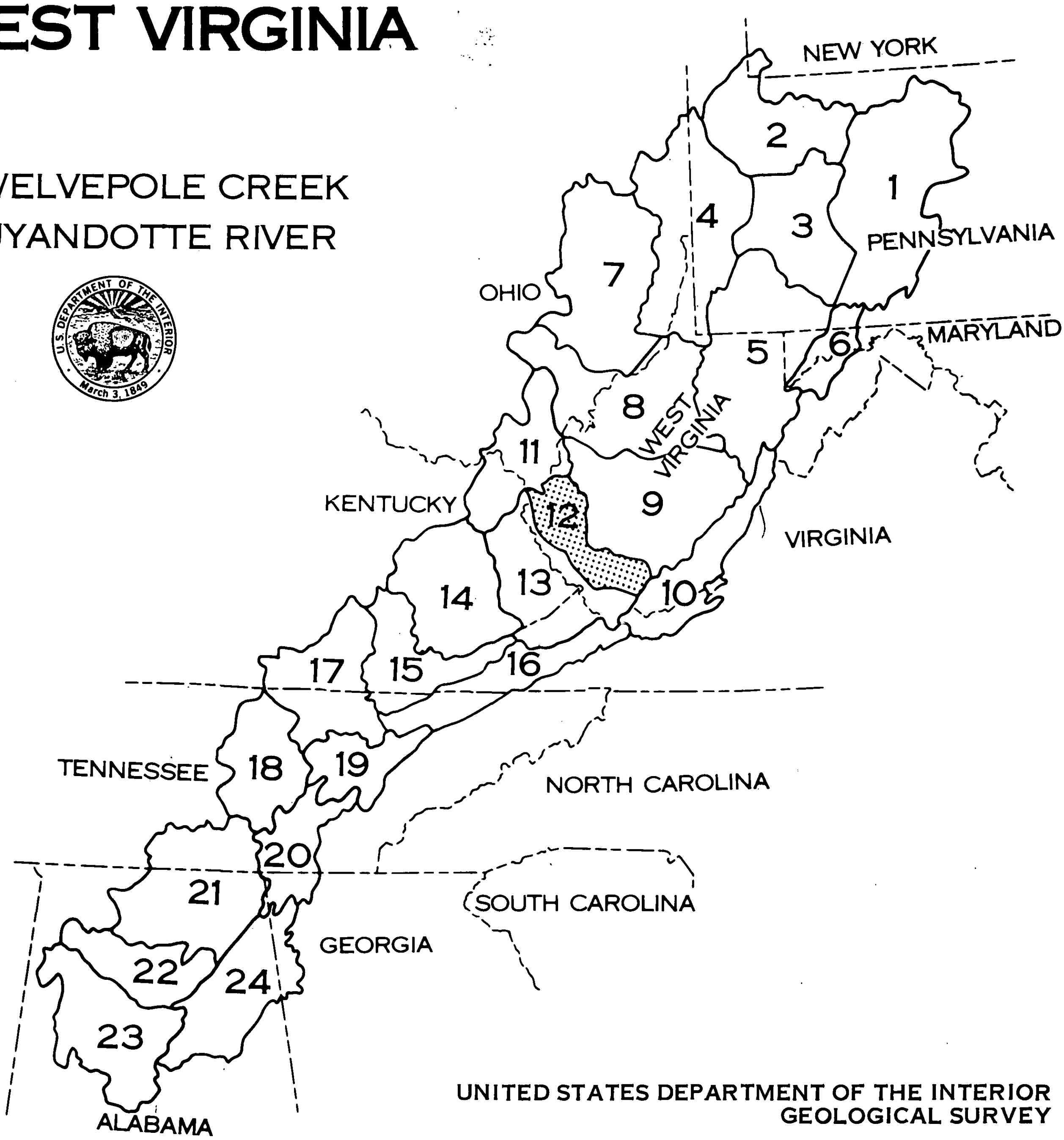
HYDROLOGY OF AREA 12, EASTERN COAL PROVINCE, WEST VIRGINIA

- TWELVEPOLE CREEK
- GUYANDOTTE RIVER



UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 81-902

HYDROLOGY OF AREA 12, EASTERN COAL PROVINCE, WEST VIRGINIA

BY
THEODORE A. EHLKE, JOHN S. BADER, CELSO PUENTE,
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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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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 [$(t/km^2)/a$]

$$°F = 1.8 \times °C + 32$$

HYDROLOGY OF AREA 12, EASTERN COAL PROVINCE, WEST VIRGINIA

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ABSTRACT

Area 12 is located in the Guyandotte River and Twelvepole Creek basins and covers an area of 2,121 square miles in southwestern West Virginia. This report is intended to convey general hydrologic information on this area to consulting engineers, mine operators, and regulatory personnel. The report format consists of brief texts and supporting illustrations and tables on a series of hydrologic topics which together describe the hydrology of the area.

Area 12 is drained by the Guyandotte River and Twelvepole Creek. The U.S. Geological Survey operates a network of 12 continuous-record gaging stations and 45 miscellaneous-measurement sites to monitor streamflow quantity and quality in the area.

Land use and land cover are strongly influenced by the mountainous topography which dominates the area. Nearly 90 percent of the land cover is forest, largely because of the rugged terrain. Agriculture and urban land use comprise 4.5 and 3.7 percent, respectively, of the total land use and are confined mostly to land along the northwestern and southeastern boundaries of the area.

Precipitation in the area averages about 42 inches annually and is greatest in the mountainous portion.

Soils are generally shallow and poorly drained because of the presence of sedimentary rock formations close to the surface. Sedimentary rocks underlying the area are divided into seven units composed of alternating beds of sandstone, shale, mudstone, and coal with minor amounts of limestone. The most important coal seams occur in the Pottsville Group. Most of the coal in the area is produced from underground mines. In 1980, 36 surface and 363 underground coal mines operated in the area.

Wells are the primary source of domestic water in the rural areas. The yields of wells in the valleys are three times greater than those of wells on hillsides or hilltops.

The quality of surface water is generally good but is affected by mining in many areas of the upper Guyandotte River basin. Underground mining contributes to increases in specific conductance, alkalinity, and concentrations of sulfate and dissolved manganese in surface water throughout the upper Guyandotte River basin. Increased pH was found in coal-mining areas due in part to the use of powdered limestone in the mines which caused alkaline discharge. Specific conductance for all sites in the area ranged from 40 to 1,500 μmhos/cm (micromhos per centimeter) and had a mean value of 254 μmhos/cm. The highest specific conductance in surface water was observed in the upper Guyandotte River basin, where most mining occurs. The pH of surface water ranged from 5.7 to 8.9 and had a median value of 7.2. Surface water in the upper Guyandotte River basin was generally alkaline. Alkalinity of surface water throughout Area 12 ranged from 4 to 246 mg/L (milligrams per liter) and had a mean value of 43 mg/L. Streams in the upper Guyandotte River basin contained the highest mean alkalinity values; Twelvepole Creek basin contained the lowest.

The concentration of sulfate in surface water ranged from 6.6 to 400 mg/L and had a mean value of 79 mg/L. Streams in the upper Guyandotte River basin contained the greatest sulfate concentrations, largely because of the effects of mining. The concentration of total iron in surface water ranged from 90 to 27,000 μg/L (micrograms per liter) and had a mean value of 1,300 μg/L. Dissolved manganese concentrations in surface water ranged from 10 to 2,100 μg/L and had a mean value of 166 μg/L. Most of the iron was transported in the suspended phase and most of the manganese was transported in the dissolved phase during the prevailing streamflow conditions (low to moderate flow) at the time of sampling in 1979 and 1980. Suspended sediment yields in the area are relatively low, ranging from about 23 to 452 tons per square mile per year.

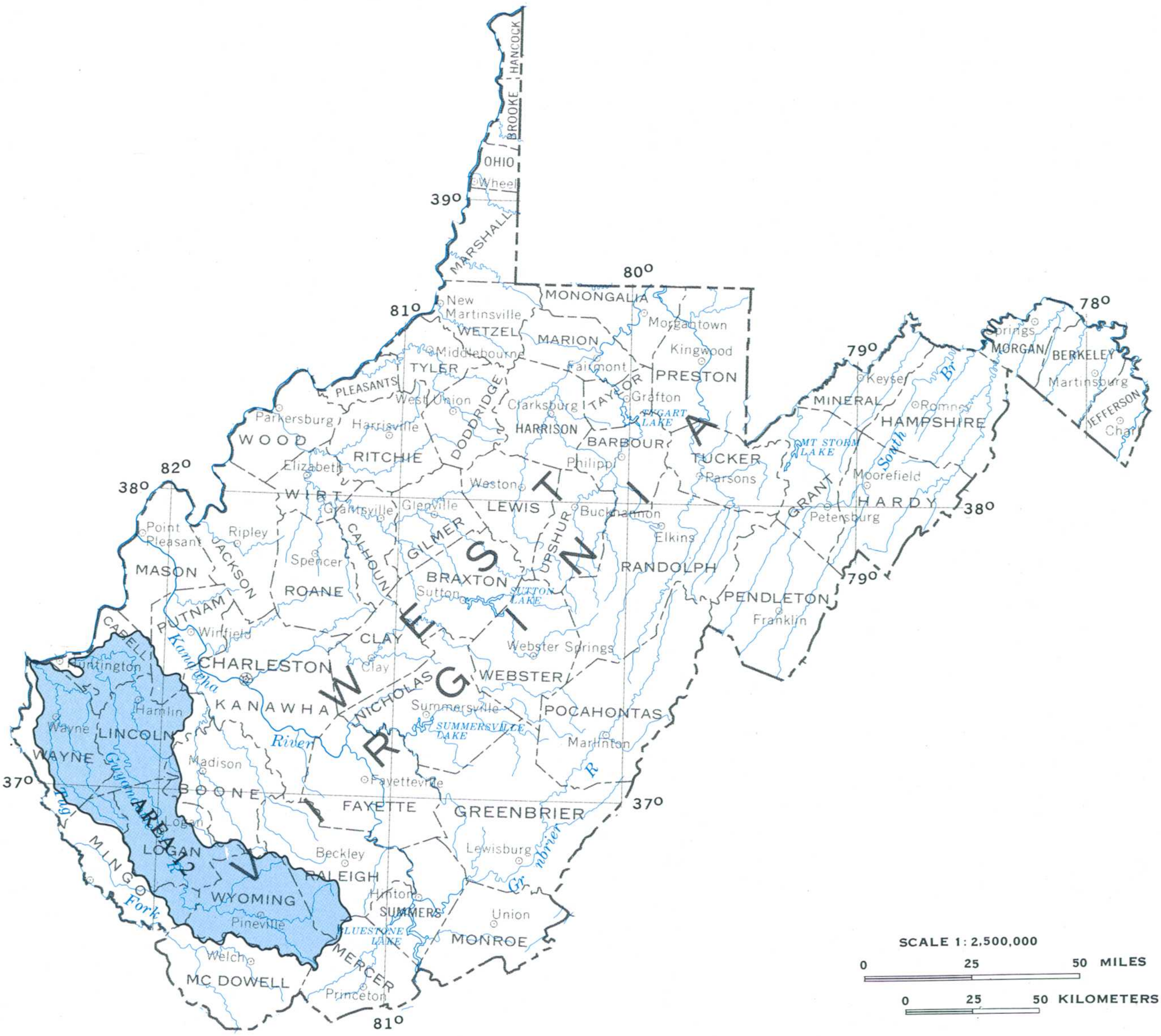
Area 12 Report to Aid Permitting

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

A need for hydrologic information and analysis on a scale never before required nationally was initiated when the "Surface Mining Control and Reclamation Act of 1977" was signed into law as Public Law 95-87, August 3, 1977. This need is partially met by this report which broadly characterizes the hydrology of Area 12, a part of the southwestern coal area of West Virginia (fig. 1.1-1). This report is one of a series that covers the coal provinces nationwide. The report contains a brief text with an accompanying map, chart, graph, or other illustration for each of a number of water-resources related topics. The summation of the topical discussions provides a description of the hydrology of the area.

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

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



BASE FROM U.S. GEOLOGICAL SURVEY
UNITED STATES BASE MAP, 1980

Figure 1.1-1 Location of Area 12 in West Virginia.

1.0 OBJECTIVES

Land Surface in Area 12 is Characterized by Deeply-Eroded Hills and Valleys with Extensive Relief

Area 12 has varied topography, with rugged, deeply-eroded hills in the headwaters and relatively flat floodplains with low hills near basin outlets. Natural resources of the area include second-growth timber, coal, natural gas, and petroleum. Coal mining is largely confined to the headwaters of the Guyandotte River, particularly Logan and Wyoming Counties. The area, which covers 2,121 square miles, includes all or part of 11 counties.

Area 12 covers 2,121 mi^2 (square miles) of some of the most rugged terrain in southwestern West Virginia. It has deeply-eroded, steep hills in the headwaters of the Guyandotte River and is characterized by a series of ridgetops dissected by a network of deeply-incised valleys, that tilt gradually towards the northwest (fig. 2.1-1). The altitude ranges from 515 feet (National Geodetic Vertical Datum of 1929) at the Guyandotte River basin outlet near Huntington to over 3,600 feet at Ivy Knob, on the Guyandotte-Coal River basin boundary. Local relief ranges from 1,000 to 1,500 feet near the basin outlet. Slope of the Guyandotte River channel above the town of Logan averages 11 ft/mi (feet per mile), whereas in the 71 miles from Logan to Barboursville the slope averages 1.8 ft/mi.

Area 12 lies within the Eastern Coal Province and includes all of Wyoming County and parts of Cabell, Mason, Putnam, Kanawha, Lincoln, Boone, Logan, Mingo, Raleigh, and Wayne Counties. The larger population centers include the towns of Mullens, Logan, Hamlin, Wayne, and Huntington. The area lies wholly within the Appalachian Plateaus physiographic province.

The major natural resources of the area include second-growth timber, natural gas, petroleum, and coal. Coal seams occur under about 85 percent of Area 12 (fig. 2.1-2). Most coal mining and natural gas production is confined to the headwaters of the Guyandotte River basin, chiefly in Logan and Wyoming Counties. The extent of commercial agriculture is small because of steep terrain.

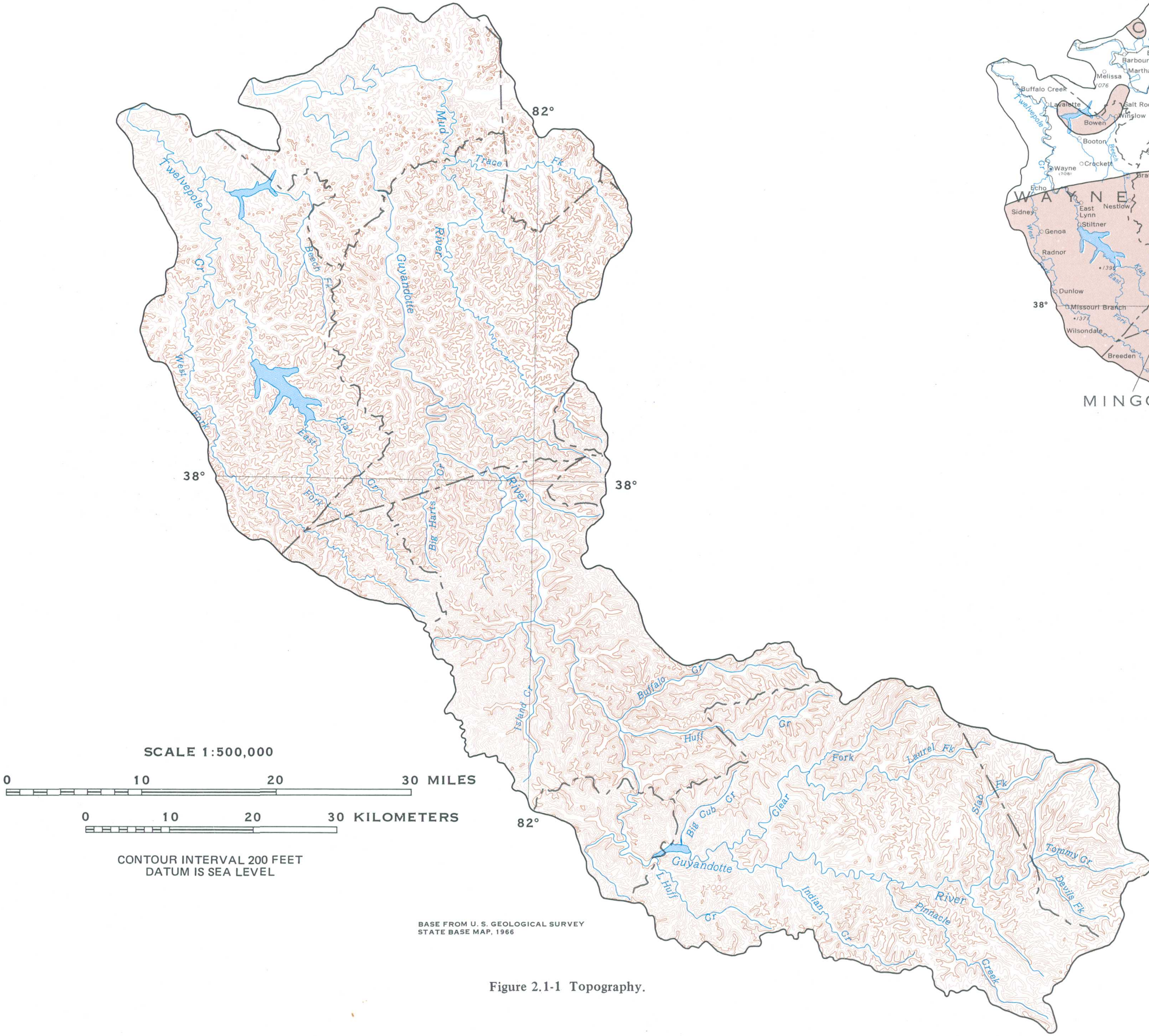


Figure 2.1-1 Topography.

