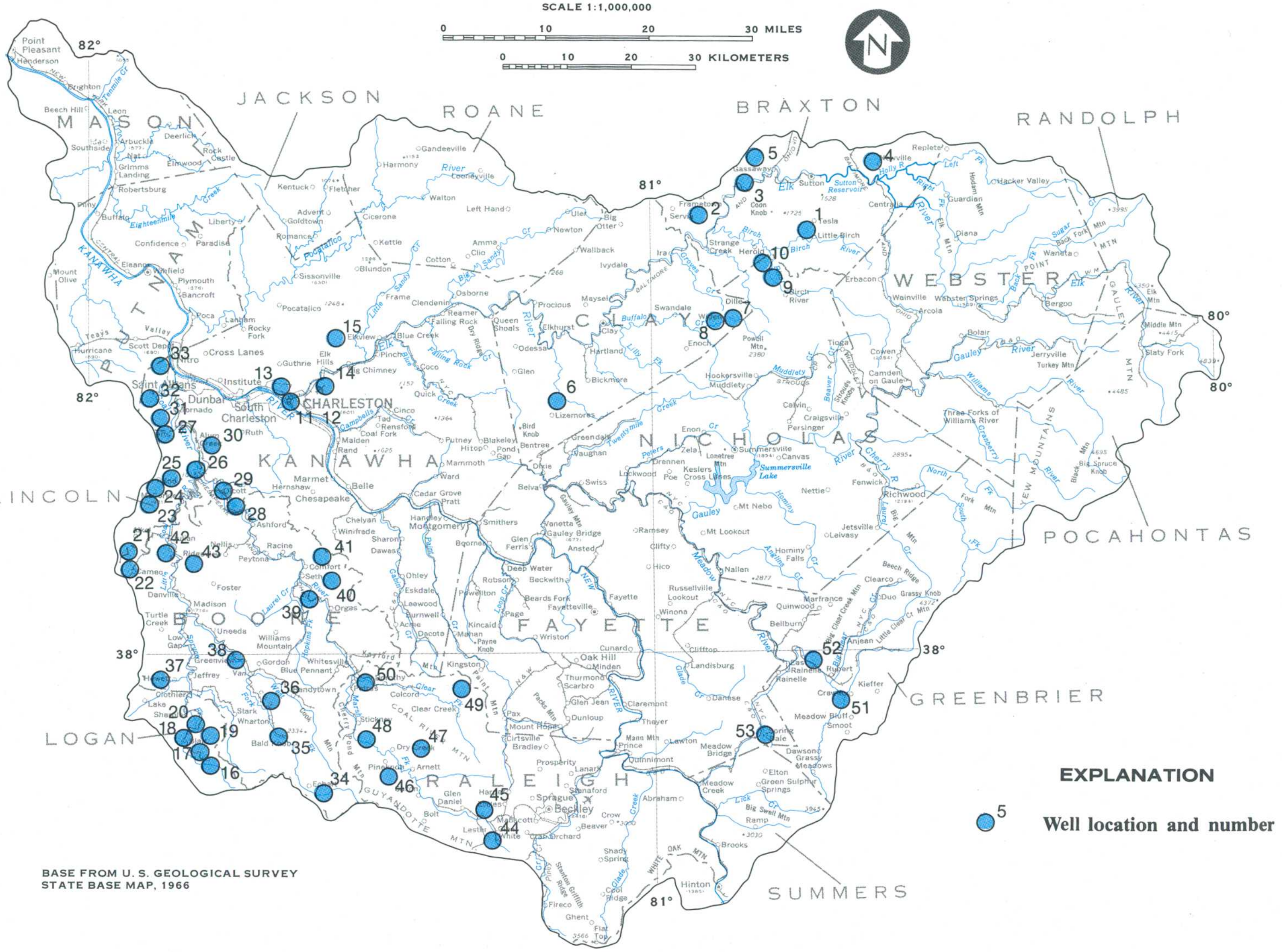


Figure 5.0-2 Location of selected wells

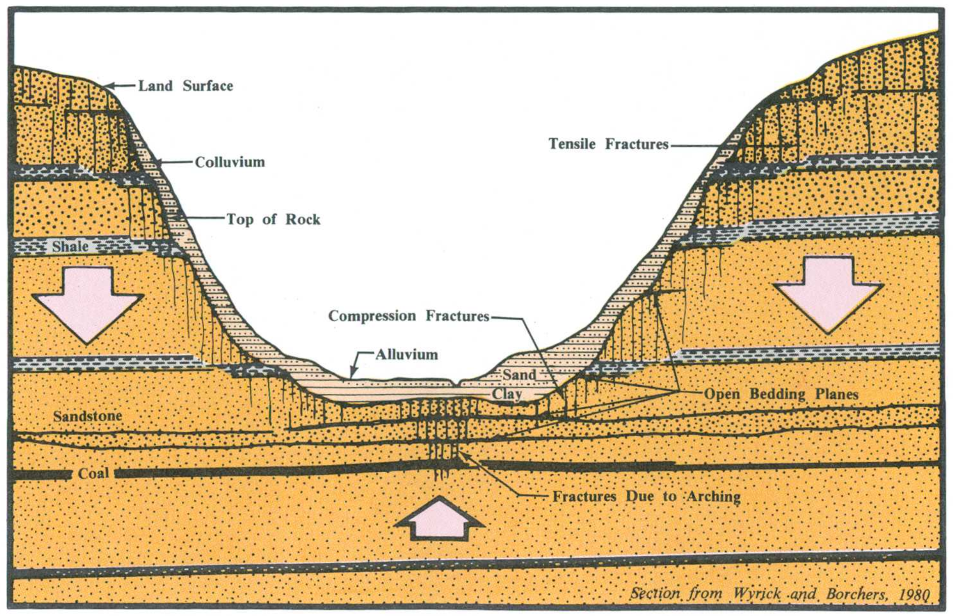


Figure 5.0-1 Generalized geologic section showing typical stress-relief fractures

Table 5.0-1 Specific capacity of selected wells in Area 9.