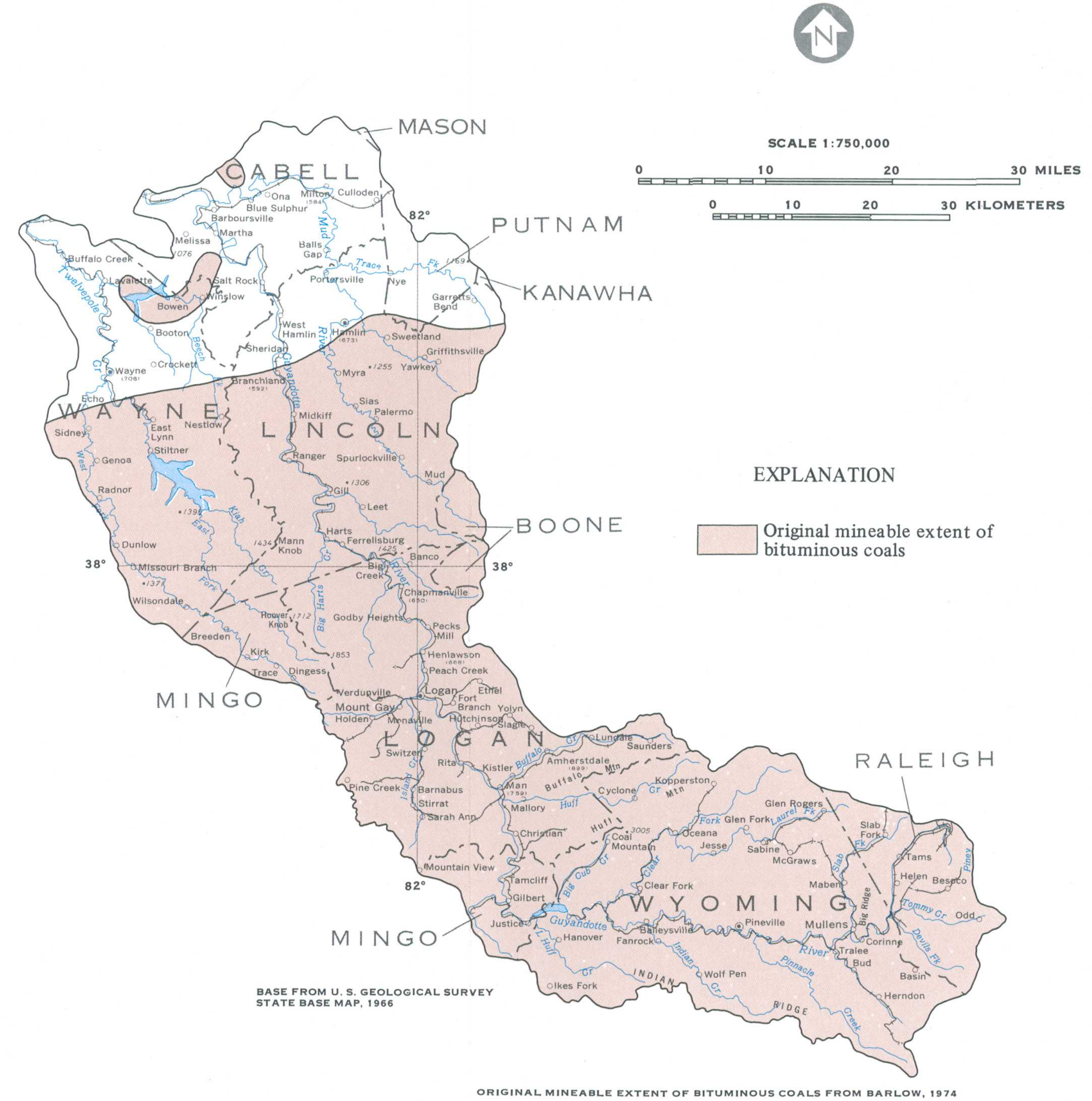


Figure 2.1-2 Original mineable extent of bituminous coals.

2.0 GENERAL FEATURES

2.1 Project Area

Two Major Rivers Drain Area

The Guyandotte River drains 1,679 square miles (79 percent) of the area. The other major stream, Twelvepole Creek, drains 442 square miles.

The Guyandotte River and Twelvepole Creek form the major surface-drainage network in Area 12. The Guyandotte River is 167 miles long, and drains 1,679 mi^2 (square miles), 79 percent of the area. The Mud River is the largest tributary of the Guyandotte River. It drains 359 mi^2 of rugged, mostly forested land in Cabell and Lincoln Counties. Clear Fork, Island Creek, and Trace Fork are smaller tributaries with drainage areas of 129, 105, and 80 mi^2, respectively. Drainage areas for many of the other larger tributaries of the Guyandotte River are described in greater detail by Mathes (1977). The Guyandotte River flows northwesterly, joining the Ohio River near Huntington, West Virginia. The Mud River joins the Guyandotte River 7.1 miles upstream from where the Guyandotte enters the Ohio River (fig. 2.2-1).

Twelvepole Creek drains a mountainous area of 442 mi^2 in Wayne, Lincoln, and Mingo Counties near the Ohio River. It flows northwesterly, entering the Ohio River downstream from Huntington near Kenova. Drainage areas for streams in Twelvepole Creek basin are given in Wilson (1979).

The area has no natural lakes other than ponds of less than 10 acres. However, there are flood protection reservoirs constructed by the U.S. Army Corps of Engineers on the Guyandotte River, East Fork Twelvepole Creek, and Beech Fork. R. D. Bailey Reservoir, located on the Guyandotte River near Justice, is a multipurpose reservoir with a maximum storage capacity of 204,000 acre-feet. East Lynn Lake on East Fork Twelvepole Creek and Beech Fork Lake on Beech Fork, having storage capacities of 82,500 and 37,500 acre-feet, respectively, provide flood protection for areas drained by Twelvepole Creek downstream from Lavalette.

Figure 2.2-1 Surface drainage basins.

Area is Characterized by Deeply-Eroded Hills with Steep Land Slopes

Area 12 is mountainous, with deeply-eroded hillsides and steep-sloped valleys. Land slopes are greatest in the central part of the area and gentler near the southeastern and northwestern boundaries. The ridges separating major subbasins generally trend northwesterly.

Topography is characterized by mountainous terrain that trends northeasterly through most of the area. Several regional uplifts and differential erosion of the rock strata gave rise to the relief in the area. Hilly to rolling uplands, high rounded to flat-topped ridges, undulating ridgelines, steep valley slopes, and narrow valley floors are found throughout the area. Average land slopes in 83 percent of the area, 1,760 mi^2 (square miles), exceed 30 percent.

Land slopes are greatest in the central part of Area 12 (fig. 2.3-1). Average land slopes in Mingo, Logan, and Boone Counties are the steepest in the State, exceeding 40 percent (West Virginia Community Development Division, 1979). Relatively level land is limited to the narrow floodplains along streams. Relief (altitude differences from valley floors to surrounding ridgetops) ranges from 500 to 1,200 feet in Mingo, Logan, and Boone Counties. The principal ridges separating major subbasins generally trend northwesterly.

The gentlest land slopes generally occur near the southeastern and northwestern boundaries of the area. Average land slopes in Raleigh, Cabell, Mason, and Putnam Counties range from 20 to 30 percent. Agriculture in Area 12 is largely confined to these regions.

Stream channel slopes are generally greatest in the areas of greatest relief. The Guyandotte River from Mullens to Logan has an average channel slope of 11 ft/mi (feet per mile), while from Logan to Barboursville the average channel slope is 1.8 ft/mi. Buffalo Creek, scene of a disasterous flood in 1972 (Runner, 1974), has an average channel slope of over 75 ft/mi. Stream channel slopes, generally less than 10 ft/mi, are gentlest in Twelvepole Creek basin and in streams tributary to the Mud River. Average channel slopes for selected streams are shown in figure 2.3-2.

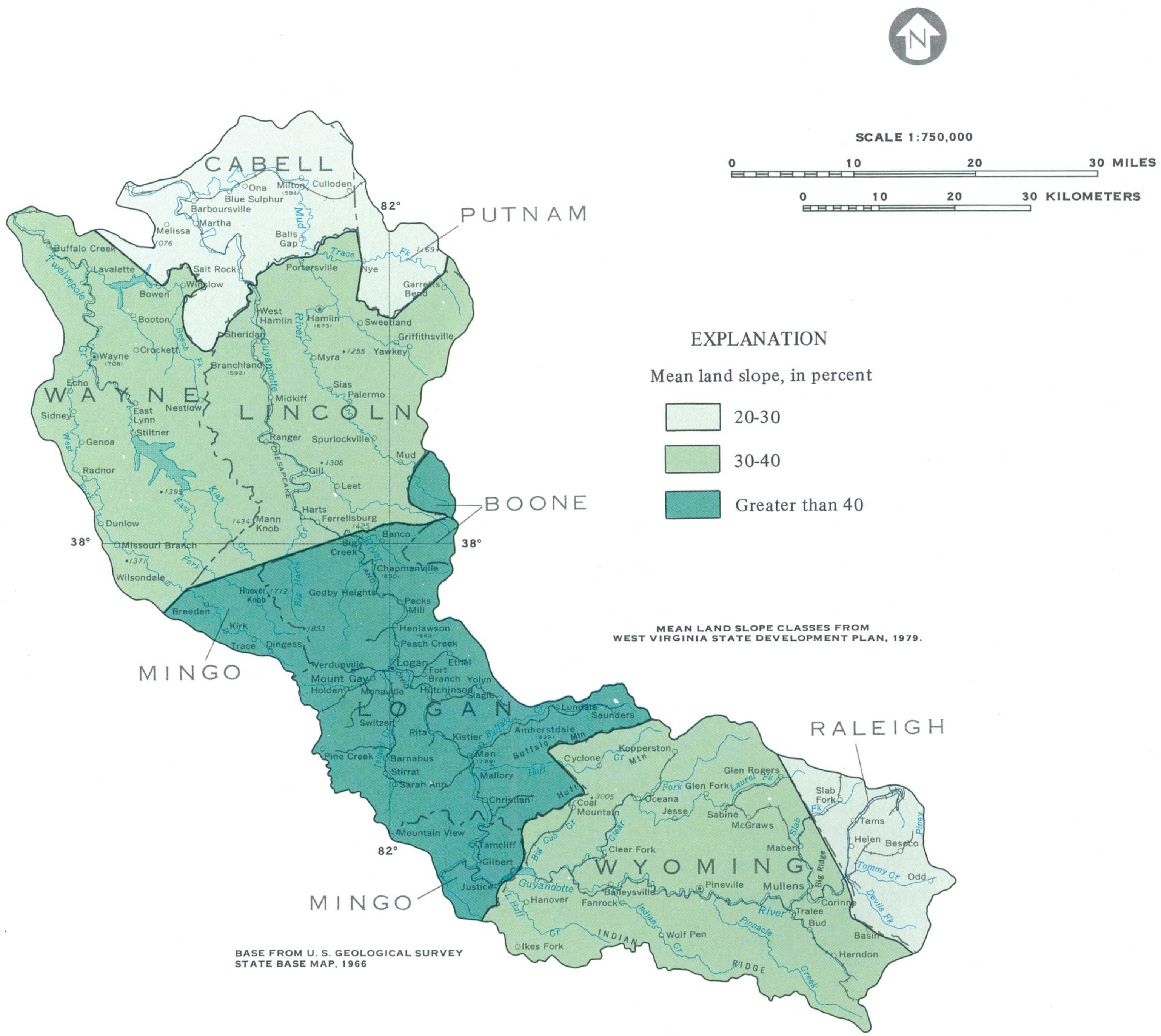


Figure 2.3-1 Mean land slope classes, by county.

Figure 2.3-2 Stream slope.

Soils in Area are Generally Shallow and Poorly Drained

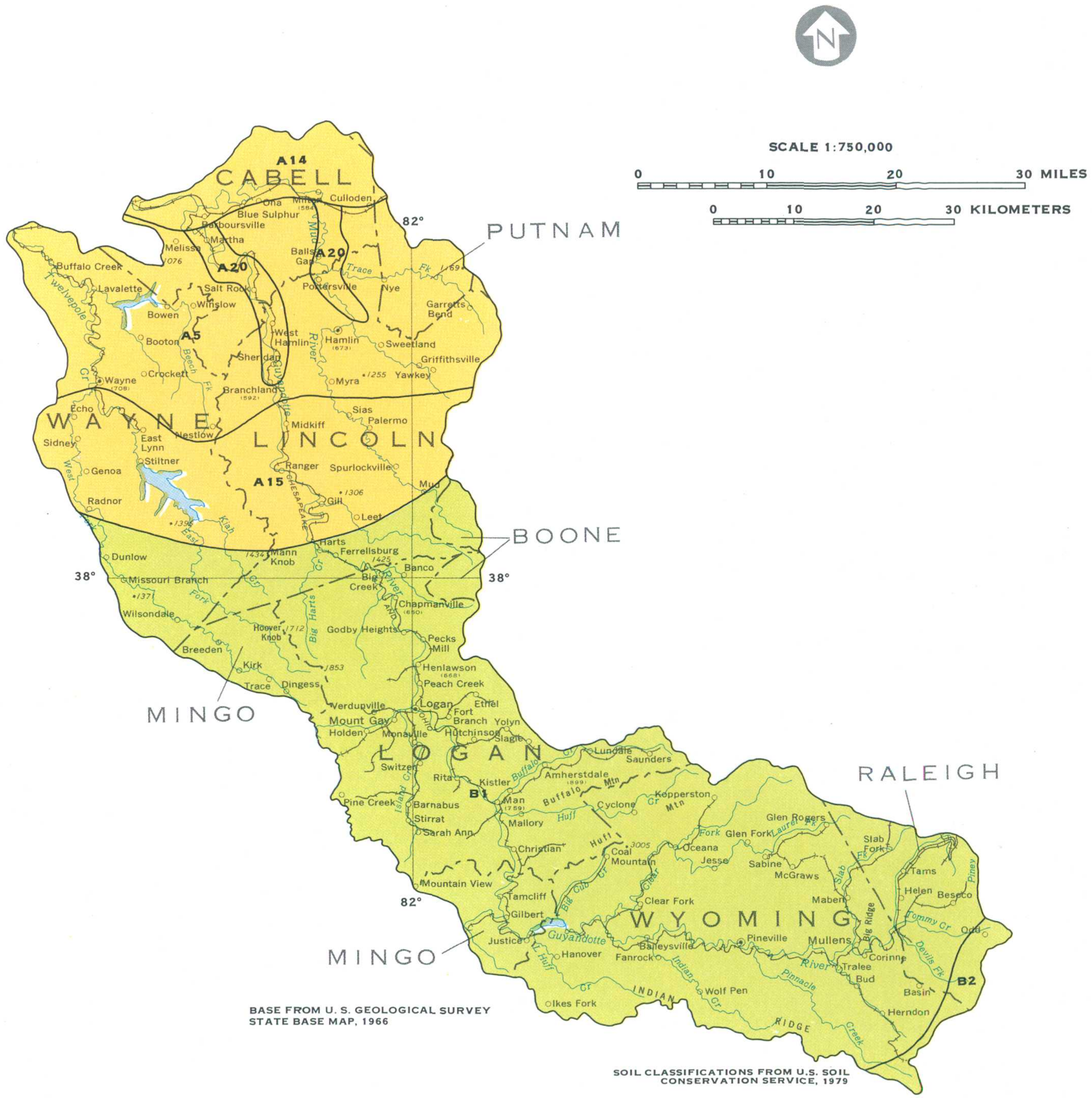
Soils in Area 12 are generally shallow and poorly drained. Soils are grouped in two Land Resource Areas on the basis of soil patterns, slope, erosion characteristics, climate, vegetation, water resources, and land use.

Soils in the area have been grouped into associations 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 characterized by a unique combination of soils, slope, erosion characteristics, climate, vegetation, water resources, and land use.

Soils in Area 12 are grouped into two Land Resource Areas: Cumberland Plateau and Mountains Association (LRA 125), and Central Allegheny Plateau Association (LRA 126). The soil series found within each Land Resource Area are shown in figure 2.4-1. A general summary of soil characteristics is also given.

Soils of the Cumberland Plateau and Mountains Land Resource Area (LRA 125) cover most of Area 12. These soils are found from the southeast boundary of the area to the southern boundaries of Wayne and Lincoln Counties. The upland soils are shallow to moderately deep, and have developed on weathered sandstone, siltstone, shale and coal of Pennsylvanian age. Drainage is generally poor because of the thin soil horizon. The major soils are those of the Clymer, Dekalb, Jefferson, and Gilpin series. Alluvial soils occur on flood plains and valley floors. The soils are generally acidic and of low fertility. Because of the rugged topography and poor drainage, less than 2 percent of the land in Wyoming County is used for agriculture. About 90 percent of LRA 125 is forested.

Soils of the Central Allegheny Plateau Land Resource Area (LRA 126) cover most of the Twelvepole Creek and lower Guyandotte River basins. The major soils are of the Gilpin and Clymer soil series. The bottomland or gently-sloped areas are normally dominated by Chavies and Pope soil series. Soils on steep slopes have a high erosion potential, and are subject to earthslides after heavy rains or when plant cover has been removed by construction, mining, silviculture, or agricultural operations. The soils having a high erosion potential include the Upshur and Vandalia series (Lessing and others, 1976).



EXPLANATION

LAND RESOURCE AREA	SOIL SERIES*	SLOPE RANGE (PERCENT)	DRAINAGE
LRA - 125	B1 Clymer (35) - Dekalb (25) - Jefferson (20) Association	3-15 15-25 25+	Fair Poor Poor
	B2 Clymer (30) - Gilpin (25) Association	3-15 15-25 25+	Fair Poor Poor
LRA - 126	A5 Gilpin (40) - Upshur (35) - Vandalia (10) Association	3-15 15-25 25+	Poor Poor Poor
	A14 Allegheny (30) - Monongahela (25) - Vincent (10) Association	3-8 8-15 15-25	Good Fair Poor
	A15 Clymer (35) - Gilpin (30) - Upshur (10) Association	3-15 15-25 25+	Fair Poor Poor
	A20 Chavies (25) - Pope (25) - Allegheny (20) Association	0-3 3-8 8-15 15-25	Fair Fair Fair Poor

*Numbers in parentheses refer to the percent of soil series in the association. Totals are less than 100 percent because of the exclusion of soil series occuring in minor proportions.

Figure 2.4-1 Classification of soils.

Area 12 has a Humid Continental Climate

Area 12 has a continental climate with marked temperature differences between winter and summer. Precipitation averages about 42 inches annually. Rainfall is greatest in mountainous areas and least near the Ohio River and the southeastern boundary. Prevailing wind direction and topography are important factors affecting the distribution of precipitation.

Area 12 has a humid continental climate with abundant rainfall. The area is approximately 300 miles from the ocean, thus is beyond the immediate climatic effect of the Atlantic Ocean. Precipitation is greatest in mountainous areas and least along the Ohio River and near the southeastern boundary of Area 12 (fig. 2.5-1).

The precipitation distribution is influenced mainly by the prevailing westerly wind and by topography. Area 12 lies in the path of storms that move in a general west to east direction across the United States. During the spring and summer, the area is also affected by storms that occur with wind currents moving northeastward from the Gulf of Mexico. Wind currents approaching the mountains are subject to orographic lifting which initiates or intensifies precipitation. Average annual precipitation increases from the Ohio River eastward to the Appalachian Mountains and decreases on the lee side near the southeastern boundary of the area. Annual precipitation at Huntington averages 39 inches in comparison to 44 inches at Logan (National Oceanic and Atmospheric Administration, 1977). Rainfall during 1979 and 1980 was somewhat greater than the long-term average (42 inches) for Area 12 (fig. 2.5-2). Annual precipitation ranged from about 45 inches near the northeastern boundary to about 60 inches near Kopperston (National Oceanic and Atmospheric Administration, 1979, 1980).

Precipitation is generally greatest during the spring and summer and least during the fall and winter. October usually is the driest month of the year. Annual precipitation distribution for selected cities is shown in figure 2.5-3. Thunderstorms occur on the average of 40 to 50 days a year and are more frequent during June and July. These storms sometimes produce intense local rainfall and cause flooding in the narrow valley bottoms. Intense storms rarely cover the entire area, but they are frequent over small drainage areas. The 10-year, 24-hour rainfall for most of the area is about four inches.

The average annual temperature for Area 12 is approximately 52°F. The highest temperatures occur near the Ohio River and lowest in mountainous regions. Average January temperature ranges from about 32°F at Hamlin to 34°F at Logan (fig. 2.5-3). In the summer, maximum temperatures average over 85°F at Hamlin and Logan, and 5° to 10°F cooler in the mountains.

Figure 2.5-1 Mean annual precipitation.

SCALE 1:1,000,000

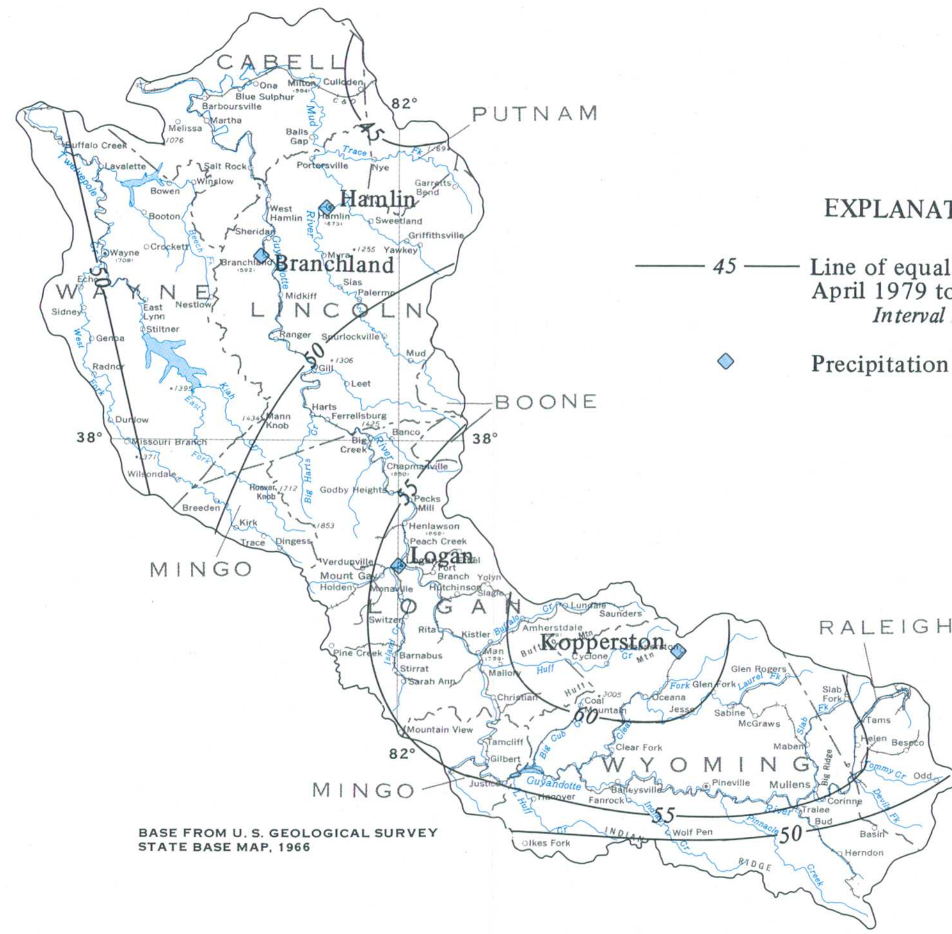
0 10 20 30 MILES

0 10 20 30 KILOMETERS

EXPLANATION

—— 42 —— Line of equal mean annual precipitation, 1931-60
Interval 2 inches

◇ Precipitation station

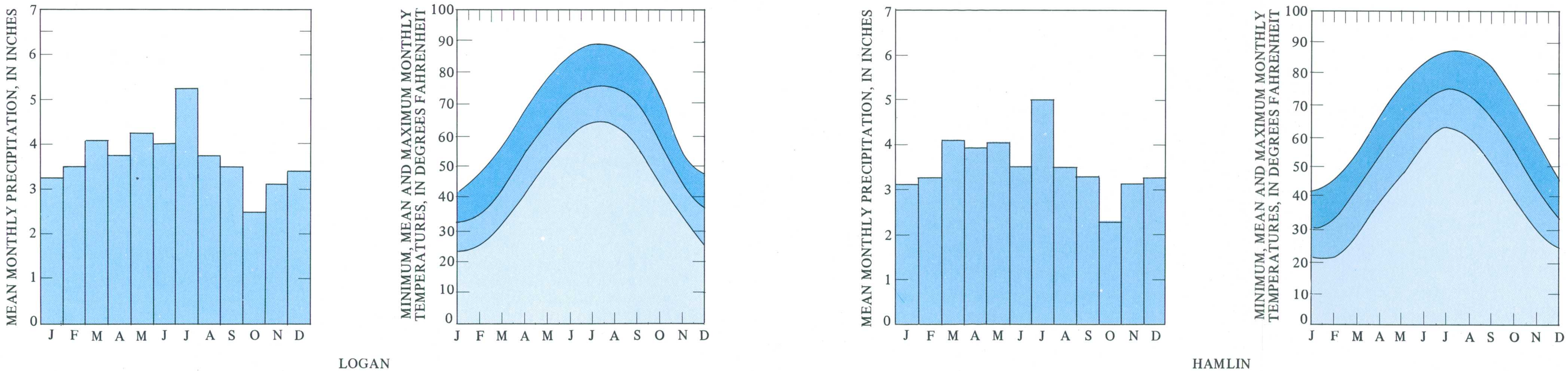


EXPLANATION

—— 45 —— Line of equal precipitation April 1979 to March 1980
Interval 5 inches

◇ Precipitation station

Figure 2.5-2 Precipitation distribution, April 1979 to March 1980.



CLIMATOLOGICAL DATA FROM NOAA, 1977.

Figure 2.5-3 Mean monthly precipitation and temperature for Logan and Hamlin, West Virginia, 1953-73.

Land Use in Area is Largely Forest

About 98 percent of the land in Area 12 is classified in forest, agriculture, or urban use categories. The remaining land is classified as water, wetland, or barren land.

Land use is strongly influenced by the mountainous topography and by the distribution of mineral resources. Much of Wayne, Lincoln, Boone, Mingo, Logan, and Wyoming Counties has average land slopes in excess of 30 percent, which are generally considered unsuited for urban development or for agricultural purposes (U.S. Environmental Protection Agency, 1980). This land is often forested, and is commonly used for outdoor recreation, wildlife management, watershed protection, and silviculture.

The majority of the land in Area 12, 1,900 mi^2 (square miles) or 90 percent, is classified as forest (fig. 2.6-1). Lincoln, Logan, Wayne, Wyoming, Boone, and Mingo Counties have a higher percentage of forest cover than Cabell, Putnam, and Raleigh Counties (table 2.6-1). Lincoln County has the highest percentage of forest cover (97.2 percent). Over 92 percent of the trees in the area are hardwoods. The dominant trees include sugar maple, yellow buckeye, birch, tuliptree, white oak, northern red oak, and basswood (West Virginia Department of Natural Resources, Division of Reclamation, 1980).

About 95 mi^2 or 4.5 percent of the land in Area 12 is classified as agricultural. Most of the agricultural land is near the Ohio River in Putnam, Cabell, and Wayne Counties. Raleigh County, in the headwaters of the Guyandotte River basin, also has some agricultural land. The more mountainous counties, such as Logan, Boone, Mingo, and Wyoming, have very little agriculture.

About 79 mi^2 or 3.7 percent of the land in Area 12 is classified as urban. Much of the urban land is in and around the City of Huntington in northern Cabell County. Other urban areas are found along major highways and at highway intersections where small communities often develop. Aside from Huntington, many urban areas are on narrow valley floors which flood periodically.

About 47 mi^2 or 2.2 percent of the area is classified as water, wetland, and barren land. Of this area, about 35 mi^2 or 1.7 percent is classified as barren land, and this largely represents abandoned surface mined areas. About 12.4 mi^2 are currently being surface mined, mainly in Logan, Mingo, and Wyoming Counties. No surface mining in Area 12 presently occurs in Lincoln, Cabell, Putnam, Wayne, Boone, Mason, or Kanawha Counties.

Land use in Area 12 has been mapped by the U.S. Geological Survey at a scale of 1:250,000 from color infrared aerial photography taken in 1973 (U.S. Geological Survey, 1978). Six types of maps are available: topographic base, county and state boundaries, minor civil divisions, river basins, federal land ownership, and land-use and land-cover maps. The land-use and land-cover maps delineate sub-areas in 37 different land-use and land-cover categories. Areal units smaller than 10 acres are not delineated in this series of maps. These maps are available for viewing at the West Virginia Geological and Economic Survey in Morgantown, West Virginia, and may 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 U.S. Geological Survey maps (West Virginia Geological and Economic Survey, 1980), which show acreages and percentage of land use for 26 categories.

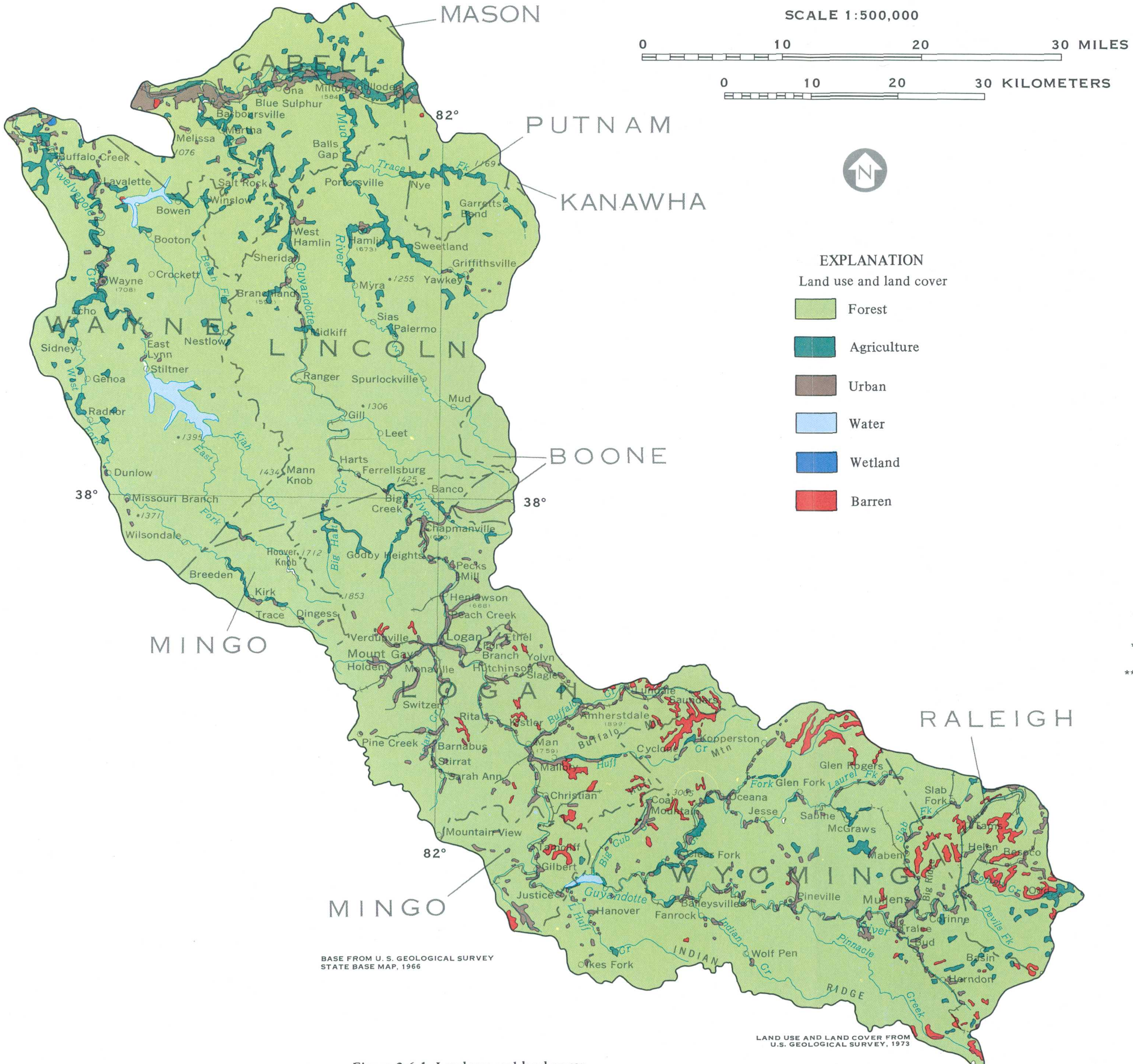


Figure 2.6-1 Land use and land cover.

Table 2.6-1 Summary of major land-use and land-cover classifications, in percent of land areas.