Well Number	Latitude	Longitude	County	Specific Capacity (gal/min)
1	38 34 49	80 42 34	Braxton	10.0
2	38 36 56	80 54 41	"	.83
3	38 40 25	80 48 22	"	8.0
4	38 40 43	80 35 27	"	3.0
5	38 41 33	80 48 55	"	2.0
6	38 20 46	81 09 47	Clay	2.5
7	38 27 39	80 51 51	"	25.
8	38 27 47	80 51 41	"	100.
9	38 30 50	80 46 17	Nicholas	.33
10	38 31 01	80 46 59	"	2.33
11	38 21 01	81 38 05	Kanawha	1.71
12	38 21 01	81 38 05	"	2.0
13	38 21 43	81 38 56	"	52.
14	38 22 11	81 34 28	"	25.
15	38 26 19	81 33 14	"	.07
16	37 51 00	81 48 27	Logan	.14
17	37 51 02	81 48 28	"	.20
18	37 52 19	81 50 18	"	.006
19	37 52 56	81 48 04	"	4.8
20	37 53 21	81 49 23	"	11.2
21	38 08 32	81 56 51	Lincoln	.012
22	38 09 15	81 56 52	"	.06
23	38 12 44	81 53 56	"	.18
24	38 13 43	81 53 30	"	.10
25	38 14 23	81 52 10	"	.04
26	38 15 29	81 48 41	"	.14
27	38 18 44	81 52 31	"	.04
28	38 12 01	81 44 29	Kanawha	.36
29	38 13 37	81 45 50	"	.04
30	38 17 33	81 46 49	"	.24
31	38 18 58	81 52 29	"	.82
32	38 21 01	81 53 13	"	.12
33	38 24 10	81 52 14	"	.12
34	37 48 06	81 35 38	Boone	2.0
35	37 53 40	81 40 20	"	.20
36	37 55 25	81 40 51	"	.04
37	37 57 20	81 52 55	"	.12
38	37 59 24	81 44 17	"	.24
39	38 04 28	81 36 29	"	.28
40	38 06 04	81 34 12	"	.32
41	38 07 36	81 35 14	"	.26
42	38 08 30	81 51 22	"	.40
43	38 07 57	81 48 54	"	.04
44	37 43 43	81 16 52	Raleigh	8.4
45	37 46 14	81 18 30	"	.62
46	37 49 15	81 28 27	"	4.8
47	37 51 34	81 25 02	"	5.0
48	37 52 30	81 30 48	"	1.0
49	37 56 21	81 21 13	"	.12
50	37 57 10	81 31 15	"	2.2
51	37 54 57	80 40 53	Greenbrier	2.0
52	37 59 05	80 42 59	"	1.0
53	37 52 39	80 47 58	Fayette	5.4

NAWDEX, WATSTORE, OWDC Have Water-Data Information

Water data are collected in coal areas by large numbers 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 6.2, 6.3, and 6.4.

NAWDEX Matches User Needs to Available Data

NAWDEX (National Water Data Exchange) is a national confederation of water-oriented organizations working together to improve access to water data. Objectives of NAWDEX are to assist users of water data in the identification, location, and acquisition of needed data. The U.S. Geological Survey manages NAWDEX through Survey headquarters in Reston, Virginia, and local assistance centers in major cities.

The function of NAWDEX is to index the data held by NAWDEX members and participants so as to provide a central source of water-data information available from a number of organizations. A central Program Office located at U.S. Geological Survey national headquarters in Reston, Virginia, provides data-exchange policy and guidelines for participants (fig. 6.2-1). The major functions of the Program Office are to (1) maintain a computerized Master Water Data Index (fig. 6.2-2), which identifies sites for which data is available and the organization responsible for the data; (2) provide access to water-data bases held by participants; and (3) maintain a Water-Data Sources Directory (fig. 6.2-3) that identifies participating organizations and locations from which data may be obtained.

Services are available through the Program Office in U.S. Geological Survey headquarters in Reston, Virginia, and through a network of 59 centers located in 45 states and Puerto Rico. A directory is available upon request which lists organizations, personal contacts, addresses, telephone numbers, and office hours for each NAWDEX assistance center [Directory of Assistance Center of National Water Data Exchange (NAWDEX), U.S. Geological Survey Open-File Report 79-423 (Revised)].

Charges for NAWDEX services may be assessed at the option of the organization providing the requested data or data service. Charges will be assessed for computer and extensive personnel time, duplicating services, or other costs encountered by NAWDEX in the course of providing services. In any case, charges will not exceed the actual direct costs involved. Estimates of cost will be provided by all NAWDEX assistance centers upon request and in all cases when costs are expected 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 EST

or

NAWDEX ASSISTANCE CENTER - West Virginia
U.S. Geological Survey
Water Resources Division
Federal Building & U.S. Court House
500 Quarrier Street, Room 3416
Charleston, West Virginia 25301