COUNTY	FOREST COVER	AGRICULTURAL LAND	URBANIZED LAND	BARREN LAND	WATER
Boone	92.7	0.5	2.0	4.8	0
Cabell	80.3	9.1	8.4	0.2	2.0
Kanawha	89.2	2.0	6.6	1.5	0.7
Lincoln	97.2	2.3	0.5	0	0
Logan	94.4	.6	3.1	1.9	0.*
Mason**	-	-	-	-	-
Mingo	94.0	.4	4.0	1.5	.1
Putnam	79.3	15.5	3.8	.1	1.3
Raleigh	83.4	7.7	4.3	4.0	.6
Wayne	92.1	5.2	2.1	.2	.4
Wyoming	93.0	1.7	2.5	2.7	.1*

* Does not reflect the contribution by R.D. Bailey Reservoir

** Data not available

Modified from West Virginia Geological and Economic Survey (1980)

Principal Water Uses are for Public Water Supply and Mining

Reported water use in Area 12 during 1979 was 45 million gallons per day. Water used for public supply accounted for 26 million gallons per day or 58 percent of the total, while most of the remainder, 19 million gallons per day or 42 percent, was water pumped from underground mines or water used in coal preparation plants.

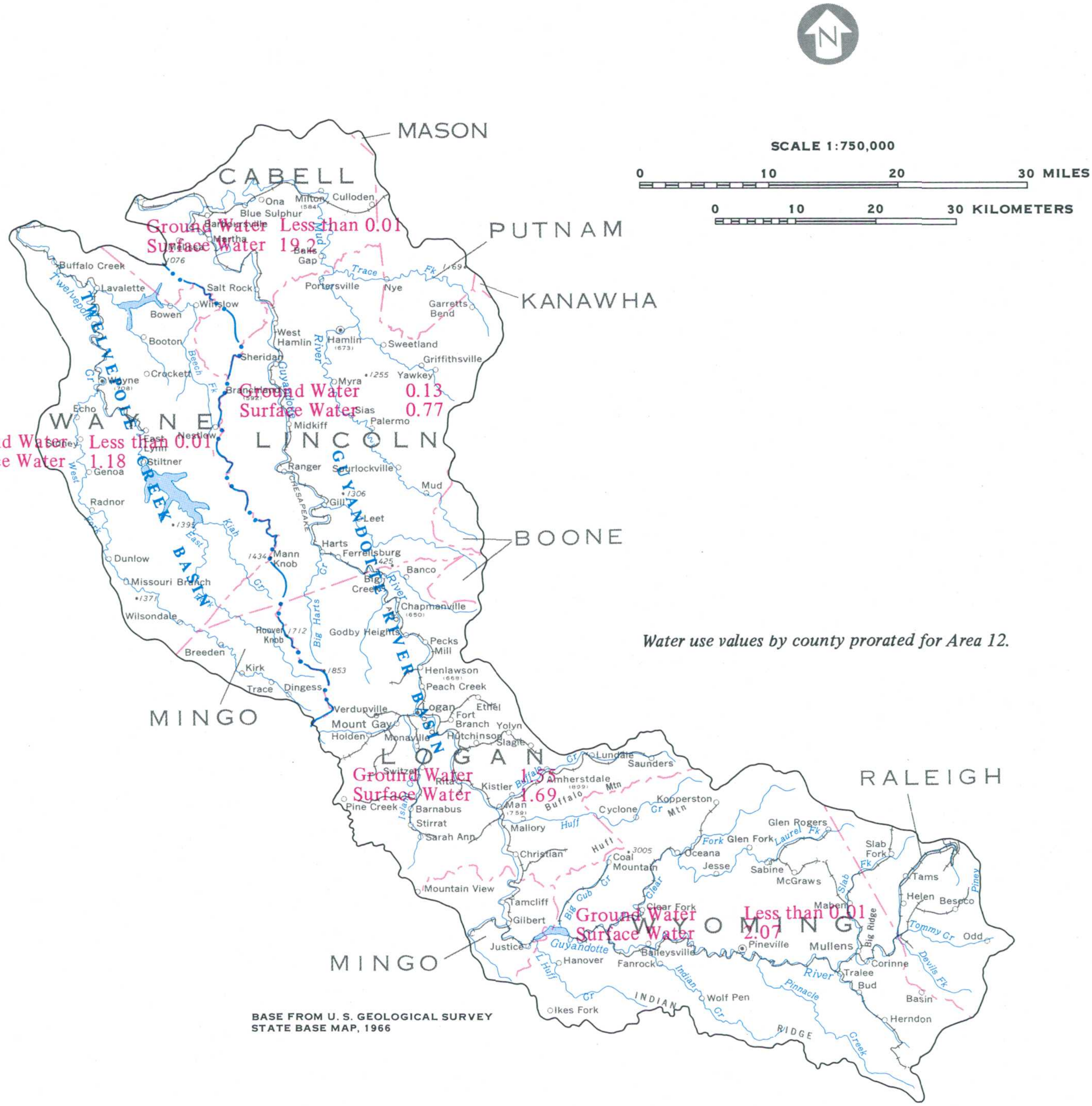
During 1979 a reported total of about 45 Mgal/d (million gallons per day) of water was withdrawn for public supply and mining in the major counties in Area 12. Water pumped for public supply, or sold by water companies to commercial, domestic, and industrial users, accounted for 26 Mgal/d or 58 percent of the total. Most of the remainder, 19 Mgal/d or 42 percent, was water pumped from underground mines or water used in coal preparation plants. Water used for agriculture was about 0.07 Mgal/d.

Water used for mining was obtained entirely from ground-water sources, whereas water used for public supply was obtained mainly from surface-water sources (94 percent). Ground-water supplies are generally inadequate for public supply.

Water used for commercial, domestic, and industrial purposes in the major counties in Area 12 is shown in figure 2.7-1. Data are inadequate for determining water use in parts of counties lying partly within Area 12. The water-use figures shown (fig. 2.7-1) are based on fairly complete records of water sold by public water suppliers and records of processed waste water from waste-treatment plants. Reported data on water use for mining are incomplete and represent records from 147 of 297 known NPDES (National Pollution Discharge Elimination System) permits for mining companies. Water use for agriculture was assumed to be the same as during 1978.

The data in this report were taken from a report entitled, "Water Use in West Virginia," (Lessing, Behling, and Hilgar, 1981). Additional information may be obtained from the West Virginia Geological and Economic Survey.

For 1980 the data will be collected and compiled by state agencies. These data will be available through the National Water Data Exchange (NAWDEX). For details about NAWDEX see section 7.2 of this report.



2.7-1 Commercial, domestic, and industrial water use in major counties, in million gallons per day, 1979.

3.0 GEOLOGY

Sedimentary Rocks Underlie the Area

Rocks underlying the area are primarily alternating beds of sandstone, shale, mudstone, and coal with minor limestone. Alluvium exists in Teays Valley and in major river valleys.

Area 12 was the site of numerous rivers, deltas, lagoons, lakes, and swamps during the Pennsylvanian Period, about 300 million years ago. Sand, silt, clay, and plant remains were deposited, and subsequently became altered to rock. Today the rocks that underlie the basin consist primarily of interbedded sandstone, shale, mudstone, and coal.

The rocks are divided into six units as shown on figure 3.0-1, and are described here from oldest to youngest. The stratigraphic nomenclature in this report follows the usage of the West Virginia Geological and Economic Survey (Cardwell and others, 1968) and differs somewhat from the usage of the U.S. Geological Survey. The rocks are so variable that a specific account of the geology in one area could differ dramatically from that of an adjacent area. The following descriptions are based on the County Reports published by the West Virginia Geological and Economic Survey and the 1968 Geologic Map of West Virginia (see Hennen, 1915; Hennen and Gawthorp, 1915; Krebs, 1911 and 1913; and Krebs and Teets, 1914, 1915, and 1916).

The Pocahontas Formation crops out in Raleigh and Wyoming Counties but is as deep as 2,300 feet elsewhere in the basin. The formation is about 500 feet thick in the basin, but only about the upper 200 feet is exposed.

The New River Formation crops out in Raleigh and Wyoming Counties. It is about 1,000 feet thick in the southern part of the basin but thins rapidly to the north.

The Kanawha Formation crops out in Raleigh, Wyoming, Mingo, Logan, Boone, Wayne, and Lincoln Counties. The formation is more than 2,100 feet thick in the southern part of the basin, thinning substantially to the north. The three formations described above are members of the Pottsville Group and their total thickness is probably less than 600 feet in the northern part of the basin. These rocks are not recognizable in the subsurface in Cabell County. Arkle (1974) discusses the stratigraphy of these rocks.

The Allegheny Formation is found on the higher hilltops of Logan, Boone, and northern Wyoming Counties and in Lincoln and Wayne Counties. It is about 150 feet thick. Few wells are known to derive water from this formation.

The Conemaugh Group crops out in Lincoln, Cabell, Wayne, Putnam, Kanawha, and Mason Counties and on a few higher mountaintops in Boone County. The unit is about 500 feet thick. The red shale in this unit is susceptible to landsliding on slopes steeper than 15 percent (Lessing and others, 1976).

The Monongahela Group crops out in Cabell, Wayne, and Mason counties and some ridgetops in southern Putnam and northern Lincoln Counties. The unit is about 250 feet thick.

The Dunkard Group crops out on a few hilltops in Cabell County in the northernmost part of the basin. It may be as thick as 1,200 feet further north, but only a few tens of feet of the lower part of the unit occur in Area 12 where it is generally above the zone of saturation. Cardwell and others (1968) gives a more detailed description of these geologic units.

Limestone is not a major rock type tapped by water wells within Area 12. However, it is present locally in the older shale and sandstone units and becomes more prevalent in the younger units.

At the time of their deposition, the layers of sandstone, shale, and coal were nearly horizontal. But later, the entire Appalachian area was subject to tremendous compression accompanying the uplifting of the Appalachian Mountains to the east. Although the force was not enough to severely fold and fracture the rocks, as in eastern West Virginia and adjacent Virginia, it was enough to cause general lifting, gentle folding, and some fracturing of the strata.

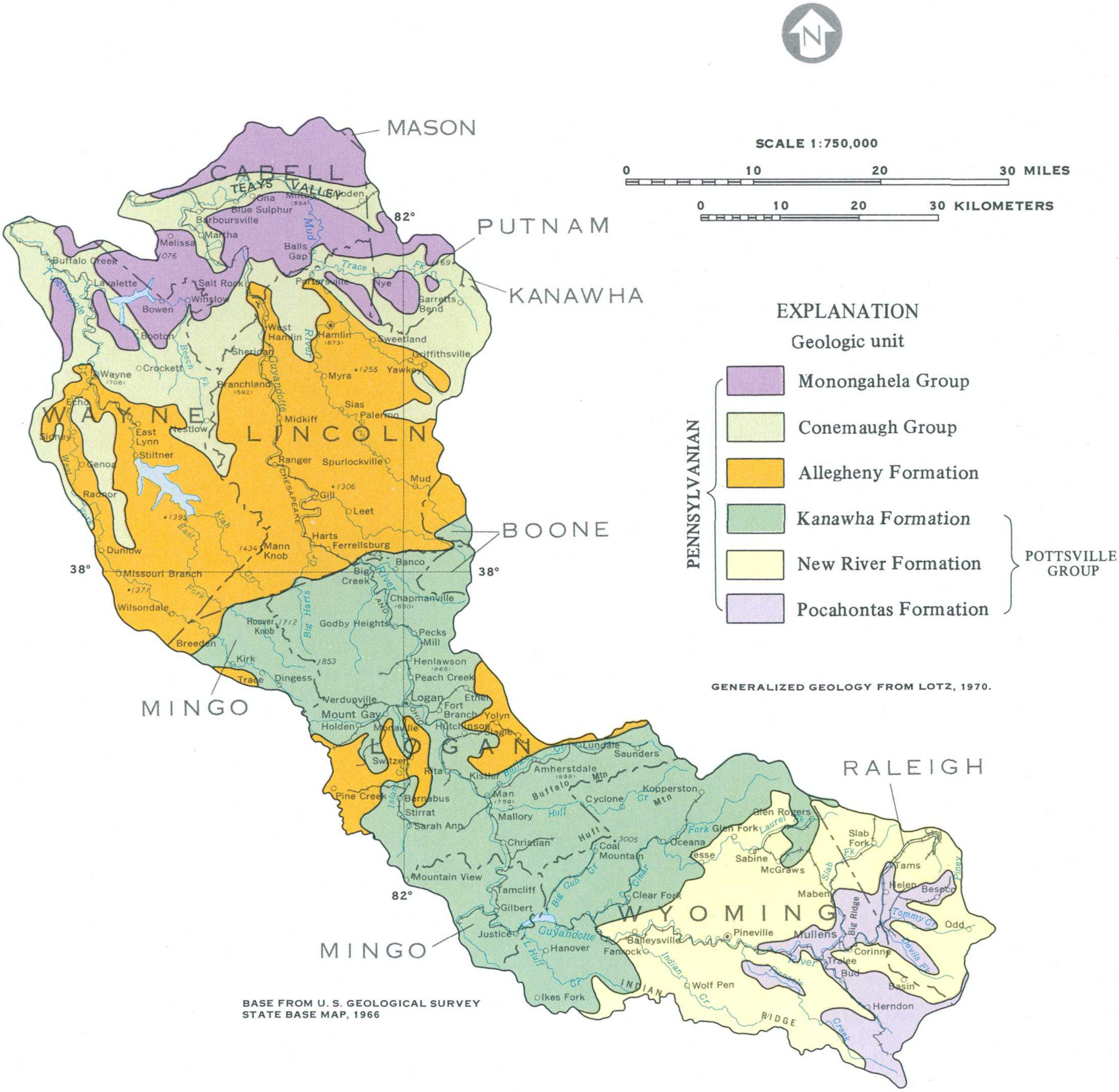


Figure 3.0-1 Generalized geology.

Rocks underlying the basin generally dip gently to the northwest in a broad monoclinal structure, but the dip is so low that it is virtually imperceptible to the eye. Superposed on that gentle dip are several anticlines and synclines.

Teays Valley (fig. 3.0-1) and the valleys of the Guyandotte River, Mud River, and many tributaries contain alluvium -- unconsolidated clay, silt, sand, and gravel. Most of the alluvium is typically thin (probably less than 10 feet) but is thickest along the larger streams. Significant alluvial deposits are found in Teays Valley and along the Guyandotte River beginning about 5 miles upstream from Teays Valley. The history of the alluvial deposits in Teays Valley is treated in a report by Rhodehamel and Carlston (1963).

4.0 COAL STATISTICS
4.1 Coal Production

Fifteen Percent of the West Virginia Coal in 1979 was Produced from Area 12

In 1979, Area 12 mines produced nearly 17 million tons of bituminous coal, 15 percent of West Virginia's total coal production. About 90 percent of the production was produced by underground mining methods. In 1980, 36 surface and 363 underground coal mines were operated in Area 12.

West Virginia produced 84.7 million tons of bituminous coal in 1978 and was the Nation's second largest producer. Coal production in 1979 was 112 million tons but was less than the peak production of 153 million tons mined in 1967. About 11 and 17 million tons were mined during 1978 and 1979 respectively in Area 12. This was 14 and 15 percent of West Virginia total coal production in 1978 and 1979, respectively. Most coal (90 percent) was mined underground in 1979. There were 363 underground and 36 surface mines active as of April 1, 1980 in Area 12 (West Virginia Department of Mines, 1980).

Coal production in Area 12 is primarily from the mountainous region in the upper Guyandotte River basin. The greatest total production in 1979 came from Logan and Wyoming Counties, which together produced 89 percent of Area 12 coal (table 4.1-1).

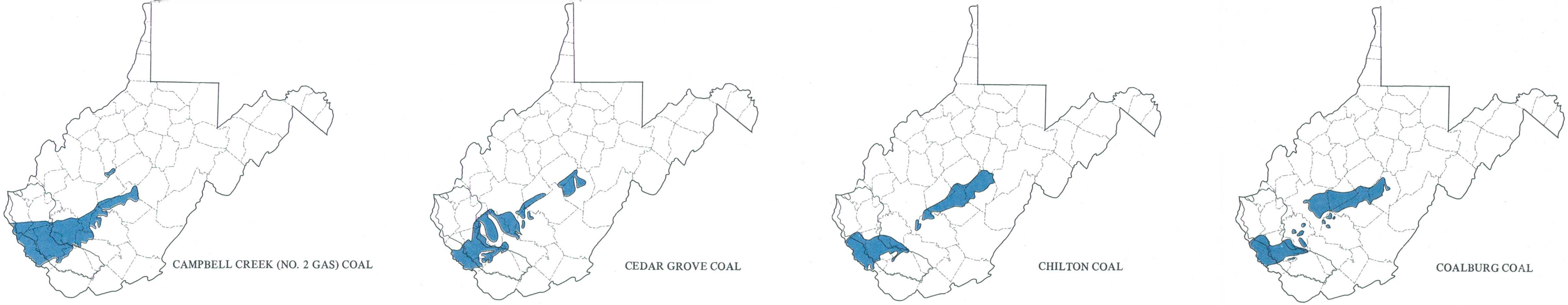
Coal seams underlie about 85 percent of Area 12. The entire southern part of the area is underlain by various coal seams. Coal in the northern part of the area, including much of Cabell, Wayne, and Putnam Counties, is nearly absent because of erosion of the coal-bearing geologic strata over geologic time. There are 62 coal seams in West Virginia that are considered mineable (12 inches or more thick) although not all are found in Area 12 (West Virginia Department of Mines, 1980). In Area 12, half of the production comes from 10 seams: Pocahontas No. 3, Eagle, Coalburg, Cedar Grove, Campbell Creek, Winifrede, Chilton, Gilbert, Pocahontas No. 6, and Sewell. Twenty percent of the production in Area 12 in 1979 was from the Pocahontas No. 3 seam (West Virginia Department of Mines, 1980). The general extent of these seams in West Virginia is shown in figure 4.1-1. These coals are mostly contained in the Pottsville Group.

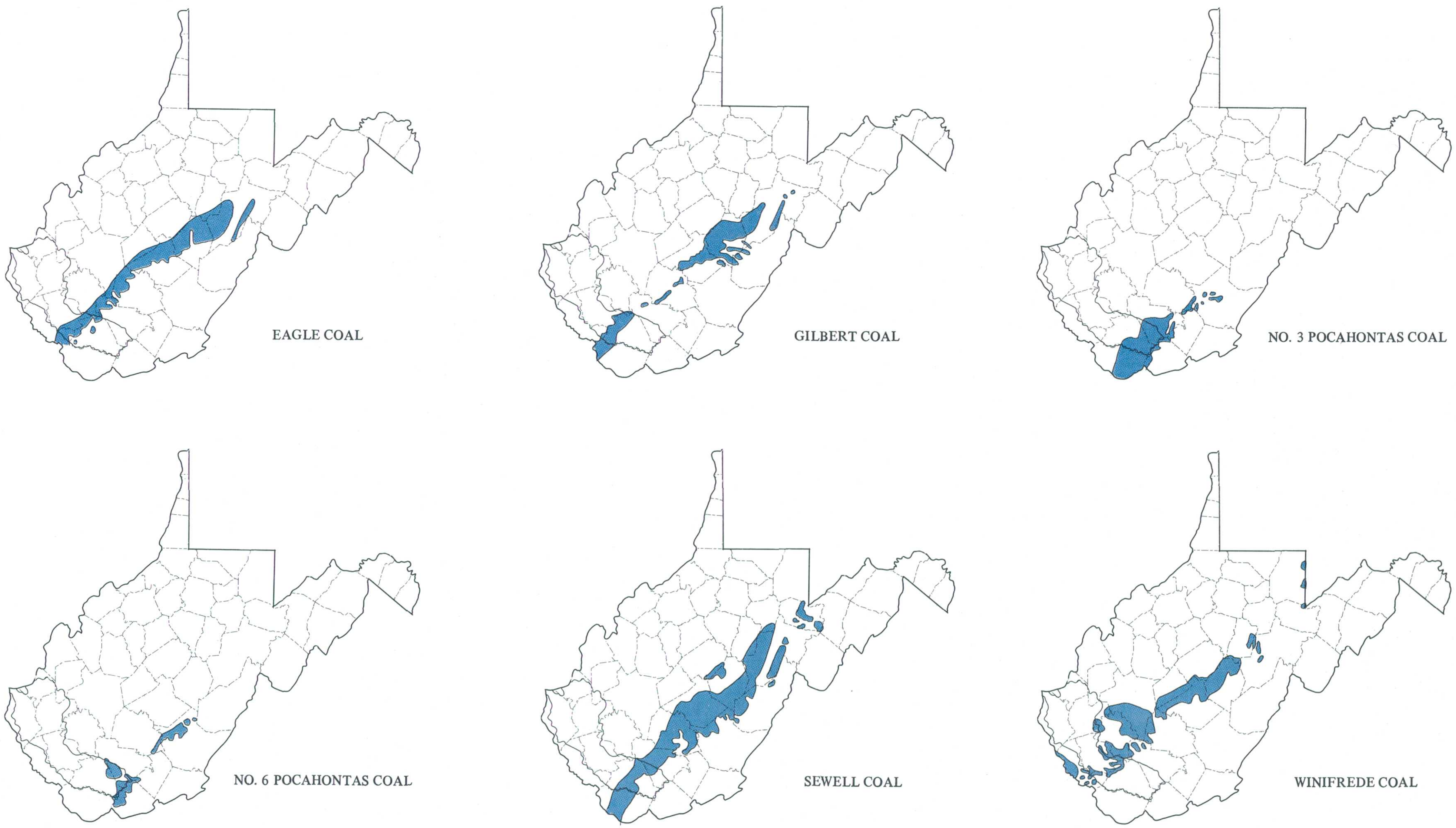
Coals differ widely in carbon, ash, sulfur, and heat content. The coal-bearing rocks in Area 12 are divided into northern and southern fields, separated by a "hinge line" of coal-poor rocks (fig. 4.1-2). Most coal produced in the northern coal field contains more than 1.5 percent sulfur, whereas most 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 for the steel industry.

Table 4.1-1 Coal production*, in tons, for surface and underground mines during 1978 and 1979.

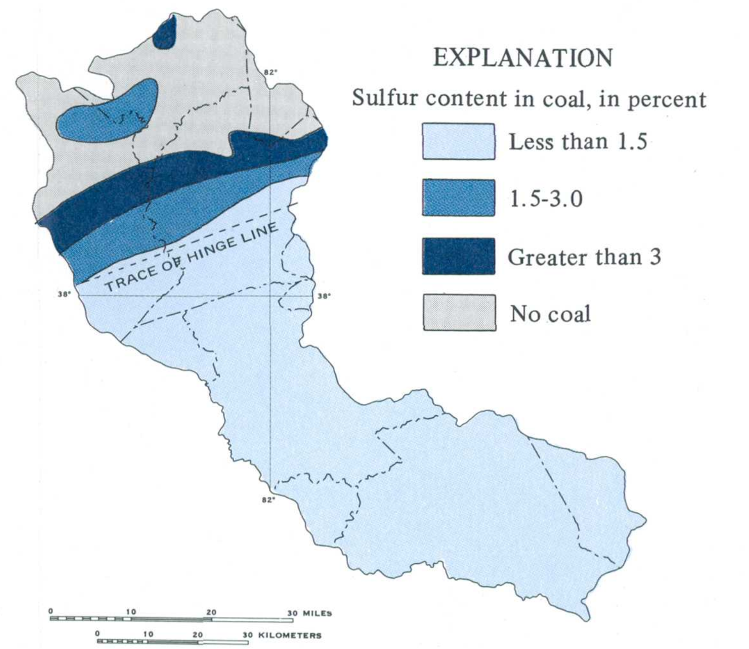
COUNTY	1978		1979	
	SURFACE	UNDERGROUND	SURFACE	UNDERGROUND
Boone	**	19,906	**	26,672
Cabell	**	0	**	0
Lincoln	**	0	**	0
Logan	1,088,695	3,964,755	1,209,880	4,832,794
Mingo	53,554	547,036	35,932	1,065,936
Raleigh	**	617,491	**	775,590
Wyoming	225,473	4,977,264	484,500	8,507,045
Wayne	**	0	**	26,708
Kanawha	0	0	0	0
Mason	0	0	0	0
Putnam	0	0	0	0
Yearly total	1,367,722	10,126,452	1,730,312	15,234,745

*Production figures reflect mines within Area 12 only
**Production figures are assumed to be zero
Source: West Virginia Department of Mines, 1980





GENERALIZED EXTENT OF MAJOR COAL SEAMS FROM LOTZ, 1970



GENERALIZED SULFUR CONTENT OF BITUMINOUS
MODIFIED FROM BABU AND OTHERS, 1973.

Figure 4.1-2 Generalized sulfur content of bituminous coal.

Ten Percent of 1979 Coal Production is from Surface Mines

In 1979, 36 surface mines in Area 12 produced 1.7 million tons of coal, 10 percent of the area's coal production. Most of the surface mines are located in Logan and Wyoming Counties.

The number of surface coal-mining operations in West Virginia has increased from 386 in 1975 to 882 as of April 1980 (Welker and others, 1980). One reason for this growth is the high productivity of surface mines. During 1979, surface mines produced 17.4 tons of coal per man day, whereas underground mines produced only 8.8 tons per man day (West Virginia Department of Mines, 1980). However, surface mining is feasible only where the coal is close to the surface. The most productive coal seams, such as the Pocahontas, are too deep to be surface mined.

As of April 1980, 36 surface mines had permits to mine 12.4 mi^2 (square miles) in Area 12 (fig. 4.2-1). In 1979, surface mines produced 1.7 million tons, 10 percent of the total coal production for the area. Over half of the active surface mines (19) are in Logan County. Other counties with substantial mining operations include Wyoming (9 mines) and Mingo (8 mines) (table 4.2-1). Most surface mining in Area 12 occurs in the upper Guyandotte River basin between the towns of Logan and Justice. There are no surface mines that operate in Wayne, Lincoln, Boone, Cabell, Mason, Putnam, or Kanawha Counties within Area 12.

Surface mines have increased in size as well as in number. In 1977, mining permits were for an average area of 76.6 acres, while in 1979 the new permits were for an average of 99.6 acres. For the first quarter of 1980, permit applications were for an average of 131.5 acres (Welker and others, 1980). About 129 mi^2 (6.1 percent) of Area 12 has been surface mined (West Virginia Department of Natural Resources, 1980a). Practically all the surface mines are in the upper Guyandotte River basin where the generally steep slopes have a high potential for soil erosion.

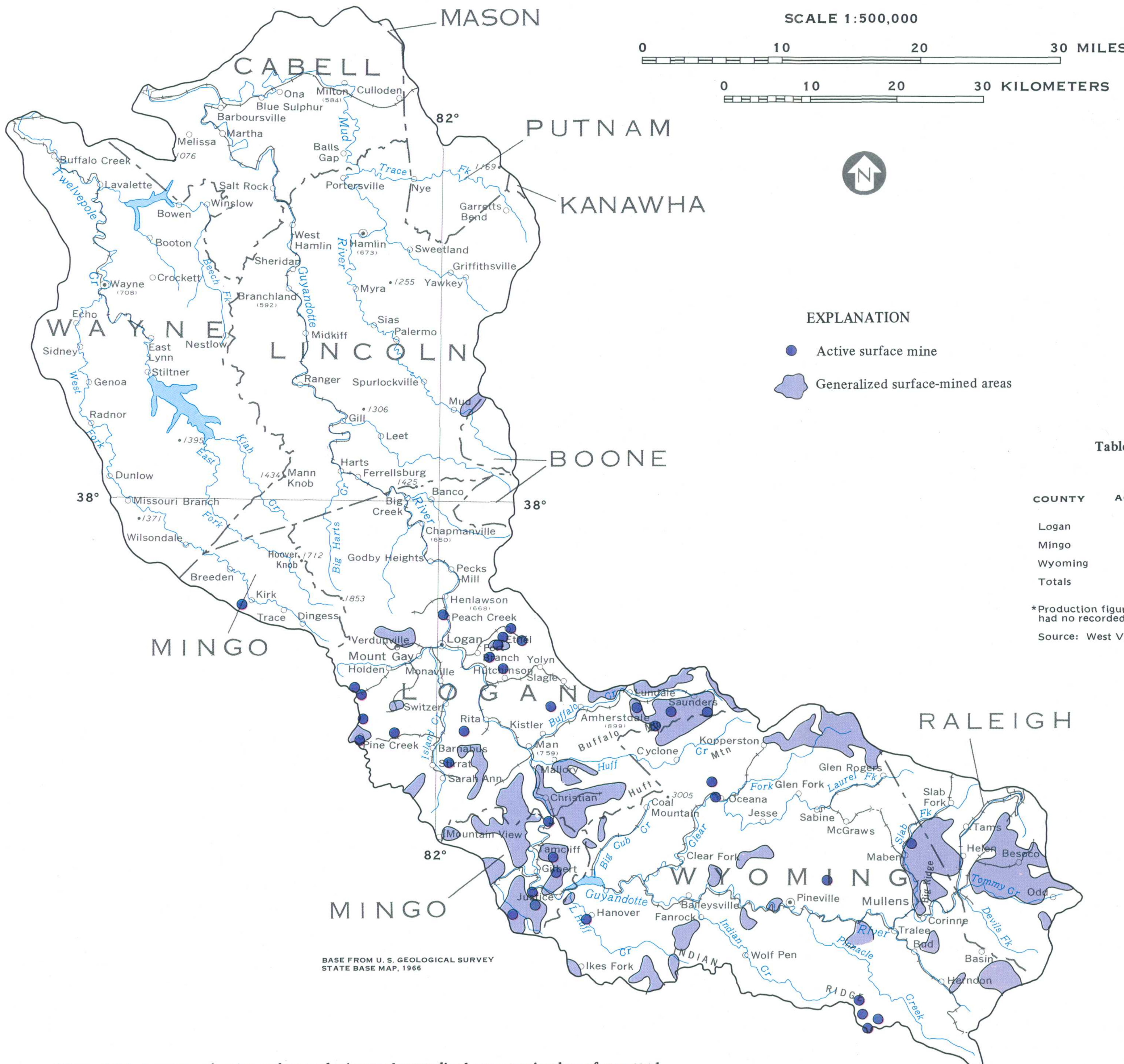


Figure 4.2-1 Location of active surface coal mines and generalized areas previously surface mined.

Table 4.2-1 Production from surface coal mines during 1978 and 1979 and distribution of active mines.

COUNTY	NUMBER OF ACTIVE SURFACE MINES (APRIL 1980)	PERMIT AREA, IN ACRES	PRODUCTION, IN TONS* 1978	1979
Logan	19	4,972	1,088,695	1,209,880
Mingo	8	1,283	53,554	35,932
Wyoming	9	1,688	225,473	484,500
Totals	36	7,943	1,367,722	1,730,312

*Production figures are for mines within Area 12. Counties not listed had no recorded surface production in 1978 or 1979 in Area 12.

Source: West Virginia Department of Mines, 1980

Ninety Percent of 1979 Coal Production is from Underground Mines

In 1979, 363 underground coal mines produced 15.2 million tons of coal, 90 percent of the area's coal production. Most of the mines are located in the upper Guyandotte basin.

In 1979, 90 percent of the coal production in Area 12 (15,200,000 tons) was produced from 363 underground mines (West Virginia Department of Mines, 1980) (fig. 4.3-1).

Underground mining occurs chiefly in the upper Guyandotte River basin. More than 84 percent of the mines are in Logan or Wyoming Counties. Other counties with significant underground mining include Mingo (33 mines) and Raleigh (16 mines) (table 4.3-1). Very few mines are located in the lower Guyandotte River basin or in Twelvepole Creek basin because the coal has been removed by erosion over geologic time.

About 328 mi^2 (square miles) (15 percent) of the area has been deep mined in one or more coal seams (West Virginia Department of Natural Resources, 1980a). Most of this mining occurred in the Guyandotte River basin upstream from the town of Logan (fig. 4.3-1). Large quantities of spoil material are often discarded near mine portals. Some of the larger piles shown in figure 4.3-1 are indicators of past mining activity. Drainage from spoil areas may contain high concentrations of iron, manganese, sulfate, magnesium, aluminum and calcium (Krothe and others, 1980), and degrade the water quality of receiving streams. About 288 miles of streams in the Guyandotte River basin are continuously affected by mine drainage, organic material, or by a combination of both (West Virginia Department of Natural Resources, 1976).

A danger associated with coal-mine spoil piles is the possibility of stream blockage and temporary impoundment of large volumes of water behind mine refuse that has accumulated in hollows. Sudden collapse of a mine-refuse dam after a period of heavy rainfall in Logan County caused the disasterous Buffalo Creek flood in 1972 (Runner, 1974).

Most of the coal mined by underground methods comes from coal seams in the Pottsville Group. The Pocahontas No. 3 seam yielded 3.4 million tons of coal in 1979, 20 percent of the area production. Other seams yielding 0.5 million tons or more in 1979 include: Eagle, Coalburg, Cedar Grove, and Campbell Creek (West Virginia Department of Mines, 1980).