Telephone (304) 343-6181, Ext. 310
FTS 924-1310

Hours: 7:45 - 4:30 EST

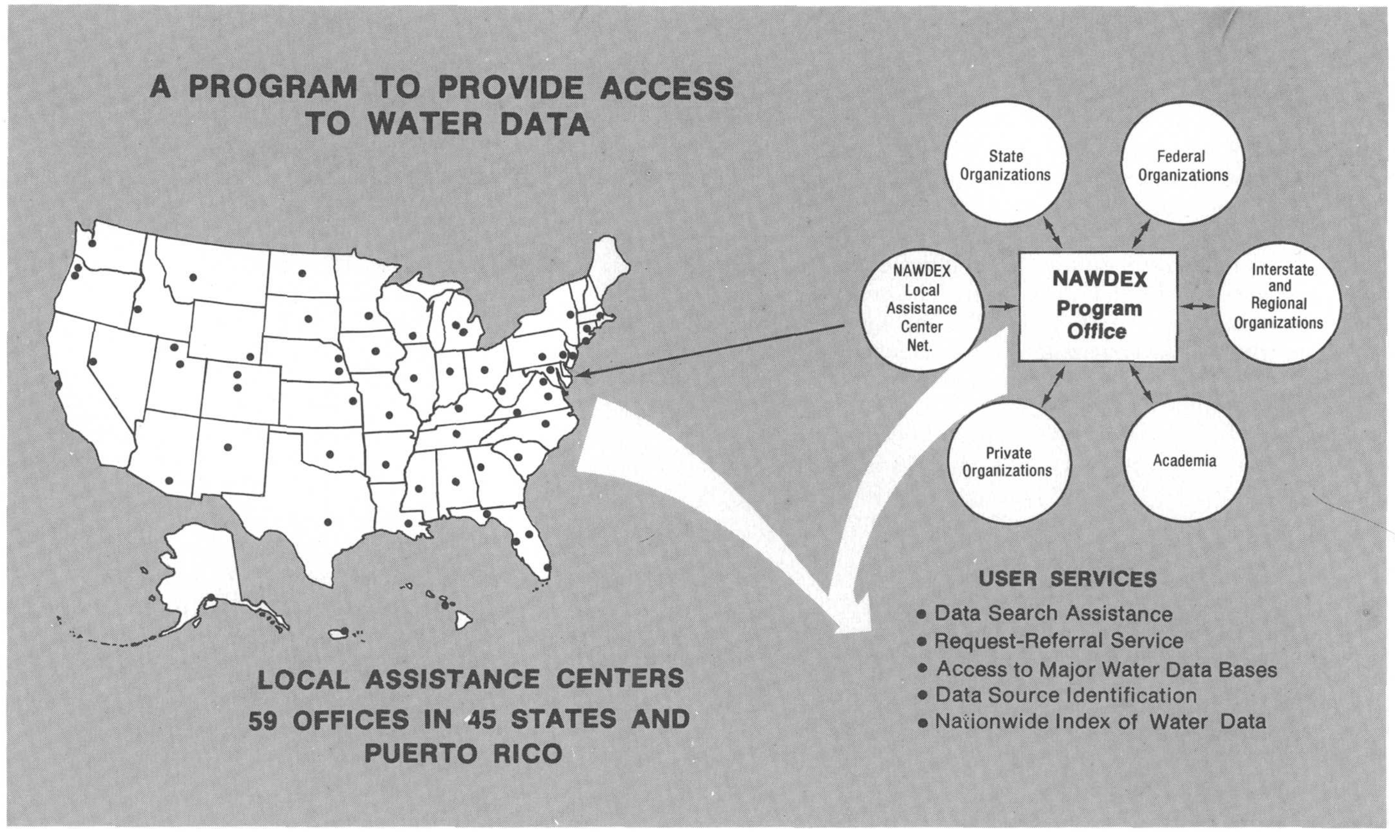


Figure 6.2-1 Function of NAWDEX Program Office

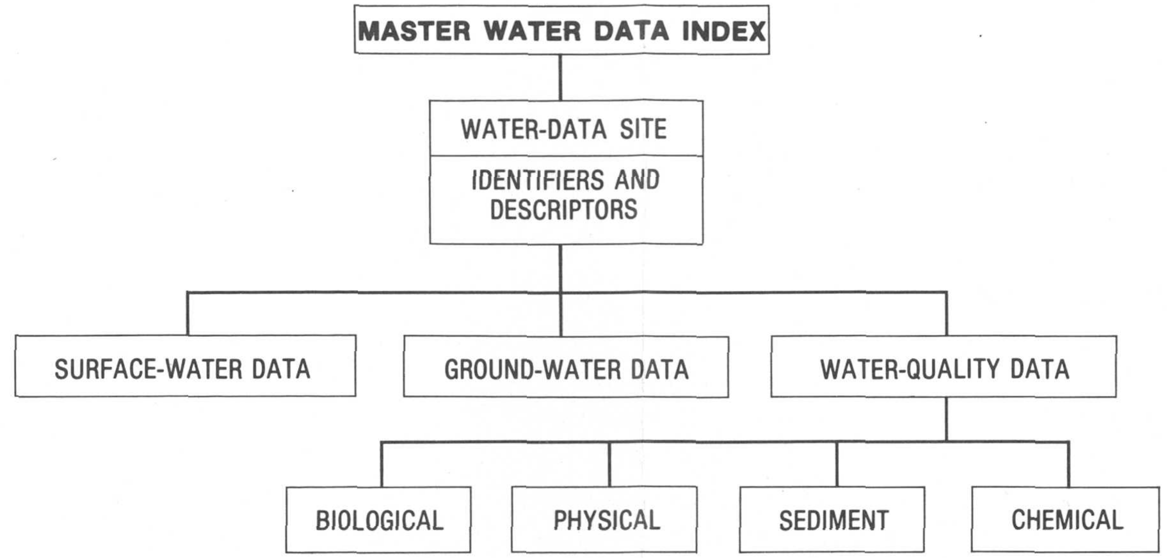


Figure 6.2-2 Master Water-Data Index

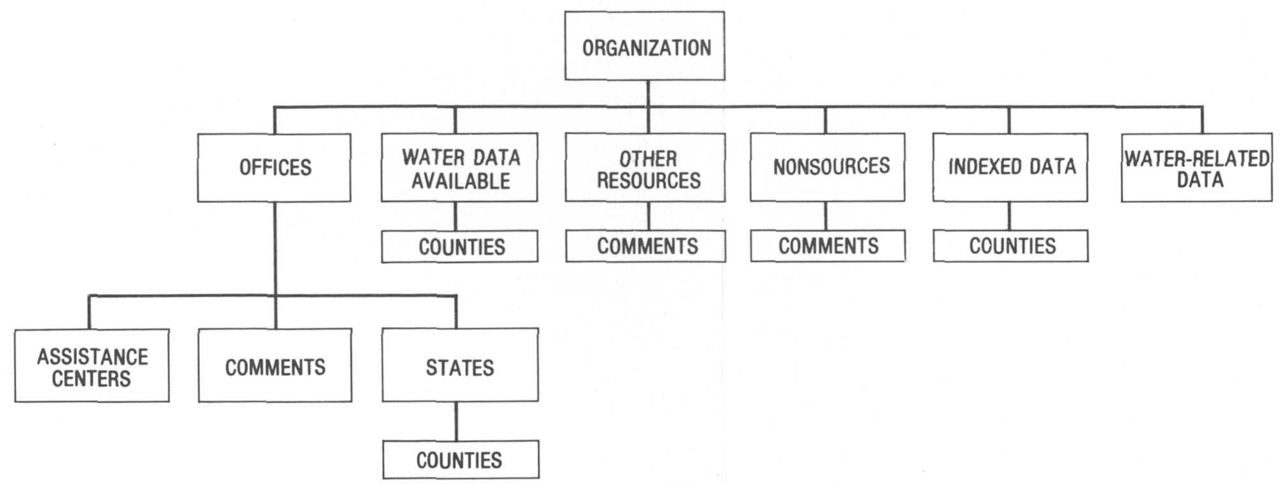


Figure 6.2-3 Water Data Sources Directory

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, Virginia 22092

or

U.S. Geological Survey
Water Resources Division
500 Quarrier St., Room 3416
Charleston, West Virginia 25301

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. 6.3-1). 