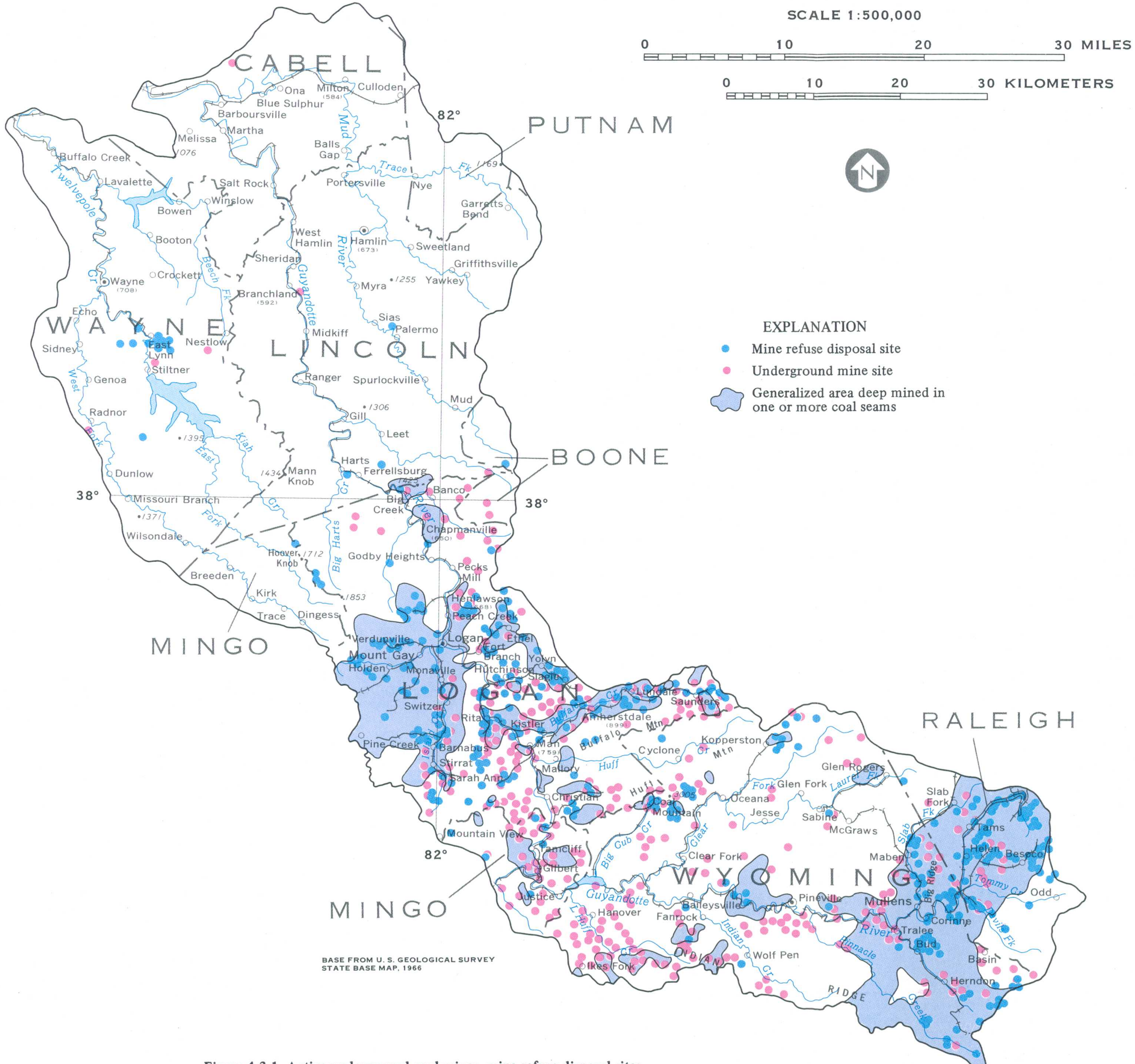


Figure 4.3-1 Active underground coal mines, mine refuse disposal sites and generalized areas deep mined in one or more coal seams.

Table 4.3-1 Production from underground coal mines in Area 12 for 1979 and distribution of mines.

COUNTY*	NUMBER OF MINES	1979 COAL PRODUCTION, IN TONS
Boone	2	26,672
Cabell	1	0
Lincoln	2	0
Logan	150	4,832,794
Mingo	33	1,065,936
Raleigh	16	775,590
Wayne	3	26,708
Wyoming	156	8,507,045
TOTALS	363	15,234,745

*Counties not listed had no recorded production or mines in 1979.

Source: West Virginia Department of Mines, 1980

Ground Water is Derived from Precipitation

In Area 12, a small part of the average annual precipitation reaches the ground-water reservoir. This water moves slowly through fractures in the ground-water reservoir to nearby stream valleys, where it is released through seeps, springs, or directly into streambeds.

The source of ground water in Area 12 is precipitation chiefly in the form of rain. On steep hillsides the amount of water that runs off is large compared to the amount that infiltrates the ground. When water infiltrates, a part is retained at shallow depth as soil moisture (later to be available for withdrawal by transpiration or evaporation), and a part moves downward to the zone of saturation. Locally, perched water bodies exist above the zone of saturation. They may be found above impermeable rock layers which impede the downward percolation of water (fig. 5.1-1). Where the zone of saturation is overlain by permeable rocks that allow water from precipitation to enter directly by downward percolation, unconfined or water-table conditions exist. Artesian conditions exist where water-bearing zones lie between or beneath relatively impermeable rock.

Two types of rock openings are of principal importance for the storage and circulation of ground water -- intergranular openings and fractures. Intergranular openings or pores are generally of primary origin, having been formed when the rocks were deposited as sediment. In Area 12, compaction and cementation with mineral matter have nearly eliminated connected pores in consolidated rocks. Although the unconsolidated alluvium along major streams has been only slightly affected by compaction and cementation, it has such low permeability that it acts as a confining layer in many parts of the area (Wyrick and Borchers, 1981).

Rock fractures such as faults and joints are cracks caused by rock deformation after deposition and consolidation. Faults are fractures along which rocks have moved, and, although many zones of fractured rock are evident in road cuts, few faults are found in Area 12. However, minor movement has taken place on nearly all valley walls, where blocks of sandstone have tilted, slumped, or slid downward a short distance in response to gravity. Joints are breaks in the rock cutting across the bedding and along which virtually no movement has occurred. They are sets of approximately parallel linear cracks spaced from several inches to many feet apart. In Area 12, joints and fractures are the major openings for accumulation and movement of water.

Fractures are more prevalent near the axes of folds. Because anticlines were under tension during folding, the fractures are open so that water can flow through them. Synclines at the same time were under compression, so fractures there are generally tightly closed. Fracture zones on the few anticlines are among the more significant water-bearing zones in Area 12. For example, according to Bader and others (1976), the flow of Rock Creek in the Coal River basin (adjacent to Area 12) doubled after crossing the axis of the Warfield anticline when measured on October 3, 1974.

Another probable cause of fractures in the area is the unloading effect (stress relief) caused by erosion of the valleys as described by Wyrick and Borchers (1981). Fracturing caused by unloading is local and confined to the valley sides and bottom. It significantly affects the occurrence and movement of ground water in those areas.

Topography has a bearing on the location of successful water wells in the area. The water table is generally shaped like the topography (fig. 5.1-1); that is, the altitude of the water table is highest under hills and lowest in valleys. However, the section of unsaturated rock on the hill is generally thicker, necessitating a deeper well. By contrast, a valley well typically penetrates a thinner unsaturated section and has a higher static water level.

The dewatering of mined areas has caused a decline in water level in many areas. Sometimes the decline is permanent and at other times the water level recovers when mining ceases.

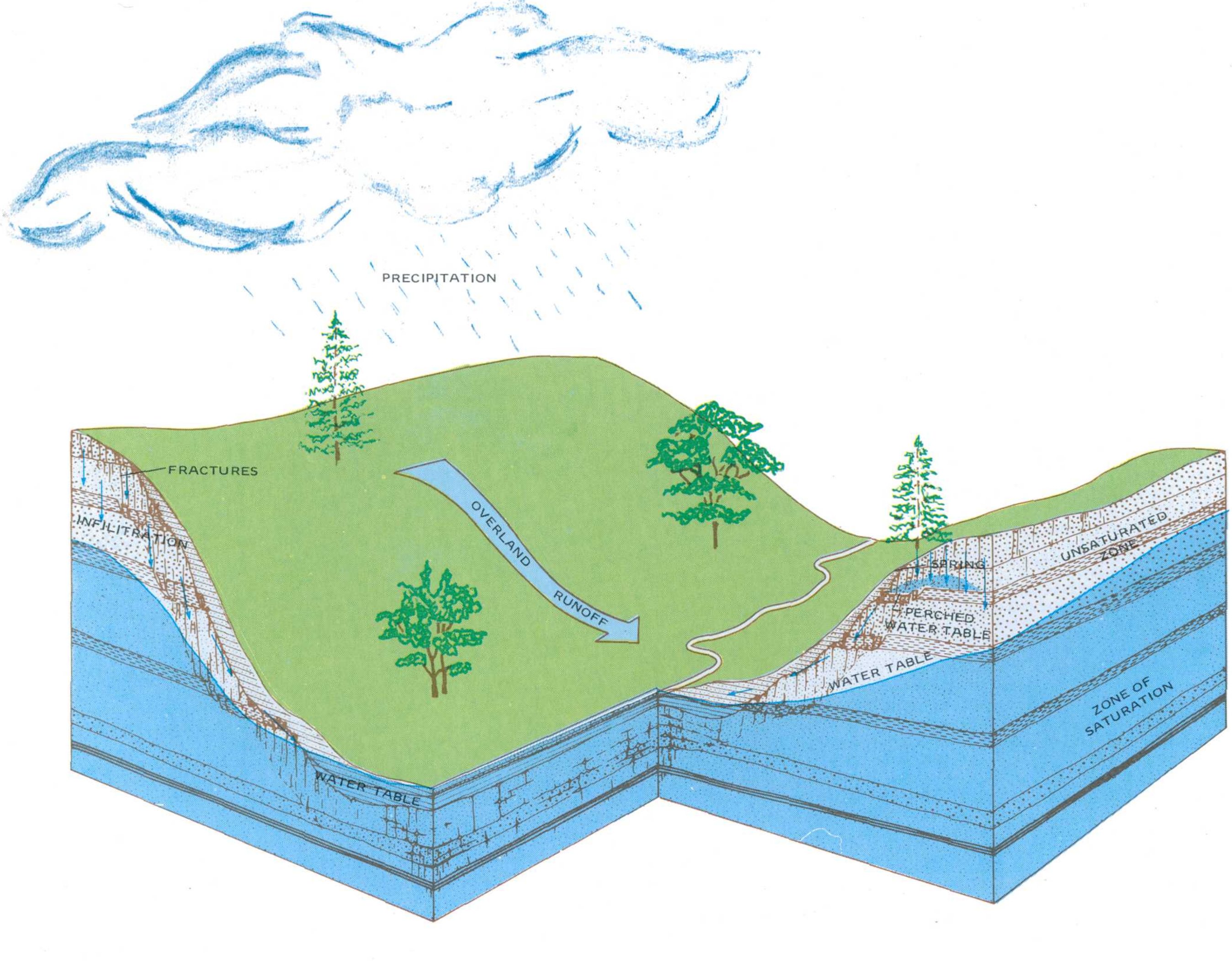


Figure 5.1-1 Generalized ground-water movement.

Yield of Wells Ranges from 0.5 to 340 Gallons per Minute

Fractures in the rocks are the most significant source of ground water in Area 12. Wells in valleys produce the most water.

The yield of a water well is a function of the amount of water recharging the storage reservoir, the geology of the area, the amount of fracturing, the efficiency and size of the well and the pump, the depth of the well, and the proximity of other wells. Well-yield data for Area 12 were reported by water-well drillers and well owners. These data indicate that the yield of wells in the valleys is about three times that of wells on hillsides or hilltops. The average yield from wells in valleys was nearly 27 gal/min (gallons per minute), whereas that from wells on hills was less than 9 gal/min. The yield of wells in the area ranged from 0.5 to 340 gal/min.

Fractures in the rocks are the most significant source of ground water in Area 12. Alluvium yields little water in the area because it is present only locally, and then usually very thin and unsaturated. The thicker deposits in Teays Valley contain thick deposits of clay and are of very low permeability. The data are summarized in table 5.2-1.

Water levels are closer to the land surface in valleys in Area 12; artesian conditions are sometimes encountered and some flowing wells are found in these areas. Because pumping lift is less under these conditions, yields are higher per unit of pumping energy. A summary of water-level data is given in table 5.2-2.

Wells in valleys are not as deep as wells on hills because the unsaturated zone is much thinner. Consequently, the wells reach the water table at a shallower depth. A summary of well-depth data is given in table 5.2-3.

Table 5.2-1 Summary of well-yield data.

TOPOGRAPHIC SETTING AT WELL	MINIMUM YIELD (GAL/MIN)	MAXIMUM YIELD (GAL/MIN)	AVERAGE YIELD (GAL/MIN)	NUMBER OF WELLS
Valley	0.5	340	26.8	176
Hillside	0.5	50	8.3	71
Hilltop	0.5	50	8.5	12

Table 5.2-2 Summary of water-level data.

TOPOGRAPHIC SETTING AT WELL	MINIMUM DEPTH TO WATER (FEET)	MAXIMUM DEPTH TO WATER (FEET)	AVERAGE DEPTH TO WATER (FEET)	NUMBER OF WELLS
Valley	0.9	139	22.7	208
Hillside	2.5	250	40.7	100
Hilltop	14.2	444	89.2	21

Table 5.2-3 Summary of well-depth data.

TOPOGRAPHIC SETTING AT WELL	MINIMUM WELL DEPTH (FEET)	MAXIMUM WELL DEPTH (FEET)	AVERAGE WELL DEPTH (FEET)	NUMBER OF WELLS
Valley	7.0	800	90.7	251
Hillside	10	525	101	112
Hilltop	38	534	148	22

Ground-Water Quality Best in Alluvium

Samples of well water in the Upper Pennsylvanian rocks have highest specific conductance, pH, alkalinity, carbonate hardness, dissolved solids, and iron. Samples from water in the alluvium have lowest specific conductance, pH, alkalinity, chloride, carbonate hardness, iron, and manganese.

Chemical analyses of water from the sampled wells in Area 12 were sorted by geologic unit, and whether they appeared to be affected by mining or salt-water intrusion. The chemical analyses of water in wells in those categories were evaluated on the basis of well location relative to nearby land use, depth of wells, and select constituent concentrations to determine if differences in water quality existed. The results show that the water from wells in the alluvium is of the highest quality and that poorest quality water is from wells in the Upper Pennsylvanian rocks (Conemaugh and Monongahela Groups). The comparison of ground water in the three geologic units is shown in table 5.3-1. Those results are for wells determined to be relatively unaffected by mining or salt water. The mean specific conductance of water in the Upper Pennsylvanian rocks is more than twice that of water in the alluvium; alkalinity is four times greater; dissolved solids nearly 2.5 times greater; iron 16 times greater; and manganese nearly 15 times greater. With the exception of iron, mean values for constituents in ground water from the Lower Pennsylvanian rocks (Pottsville Group) lie between the values for those from the alluvium and the upper Pennsylvanian rocks.

Comparison of chemical analyses from water in wells affected by mining in the Upper and Lower Pennsylvanian rocks shows similar results. For example, the mean specific conductance of ground water in the upper rocks is more than twice as high as that for the lower; alkalinity more than six times as high; and dissolved solids nearly 2.5 times as high. Similar results were obtained for wells affected by salt water. These results were obtained by comparing tables 5.3-2, and 5.3-3, which summarize the analyses for water from the Upper and Lower Pennsylvanian rocks.

Table 5.3-4 lists chemical analyses of water from a well in each of the three geologic units discussed above. These water-quality analyses are "typical" of water unaffected by mining or salt-water (table 5.3-1) in the three geologic units (fig. 3.0-1). The location of the "typical" wells is shown on figure 5.3-1.

The rocks in the Upper Pennsylvanian unit are more soluble than in the other units, thus water percolating through them dissolves more minerals during a given time than in other units. Limestone is one of the more soluble minerals and it is more abundant in those rocks than in the alluvium or the lower Pennsylvanian unit. Its effect on the water chemistry is evident from the higher values for specific conductance, alkalinity, calcium, carbonate hardness, and dissolved solids (table 5.3-1).

In areas of mining, the ground-water flow pattern has been locally disturbed, permitting "fresh" water to penetrate rocks and mix with ground water which was formerly in chemical equilibrium. Consequently, recharge with a fairly high concentration of dissolved oxygen can attack oxidizable minerals such as pyrite, producing sulfate (SO_4^{-2}), hydrogen ions (H^+), and ferrous iron (Fe^{+2}) in the presence of sulfur oxidizing bacteria. The latter may be further oxidized to ferric iron (Fe^{+3}), releasing more H^+ (Nrigu and Hem, 1978). Some of that water is pumped from the mines, but some continues to percolate through the rocks until it is intercepted by a well and is pumped to the surface. Wells tapping such a water source generally yield water with a higher content of sulfate and noncarbonate hardness (tables 5.3-2 and 5.3-3).

The mixing of ground water and surface runoff influences the quality of water in Area 12. Generally, the surface runoff is of a calcium bicarbonate type, but ground water is variable chemically. Because of local recharge, ground water may be contaminated by calcium sulfate water from mines or by brine disposal in the oil and gas producing areas. Ground-water discharge from abandoned mines in the headwaters results in an increase of the dissolved-solids concentration of the receiving stream (Bader and others, 1978).