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 over 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 790,000 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 chloride. Data are recorded on 16-channel paper tape, which is removed from the recorder and transmitted over telephone lines to the receiver in Reston, Virginia. 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 chlorides, 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 decision-makers 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.

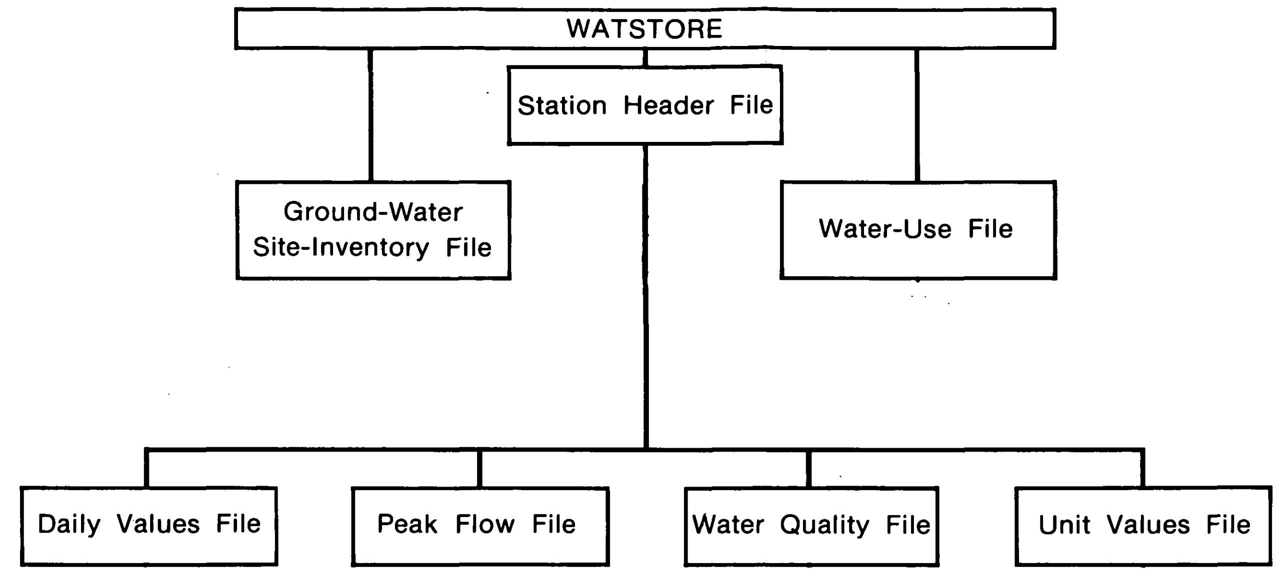


Figure 6.3-1 WATSTORE file system

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. 6.4.1): 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 6.2).

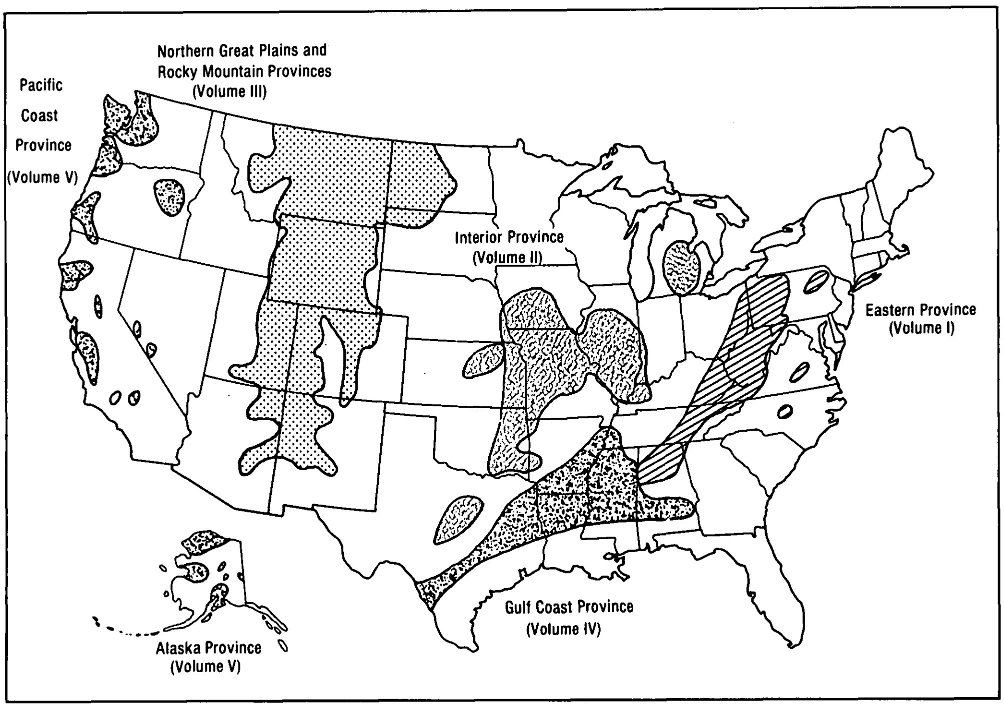


Figure 6.4-1 Index volumes and related provinces

7.0 SURFACE-WATER NETWORK

Site Number	Station Name	Latitude	Longitude	Drainage Area (sq. mi.)	Station Number[a]	Discharge	Chemical Quality	Sediment
1	Glade Creek at Highway 31 at Cool Ridge, W.Va.	37 39 17	81 04 58	14.1		1979-80	1979-80	1980[b]
2	Piney Creek at Highway 25 Bridge near Crab Orchard, W.Va.	37 42 37	81 11 40	24.5		1979-80	1979-80	1980[b]
3	Piney Creek at Raleigh, W.Va.	37 45 40	81 09 50	52.2	03185000	1951-80	1975-80	1979-80
4	Laurel Creek at Willis Bridge near Sandstone, W.Va.	37 45 42	80 51 35	14.4		1979-80	1979-80	1980[b]
5	Marsh Fork at Highway 99 Bridge at Fairdale, W.Va.	37 46 45	81 22 18	32.0		1979-80	1979-80	1980[b]
6	Lick Creek at Private Bridge near Sandstone, W.Va.	37 47 19	80 53 02	37.5		1979-80	1979-80	1980[b]
7	Sandlick Creek at Highway 3/9 Bridge near Arnett, W.Va.	37 49 28	81 24 52	19.9		1979-80	1979-80	1980[b]
8	Pond Fork at Highway 85 Bridge near Rock Lick, W.Va.	37 49 55	81 37 53	18.0		1979-80	1979-80	1980[b]
9	Meadow Creek at Highway 7/1 Bridge at Claypool, W.Va.	37 50 08	80 52 23	18.2		1979-80	1979-80	1980[b]
10	Laurel Creek at Highway 41/9 Bridge at Laurel Creek, W.Va.	37 51 27	80 59 37	21.4		1979-80	1979-80	1980[b]
11	Paint Creek at Highway 23 Bridge at Willis Branch, W.Va.	37 53 39	81 15 48	26.7		1979-80	1979-80	1980[b]
12	Spruce Fork at Highway 17 Bridge at Five Block, W.Va.	37 53 40	81 49 26	25.6		1979-80	1979-80	1980[b]
13	Packs Bridge at Highway 27 Bridge at Packs Branch, W.Va.	37 54 15	81 14 28	4.61		1979-80	1979-80	1980[b]
14	Meadow River at Highway 60/32 Bridge near Meadow Bluff, W.Va.	37 54 49	80 40 26	28.1		1979-80	1979-80	1980[b]
15	Spruce Laurel Fork at Railroad Bridge at Clothier, W.Va. (Spruce Laurel Fork at Clotheir, W. Va.)	37 56 45	81 48 23	31.8	03198720	1979-80	1979-80	1980[b]
16	Pond Fork at Bridge at Bob White, W.Va. (Pond Fork at Bob White, W. Va.)	37 57 15	81 43 10	58.3	03198880	1979-80	1979-80	1980[b]
17	Clear Fork at Highway 1/21 Bridge at Leevale, W.Va.	37 57 58	81 31 28	63.2		1979-80	1979-80	1980[b]
18	Marsh Fork at Highway 1 Bridge at Whitesville, W.Va.	37 58 09	81 31 58	162		1979-80	1979-80	1980[b]
19	Hewitt Creek at Private Bridge at Jeffrey, W.Va.	37 58 14	81 49 33	18.9		1979-80	1979-80	1980[b]
20	West Fork at Railroad Bridge at Van, W.Va. (West Fork at Van, W. Va.)	37 58 20	81 42 38	42.7	03198885	1979-80	1979-80	1980[b]
21	Little Clear Creek at Highway 8 Bridge near Crawley, W.Va.	37 58 26	80 38 32	21.0		1979-80	1979-80	1980[b]