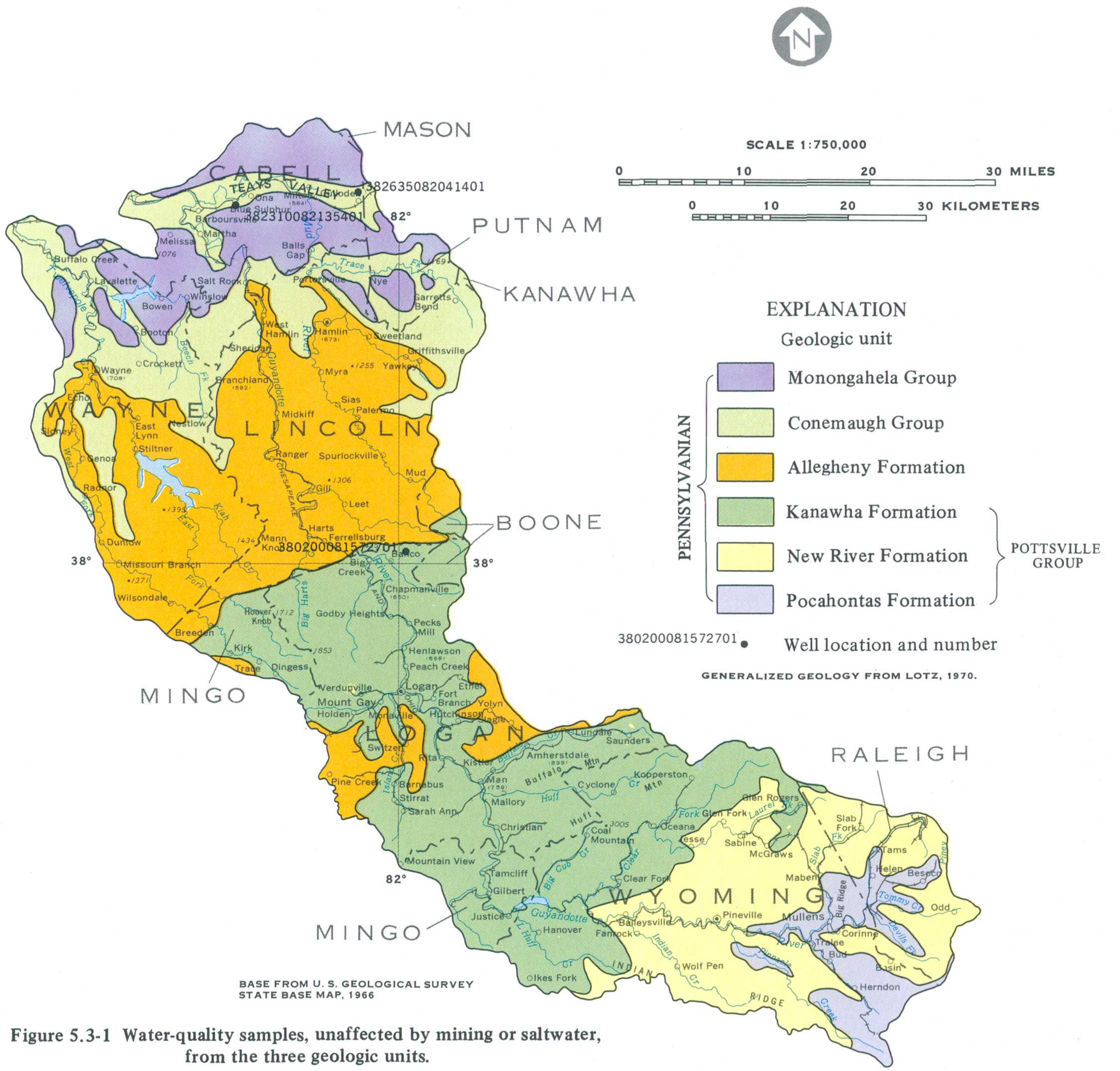


Figure 5.3-1 Water-quality samples, unaffected by mining or saltwater, from the three geologic units.

Table 5.3-1 Comparison of water analyses from wells unaffected by mining or salt water.

		Specific conductance (µmhos/cm)	pH (units)	Alkalinity (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Hardness as CaCO3 (mg/L)	Hardness non-carbonate (mg/L)	Dissolved solids (sum) (mg/L)	Dissolved iron (µg/L)	Dissolved manganese (µg/L)	Number of wells
Alluvium	Max	710	7.3	246	29	110	200	110	433	170	60	14
	Min	100	5.5 *	12	0	11	26	0	55	0	0	
	Mean	224	6.6	57	8.7	38	77	23	136	100	19	
Upper Pennsylvanian	Max	1,000	8.9	435	120	100	300	53	646	32,000	3,900	94
	Min	100	6.2 *	0	1.0	0.1	3	0	119	0	0	
	Mean	499	7.2	229	19	21	109	3.7	318	1,686	274	
Lower Pennsylvanian	Max	930	8.3	435	180	88	230	75	588	16,000	8,900	191
	Min	45	4.5 *	9	0.8	0	3	0	21	10	0	
	Mean	269	7.0	94	14	34	68	6.5	152	3,266	232	

*Median value.

Table 5.3-2 Summary of water analyses from wells in the Upper Pennsylvanian System.

		Specific conductance (µmhos/cm)	pH (units)	Alkalinity (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Hardness as CaCO3 (mg/L)	Hardness non-carbonate (mg/L)	Dissolved solids (sum) (mg/L)	Dissolved iron (µg/L)	Dissolved manganese (µg/L)	Number of wells
Wells unaffected by mining or salt water	Max	1,000	8.9	435	120	100	300	53	646	32,000	3,900	94
Wells affected by mining	Max	1,750	7.4	328	78	870	950	670	1,520	7,100	640	7
Wells affected by salt water	Max	5,500	8.4	361	2,200	28	1,900	1,900	3,420	77,000	1,400	7
Wells unaffected by mining or salt water	Min	100	6.2	0	1.0	0.1	3	0	119	0	0	94
Wells affected by mining	Min	300	6.1	68	0.8	60	130	57	200	20	10	7
Wells affected by salt water	Min	850	7.2	0	100	0.4	6	0	529	30	0	7
Wells unaffected by mining or salt water	Mean	499	7.2*	229	19.2	20.9	109	3.7	318	1,690	274	94
Wells affected by mining	Mean	1,000	7.2*	207	19	353	496	290	746	1,400	196	7
Wells affected by salt water	Mean	2,150	7.9*	235	643	11	397	313	1,300	13,360	280	7

*Median value

Table 5.3-3 Summary of water analyses from wells in the Lower Pennsylvanian System (Pottsville).

		Specific conductance (µmhos/cm)	pH (units)	Alkalinity (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Hardness as CaCO3 (mg/L)	Hardness non-carbonate (mg/L)	Dissolved solids (sum) (mg/L)	Dissolved iron (µg/L)	Dissolved manganese (µg/L)	Number of wells
Wells unaffected by mining or salt water	Max	930	8.3	435	180	88	230	75	588	16,000	9,900	191
Wells affected by mining	Max	2000	8.0	130	250	1,200	1,300	1,300	1,790	180,000	9,900	38
Wells affected by salt water	Max	3500	7.6	254	1,000	3.1	210	38	1,930	9,800	650	10
Wells unaffected by mining or salt water	Min	45	4.5	9	0.8	0	3	0	21	10	0	191
Wells affected by mining	Min	70	4.1	0	1.0	0.4	24	13	42	0	0	38
Wells affected by salt water	Min	650	6.7	123	140	0	32	0	385	60	10	10
Wells unaffected by mining or salt water	Mean	269	7.0*	94	14	34	68	6.5	152	3,270	232	191
Wells affected by mining	Mean	482	6.6*	32	19	172	183	150	324	16,500	4,230	38
Wells affected by salt water	Mean	1,250	7.2*	174	304	1.2	100	3.8	696	2,587	196	10

*Median value

Table 5.3-4 "Typical" chemical analyses from wells not affected by mining or salt-water intrusion in the three major geologic units.

Geologic unit / Well number	Date sampled	Temperature (OC)	Specific conductance (µmhos/cm)	pH (units)	Alkalinity (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Hardness as CaCO3 (mg/L)	Hardness non-carbonate (mg/L)	Dissolved solids (mg/L)	Dissolved iron (µg/L)	Dissolved manganese (µg/L)
ALLUVIUM 382635082041401	03-24-76	14.0	235	6.6	36	25	6.6	8.5	12	29	90	54	115	30	10
UPPER PENNSYLVANIAN 382310082135401	04-21-76	16.0	500	7.1	203	49	11	43	6.8	53	170	0	307	2,500	520
LOWER PENNSYLVANIAN 380200081572701	05-04-77	16.0	230	7.1	78	25	5.0	8.0	2.3	15	83	5	122	2,600	220

Hydrologic Data Systematically Collected at 12 Gaging Stations

Streamflow and water-quality data are collected at 12 continuous-record gaging stations in the area.

Long-term, systematic collection of data at an established network of river stations is needed for the assessment of streamflow characteristics. The locations of 12 active gaging stations (1980) are shown in figure 6.1-1. Drainage area, type data, sampling frequency, and other data are given in section 8.0. Gaging stations, which are also termed continuous-record stations, are stream sites where records of stage are recorded by automatic recorders. Records of stage are combined with stage-discharge relationships to determine actual rates of streamflow. The streamflow data are published annually as daily mean discharge by the U.S. Geological Survey in "Water Resources Data for West Virginia." Data for inactive and active stations are available from computer storage through the National Water Data Exchange (NAWDEX). (See Section 7.0.)

Surface-water quality is dependent on streamflow, precipitation, geology, land and water use, and wastewater discharge. Thus, water quality is often highly variable and systematic collection of water-quality data under differing streamflow conditions is usually necessary to evaluate water-quality conditions.

Water-quality data were collected at 10 of the gaging stations at various intervals. Specific conductance, pH, water temperature, and alkalinity were measured on site at monthly intervals at most stations (fig. 6.1-1). Water samples were collected monthly for determination of most dissolved major constituents (calcium, magnesium, sodium, bicarbonate, chloride, and sulfate) and for dissolved and total concentrations of iron and manganese. Suspended-sediment concentrations were measured once daily or less frequently at selected sites shown in figures 6.1-1 and 6.4.8-1. Water-quality data for all sites are available from computer storage through National Water Data Exchange (NAWDEX). Data for active sites are published annually by the U.S. Geological Survey in "Water Resources Data for West Virginia."

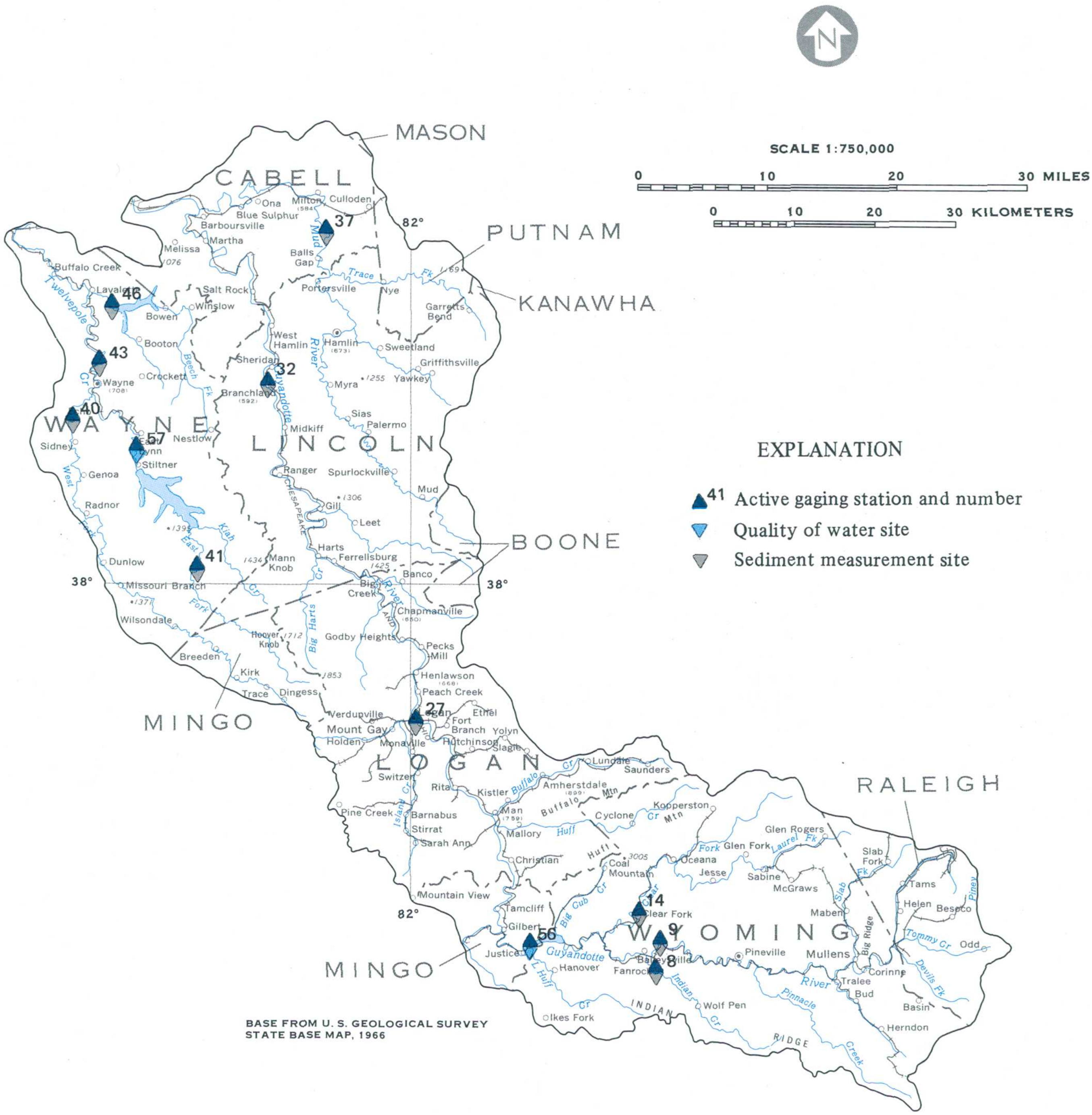


Figure 6.1-1 Location of gaging stations active in 1980.

Hydrologic Data Collected Intermittently at 36 Synoptic Sites

Streamflow and water-quality data were collected at 36 ungaged synoptic sites. Drainage areas of the sites were generally less than 50 square miles and data collection was on an intermittent basis under different streamflow conditions.

Hydrologic information on small streams is a necessary supplement to data collected at regular gaging stations if mining and other land-use impacts are to be detected. Generally, data acquired at regular gaging stations reflect large drainage basins with multiple land uses. The average drainage area for gaging stations in the area is 332 mi^2 (square miles). Water quantity and quality impacts due to mining are less obscured if data is acquired for small basins. For this reason a network of 36 miscellaneous sites was established where a series of synoptic measurements would serve to supplement data from the continuous record stations. Drainage areas of the synoptic sites were generally less than 50 mi^2 and data collection was on an intermittent basis under different streamflow conditions. Drainage areas, site identification, type and period of record, and sampling frequency for all sites are given in section 8.0. Site locations are shown in figure 6.2-1.

Streamflow during synoptic-site sampling in 1979 and 1980 was primarily low to moderate. Instantaneous streamflow, pH, specific conductance, water temperature, and alkalinity were measured on site. Water samples were collected for the determination of most dissolved major constituents (calcium, magnesium, sodium, bicarbonate, chloride, and sulfate), and for dissolved and total concentrations of iron and manganese. Samples were also collected once for total concentrations of selected trace elements in stream-bottom sediment. Water samples were collected at sites 6, 21, and 35 during selected storms and analyzed for suspended sediment. 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."

Figure 6.2-1 Drainage areas and locations of synoptic sites.

Basin and Climate Characteristics Affect Low Flow of Streams in Area

Low flow of streams in Area 12 is influenced by basin and climate characteristics as well as by activities of man. Streamflows in this area become very low during drought and many go dry. Low-flow data are available for 6 sites in the area.

Low-flow statistics for streams are often used in the planning of water-supply facilities to assure an uninterrupted supply during dry periods. They are also used in the design of waste treatment facilities to ensure adequate dilution of wastewater discharged to streams during low-flow periods. Low flow is affected by streamflow regulation, size of drainage area, geology, climate, wastewater discharge, mining, and by withdrawals from streams for domestic, industrial, and agricultural purposes.

A commonly used streamflow characteristic is the lowest 7-consecutive day mean low flow at 10-year recurrence intervals ($M_{7,10}$). The probability that the actual low-flow value during any one year will be less than the calculated low-flow value is equal to the reciprocal of the recurrence interval. That is, there is a 10 percent chance that the average flow for the lowest 7 consecutive days during any year will be less than the calculated $M_{7,10}$ value.

Low-flow statistics ($M_{7,2}$; $M_{7,10}$) at selected sites in Area 12 (fig. 6.3.1-1 and table 6.3.1-1) were calculated by fitting discharge values to a Log-Pearson type III frequency distribution (Hutchinson, 1975). Some of the data for streams in table 6.3.1-1 represent streamflow from non-concurrent time periods and are not suitable for comparison between stations.

Streamflow regulation by dams affects discharge in the Guyandotte River, Beech Fork, and East Fork Twelvepole Creek. Regulation generally augments low flows during dry periods. The basin climate and size of drainage area also affect low flow. The smaller the drainage area, the greater the chance that a stream may go dry during periods of drought. Wastewater discharges also increase streamflow and may change water quality. It has been estimated that water use is approximately 50-80 gal/d (gallons per day) per person and the water is mostly returned to streams as wastewater.

Mine drainage and mine pumpage can also increase streamflow. In a study of five small drainage areas in the Guyandotte River basin, mine drainage was 14 to 34 percent of the streamflow in heavily mined basins during a period of low streamflow (James W. Borchers, written communication, 1981). Hobba (1981) reported similar findings in a study of underground mining and mine collapse in northern West Virginia.

Table 6.3.1-1 Low-flow statistics for selected streams.