22	Sewell Creek at Highway 60/1 Bridge at East Rainelle, W.Va.	37 58 26	80 45 53	40.1		1979-80	1979-80	1980[b]
23	Glade Creek at Highway 41/18 Bridge at Babcock State Park, W.Va.	37 58 45	80 56 48	33.9		1979-80	1979-80	1980[b]
24	Meadow River at Highway 60 Bridge at McRoss, W.Va.	37 59 09	80 45 00	156	03189890	1979-80	1979-80	1980[b]
25	Big Clear Creek at Highway 1/2 Bridge at Kessler, W.Va.	37 59 11	80 40 05	47.1		1979-80	1979-80	1980[b]
26	Fifteenmile Fork at Highway 76/1 Bridge near Decota, W.Va.	38 00 12	81 25 28	4.53		1979-80	1979-80	1980[b]
27	Cabin Creek at Railroad Bridge at Decota, W.Va.	38 01 01	81 25 10	5.77		1979-80	1979-80	1980[b]
28	Paint Creek at Railroad Bridge at Mahan, W.Va.	38 01 07	81 21 11	83.0		1979-80	1979-80	1980[b]
29	Hopkins Fork at Highway 5 Bridge near Hopkins Fork, W.Va.	38 03 50	81 37 15	23.6		1979-80	1979-80	1980[b]
30	Laurel Creek at Highway 5 Bridge at Hopkins Fork, W.Va.	38 04 33	81 38 20	15.9		1979-80	1979-80	1980[b]
31	Laurel Creek Below Hopkins Fork at Hopkins Fork, W.Va.	38 05 16	81 38 21	41.3		1979-80	1979-80	1980[b]
32	Sandlick Creek at Hopkins Fork, W.Va.	38 05 36	81 38 23	6.23		1979-80	1979-80	1980[b]
33	Laurel Creek at Bridge in Beckwith, W.Va.	38 05 52	81 09 16	17.3		1979-80	1979-80	1980[b]
34	Loop Creek at Highway 61 Bridge at Robson, W.Va.	38 06 07	81 14 53	42.8		1979-80	1979-80	1980[b]
35	Drawdy Creek near Peytona, W.Va.	38 07 29	81 41 33	7.75	03198450	1968-77 1979-80	1979-80	1980[b]
36	Anglins Creek at Highway 41 Bridge near Pool, W.Va.	38 08 18	80 53 08	33.0		1979-80	1979-80	1980[b]
37	Armstrong Creek at Highway 61 Bridge at Mount Carbon, W.Va.	38 08 40	81 17 34	22.8		1979-80	1979-80	1980[b]
38	Little Coal River at Julian, W.Va.	38 09 17	81 51 10	319	03199400	1974-80	1975-80	1975-80
39	Big Horse Creek at Highway 3 Bridge at Altman, W.Va.	38 09 52	81 52 08	28.4		1979-80	1979-80	1980[b]
40	Cabin Creek at Highway 79 Bridge at Dry Branch, W.Va.	38 10 56	81 28 08	70.8		1979-80	1979-80	1980[b]
41	Hominy Creek at Highway 26/4 Crossing near Bruce, W.Va.	38 11 58	80 46 35	59.0		1979-80	1979-80	1980[b]
42	Fork Creek at Highway 2/2 near Emmons, W.Va.	38 12 27	81 46 36	10.6		1979-80	1979-80	1980[b]
43	North Fork Cherry River at Highway 39 Bridge, W.Va.	38 13 12	80 23 43	11.8		1979-80	1979-80	1980[b]
44	Kellys Creek at Highway 81/12 Bridge at Cedar Grove, W.Va.	38 13 13	81 25 37	24.1		1979-80	1979-80	1980[b]
45	Laurel Creek at Highway 39/26 Bridge at Fenwick, W.Va.	38 13 15	80 35 27	41.6		1979-80	1979-80	1980[b]

a Continuous record stations only.
b Intermittent data.

Site Number	Station Name	Latitude	Longitude	Drainage Area (sq. mi.)	Station Number [a]	Discharge	Chemical Quality	Sediment
46	Cherry River at Highway 39/18 Bridge in Richwood, W.Va.	38 13 18	80 31 59	86.6		1979-80	1979-80	1980[b]
47	North Fork Cherry River at Highway 38/17 Bridge in Richwood, W.Va.	38 13 47	80 31 29	36.4		1979-80	1979-80	1980[b]
48	Gauley River above Belva, W.Va.	38 14 00	81 10 45	1315	03192000	1928-80	1975-80	1980[b]
49	Twentymile Creek at Highway 16/3 Bridge at Belva, W.Va.	38 14 13	81 11 09	85.2		1979-80	1979-80	1980[b]
50	Brier Creek at Highway 18 Bridge at Brounland, W.Va.	38 14 22	81 46 17	15.8		1979-80	1979-80	1980[b]
51	Bells Creek at Highway 16 Bridge at Dixie, W.Va.	38 14 57	81 11 34	31.6		1979-80	1979-80	1980[b]
52	Big Coal River near Alum Creek, W.Va.	38 15 00	81 47 54	442	03198550	1974-80	1979-80	1980[b]
53	North Fork Cranberry River at Highway 76 Bridge at Cranberry River, W.Va. (North Fork Cranberry River near Hillsboro, W.Va.)	38 15 27	80 19 25	9.97	03187300	1969-71, 1980	1979-80	1980[b]
54	Peters Creek near Lockwood, W.Va.	38 15 40	81 01 20	40.2	03191500	1945-71 1979-80	1979-80	1980[b]
55	Davis Creek at Highway 23 at Kanawha State Forest, W.Va.	38 16 53	81 38 32	7.09		1979-80	1979-80	1980[b]
56	Gauley River near Craigsville, W.Va.	38 17 30	80 38 30	528	03189100	1964-80	1976-80	1980[b]
57	Cranberry River near Richwood, W.Va.	38 17 45	80 31 40	81.2	03187500	1979	1976,1978-80	1979-80
58	Trace Fork at Ruth, W.Va.	38 18 30	81 43 40	2.82	03198020	1980	1980	1980
59	Muddlety Creek at Highway 41 Bridge at Summersville, W.Va.	38 18 39	80 50 09	51.0		1979-80	1979-80	1980[b]
60	Campbells Creek at Highway 73 Bridge downstream of Coal Fork, W.Va.	38 18 54	81 32 04	32.6		1979-80	1980	1980[b]
61	Trace Fork downstream Dryden Hollow at Ruth, W.Va.	38 18 55	81 43 42	4.72	03198022	1980	1980	1980
62	Big Beaver Creek at Highway 5 Bridge at Craigsville, W.Va.	38 19 42	80 39 56	29.5		1979-80	1979-80	1980[b]
63	Coal River at Tornado, W.Va.	38 20 20	81 50 29	861	03200500	1908-11, 1911-12 1928-31, 1961-80	1972-80	1972-80
64	Williams River at Highway 135 Bridge near Handley P H A, W.Va.	38 20 27	80 13 58	51.6		1979-80	1979-80	1980[b]
65	Davis Creek upstream from Trace Fork at Davis Creek, W.Va.	38 20 32	81 42 34	35.8		1979-80	1979-80	1980[b]
66	Blue Creek at Highway 57 Bridge at Sanderson, W.Va.	38 21 45	81 21 52	50.1		1979-80	1979-80	1980[b]
67	Williams River at Dyer, W.Va.	38 22 45	80 29 05	130	03186500	1929-80	1976-80	1980[b]
68	Brushy Fork at Highway 19 Bridge at Hookerville, W.Va.	38 23 08	80 48 29	7.57		1979-80	1979-80	1980[b]
69	Sycamore Creek downstream Charley Bridge near Indore, W.Va.	38 23 08	81 09 19	27.1		1979-80	1979-80	1980[b]
70	Gauley River at Highway 46 Bridge at Williams River, W.Va.	38 23 14	80 31 11	75.3		1979-80	1979-80	1980[b]
71	Old Field Fork at Highway 219/1 Bridge near Slatyfork, W.Va.	38 23 22	80 07 42	22.9		1979-80	1979-80	
72	Middle Creek at Highway 16 Bridge upstream from Hartland, W.Va.	38 24 17	81 06 40	7.58		1979-80	1979-80	1980[b]
73	Hurricane Creek at Highway 48 Bridge near Hurricane, W.Va.	38 24 42	81 59 35	9.11		1979-80	1979-80	1980[b]
74	Big Spring Fork at Highway 219 at Slatyfork, W.Va.	38 24 58	80 07 09	21.1		1979-80	1979-80	1980[b]
75	Gauley River at Highway 42 Bridge at Jerryville, W.Va.	38 25 17	80 18 15	27.8		1979-80	1979-80	1980[b]
76	Blue Creek at Private Bridge near Blue Creek, W.Va.	38 26 16	81 26 41	78.0		1979-80	1979-80	1980[b]
77	Robinson Fork at Highway 15/4 Bridge near Enoch, W.Va.	38 26 50	80 55 25	16.6		1979-80	1979-80	1980[b]
78	Buffalo Creek at Railroad 8 1000 ft. upstream Robinson Fk., W.Va.	38 27 00	80 55 23	22.4		1979-80	1979-80	1980[b]
79	Buffalo Creek at Highway 11/9 Bridge at Clay, W.Va.	38 27 16	81 04 01	113		1979-80	1979-80	1980[b]
80	Poplar Fork at I-64 Bridge at Mount Vernon, W.Va. (Poplar Fork at Teays, W. Va.)	38 27 23	81 55 54	8.71	03201410	1967-77, 1979-80	1979-80	1980[b]
81	Falling Rock Creek at Highway 58 at Falling Rock, W.Va.	38 27 37	81 23 25	24.6		1979-80	1979-80	1980[b]
82	Little Sandy Creek at Highway 39 at Wills, W.Va.	38 27 47	81 30 00	28.2		1979-80	1979-80	1980[b]
83	Birch River at Highway 44 Bridge at Boggs, W.Va.	38 28 11	80 38 33	16.3		1979-80	1979-80	1980[b]
84	Elk River at Queen Shoals, W.Va.	38 28 20	81 17 10	1145	03197000	1928-80	1961-75, 1979-80	1980[b]
85	Leatherwood Creek at Highway 26/4 Bridge at Bergoo, W.Va.	38 29 02	80 17 59	19.2		1979-80	1979-80	1980[b]
86	Frog Creek at Highway 30 Bridge near Camp Virgil Tate, W.Va.	38 30 58	81 42 38	9.96		1979-80	1979-80	1980[b]
87	Laurel Creek at Highway 9 Bridge at Erbacon, W.Va.	38 31 08	80 35 19	36.5		1979-80	1979-80	1980[b]
88	Pocatalico River at Sissonville, W.Va.	38 31 35	81 37 50	238	03201000	1906-16, 1930-31 1937-78, 1979	1978-80	1980[b]
89	Big Sandy Creek downstream Little Blue Creek near Clendenin, W.Va.	38 31 37	81 18 55	93.4		1979-80	1979-80	1980[b]
90	Lefthand Creek at Highway 119/3 Bridge near Clendenin, W.Va.	38 31 50	81 20 24	27.8		1979-80	1979-80	1980[b]
91	Groves Creek at Railroad Bridge at Groves, W.Va.	38 33 23	80 57 40	13.8		1979-80	1979-80	1980[b]
92	Middle Fork at Highway 42 Bridge near Romance, W.Va.	38 33 28	81 37 32	29.2		1979-80	1979-80	1980[b]
93	Strange Creek at Highway 40 near Strange Creek, W.Va.	38 33 33	80 53 40	27.6		1979-80	1979-80	1980[b]
94	Pocatalico Creek at Route 21 Bridge near Romance, W.Va.	38 33 33	81 38 05	32.7		1979-80	1979-80	1980[b]
95	Grassy Creek at Highway 20 Bridge at Diana, W.Va.	38 33 36	80 27 06	19.4		1979-80	1979-80	1980[b]
96	Sugar Creek upstream from Little Sugar Creek near Skelt, W.Va.	38 34 10	80 18 20	13.9		1979-80	1979-80	1980[b]
97	Little Sugar Creek at Highway 18/3 near Skelt, W.Va.	38 34 12	80 18 22	7.29		1979-80	1979-80	1980[b]
98	Birch River at Herold, W.Va.	38 34 29	80 48 04	124	03196500	1974-75, 1978-80	1979-80	1980[b]
99	Little Birch River at Highway 40/15 near Little Birch, W.Va.	38 34 44	80 44 04	27.2		1979-80	1979-80	1980[b]
100	Elk River below Webster Springs, W.Va.	38 35 50	80 29 20	268	03194700	1959-80	1968-80	1980[b]
101	18-mile Creek at Highway 6 Bridge at White Star School, W.Va.	38 37 18	81 54 28	64.47		1979-80	1979-80	1980[b]
102	Cherry Fork at Highway 5/3 Bridge near Paradise, W.Va.	38 37 22	81 48 50	14.0		1979-80	1979-80	1980[b]
103	18-Mile Creek at Highway 5 Bridge near Paradise, W.Va.	38 37 41	81 48 34	20.4		1979-80	1979-80	1980[b]
104	Left Fork Holly River downstream Fall Run near Hacker Valley, W.Va.	38 38 04	80 19 22	12.1		1979-80	1979-80	1980[b]
105	Right Fork Holly River at Guardian, W.Va.	38 38 08	80 27 58	51.1	03195100	1974-78, 1978-79[c]	1974-79	1980[b]
106	Pocatalico River at Highway 119 Bridge at Walton, W.Va.	38 38 17	81 24 07	54.2		1979-80	1979-80	1980[b]
107	Flat Fork at Highway 32 Bridge at Ryan, W.Va.	38 38 32	81 28 23	25.7		1979-80	1979-80	1980[b]
108	Laurel Fork at Highway 3 at Hacker Valley, W.Va.	38 39 12	80 22 53	11.5		1979-80	1979-80	1980[b]
109	Left Fork Holly River near Replete, W.Va.	38 41 19	80 26 01	48.1	03195250	1979-80[c]	1979-80	1980[b]
110	Mudlick Fork at Highway 35/10 Bridge at Elmwood, W.Va.	38 41 42	81 51 11	15.9		1979-80	1979-80	1980[b]
111	Poplar Fork at Highway 35/10 Railroad at Capehart, W.Va.	38 42 47	81 52 54	28.8		1979-80	1979-80	1980[b]
112	New River at Hinton, W.Va.	37 40 15	80 53 40	6,257	03184500	1936-80	1975-80	1980[b]
113	Elk River near Frametown, W.Va.	38 35 34	80 53 06	752	03196600	1958-80	1960-66, 1967, 1971-1980	1980[b]
114	Elk River at Sutton, W.Va.	38 39 45	80 42 35	543	03195500	1938-80	1960-80	1980[b]
115	Meadow River near Mt. Lookout, W.Va.	38 11 25	80 56 55	365	03190400	1966-80	1975-80	1980[b]
116	Little Coal River at Danville, W.Va.	38 04 47	81 50 12	270	03199000	1930-80	1972-80	1974-80
117	Coal River at Alum Creek, W.Va.	38 17 11	81 48 25	835	03199700	1974-79 discontinued	1974-80	1974-80
118	Kanawha River at Winfield Dam, W.Va.	38 31 32	81 54 40	11,809	03201300	1957-1970, 1974-80	1956-70 1974-80	1973-80
119	Kanawha River at Kanawha Falls, W.Va.	38 08 20	81 12 45	8,367	03193000	1916-18, 1927-28 1977-80	1957-66 1968-80	1980[b]
120	Big Coal River at Ashford, W.Va.	38 10 45	81 42 40	393	03198500	1908-16, 1930-80	1973-80	1980[b]
121	Kanawha River at Charleston, W.Va.	38 22 10	81 42 05	10,419	03198000	1939-80	1953-70 1971-80	1980[b] 1980[b]
122	Gauley River below Summersville Dam, W.Va.	38 13 00	80 53 30	804	03189600	1966-80	1974-80	
123	New River at Bluestone Dam, W.Va.	37 38 35	80 53 00	4,604	03180000	1923-69 1975-80	1953-67, 1969-80,	1980[b] 1980[b]
124	Elk River at Clay, W.Va.	38 27 36	81 05 15	994	03196800	1979-80[c]	1979-80	1980[b]
125	Twenty-Mile Creek at Highway 20/1 Bridge near Vaughan, W.Va.	38 19 27	81 01 17	19.20		1979-80	1979-80	
126	Gauley River at Camden on Gauley, W.Va.	38 21 55	80 36 05	236	03187000	1908-16, 1929-75 discontinued		1980[b]
127	Cherry River at Fenwick, W.Va.	38 13 45	80 35 00	150	03189000	1929-69, 1979-80	1979-80	
128	Collison Creek near Nallen, W.Va.	38 10 35	80 52 07	2.78	03189650	1966-77 discontinued	1975-78	
129	Granny Creek at Sutton, W.Va.	38 40 36	80 42 47	6.98	03195600	1967-77 discontinued	1975-77	1980[b]
130	Rock Creek near Danville, W.Va.	38 06 01	81 49 48	12.2	03199300	1978-79	1978-79	

[a] Continuous record stations only.
[b] Intermittent data.
[c] Stage only, no discharge

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