SITE NUMBER	STATION NAME	PERIOD OF RECORD	$M_{7,10}$ (FT^3/S)	$M_{7,2}$ (FT^3/S)
9	Guyandotte River near Baileysville	1968-80	29.9	55.9
27	Guyandotte River at Logan (Unregulated period)	1962-74	43.6	76.5
32	Guyandotte River at Branchland (Unregulated period)	1930-73	26.4	74.5
37	Mud River near Milton	1938-80	0.19	1.57
41	East Fork Twelvepole Creek near Dunlow	1964-80	.03	0.40
43	Twelvepole Creek below Wayne	1927-31 1946-54 1955-72	1.67	5.94

Figure 6.3.1-1 Location of selected low-flow sites.

Floods Vary with Drainage Area

Drainage-area size is the primary factor determining the magnitude of floods in Area 12.

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 generally expressed in terms of probability of occurrence or recurrence interval. For example, a flood having a 2 percent chance of being exceeded in any one year is also described as a 50 (inverse of 0.02) year recurrence-interval flood.

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. 6.3.2-1), are applicable to streams with drainage areas ranging from 0.3 to 2,000 mi^2. The equations applicable to Area 12 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 discharge for streams in Area 12 are shown in figure 6.3.2-2. An example of peak discharge determinations for a stream is also illustrated in figure 6.3.2-2. In the example, the Q_{10}, Q_{50}, and Q_{100} for a stream with a drainage area of 50 mi^2 are 4,100, 6,200, and 7,300 ft^3/s, respectively.

The relations presented here should not be used to estimate peak flows for streams draining urban areas, streams with significant regulation, or with drainage areas less than 0.3 or greater than 2,000 mi^2.

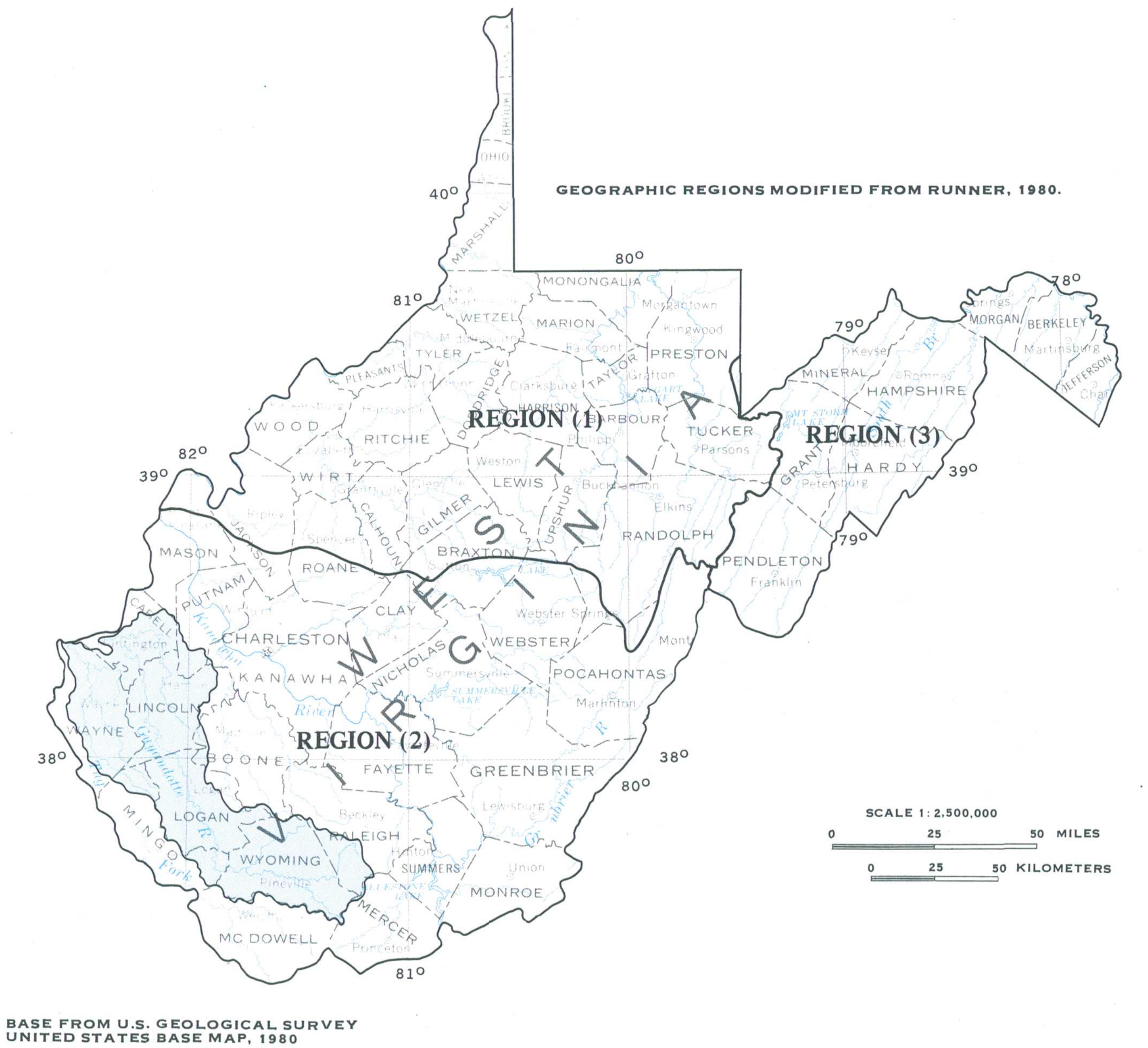


Figure 6.3.2-1 Relation of Area 12 to flood frequency geographic regions in West Virginia.

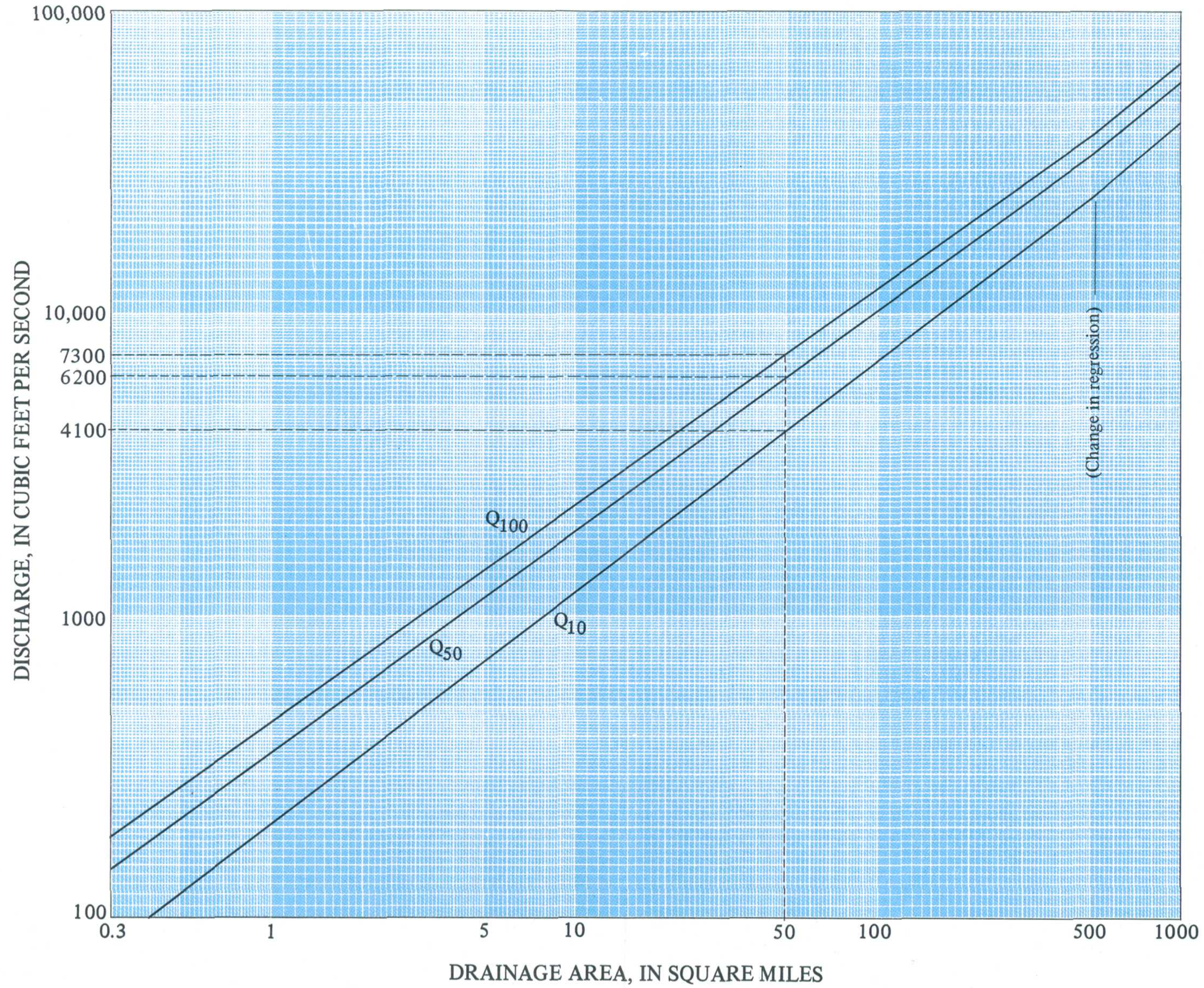


Figure 6.3.2-2 Relation of 10-year, 50-year, and 100-year peak discharge to drainage area in Area 12.

Flood-Prone Area Maps Available for Area

The limits of the 100-year recurrence interval flood in Area 12 are delineated on 47 selected 7½-minute quadrangles.

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 delineate 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. 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 of 47 flood-prone area maps in Area 12 are shown on figure 6.3.3-1. Completed flood-prone area maps are shown with the quadrangle name for each available 7½-minute map. The maps are open-file and available upon request from the U.S. Geological Survey District Office, 3416 Federal Building, Charleston, West Virginia 25301.

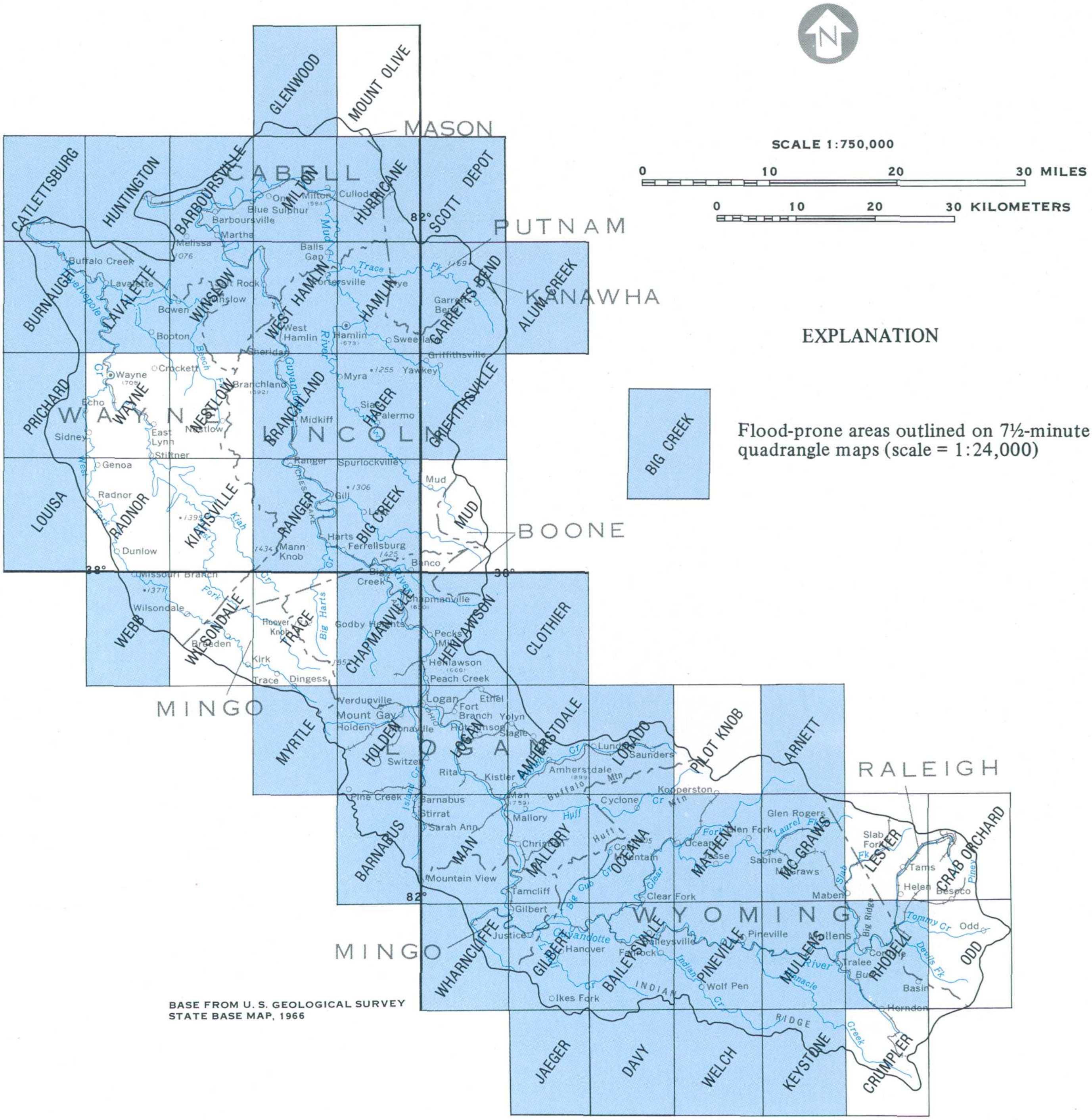


Figure 6.3.3-1 Index of flood-prone area maps.

Flow-Duration Curves for Streams in Area 12 Summarize the Effects of Basin Characteristics on Streamflow

Streamflow duration is affected by topography, geology, climate, size of drainage area, and by man's activities including streamflow regulation and mining. Streamflow duration data are available for 8 stations in the area.

A flow-duration curve is a cumulative frequency curve showing the percentage of time that a specific daily discharge was equaled or exceeded during a given period of time. The curves are often used to demonstrate streamflow distribution and variability. The flow-duration curve is one way of representing the flow characteristics of a stream throughout the range of discharge without regard to the sequence of occurrence. It is applicable only to the period of record used to develop the curve. Flow-duration curves can be used in computing suspended-sediment or dissolved-solute loads if the appropriate streamflow versus sediment or chemical solute transport curves are known.

Flow-duration data for selected gaging sites (fig. 6.3.4-1) are summarized in table 6.3.4-1 for unregulated and regulated periods of time. Some of the data in table 6.3.4-1 represent streamflow from nonconcurrent time periods and are not suitable for comparisons between sites.

Regulation affects streamflow variability and the shape of flow-duration curves by reducing flood peaks and increasing low flows. Figure 6.3.4-2 shows flow-duration curves at site 43 (Twelvepole Creek below Wayne) for unregulated and regulated periods. The curve for regulated conditions (1972 to 1979) indicates decreased high flows at discharges greater than 2,700 ft^3/s (cubic feet per second) and increased low flows at discharges less than about 15 ft^3/s. The substantial flattening in the upper and lower portions of the duration curve reflects the effects of regulation of East Lynn Reservoir. Similarly, the difference between the curves from the 5 to 95 percent durations shown in figure 6.3.4-2 reflects the overall variation in precipitation occurring during the unregulated and regulated time periods.

Flow duration is also affected by the annual distribution of precipitation. For example, discharge corresponding to 50 percent duration at site 37 (Mud River near Milton) for April during the entire period of record was 230 ft^3/s, whereas discharge at the same duration for October was 6.5 ft^3/s.

Discharges around the 20-30 percent duration usually correspond to the stream's mean flow, whereas streamflow occurring at or greater than 75 percent duration is generally considered low flow. Streamflow occurring at or less than 10 percent duration is generally considered high flow. Flow duration is affected by many natural basin characteristics such as topography, geology, size of drainage area, climate, and by activities of man, including streamflow regulation and mining.

Basin topography and geology have a major influence on the shape of the flow-duration curve. Streams receiving direct surface runoff with limited contribution from ground-water storage typically have flow-duration curves with a steep slope. Streams receiving delayed surface runoff and ground-water storage have flow-duration curves with flatter slopes, particularly in the low-flow portion. The flow-duration curve for site 41 (East Fork Twelvepole Creek near Dunlow) (fig. 6.3.4-2) is steep and reflects limited contribution of ground water. East Fork Twelvepole Creek drains 38.2 mi^2 (square miles) of mountainous terrain in the headwaters of Twelvepole Creek basin where land slopes generally exceed 30 percent.

Surface and underground mines can also affect streamflow duration when streamflow is augmented by mine drainage or pumpage. The effect on the low-flow portion of the curve is similar to streamflow sustained by ground-water discharge during dry periods. Melvin V. Mathes (written communication, 1981) indicated that in several small basins in the Guyandotte River basin, high streamflows were less and low flows were greater in heavily mined basins than in unmined basins.

Figure 6.3.4-1 Location of selected gaging stations for determination of flow duration.

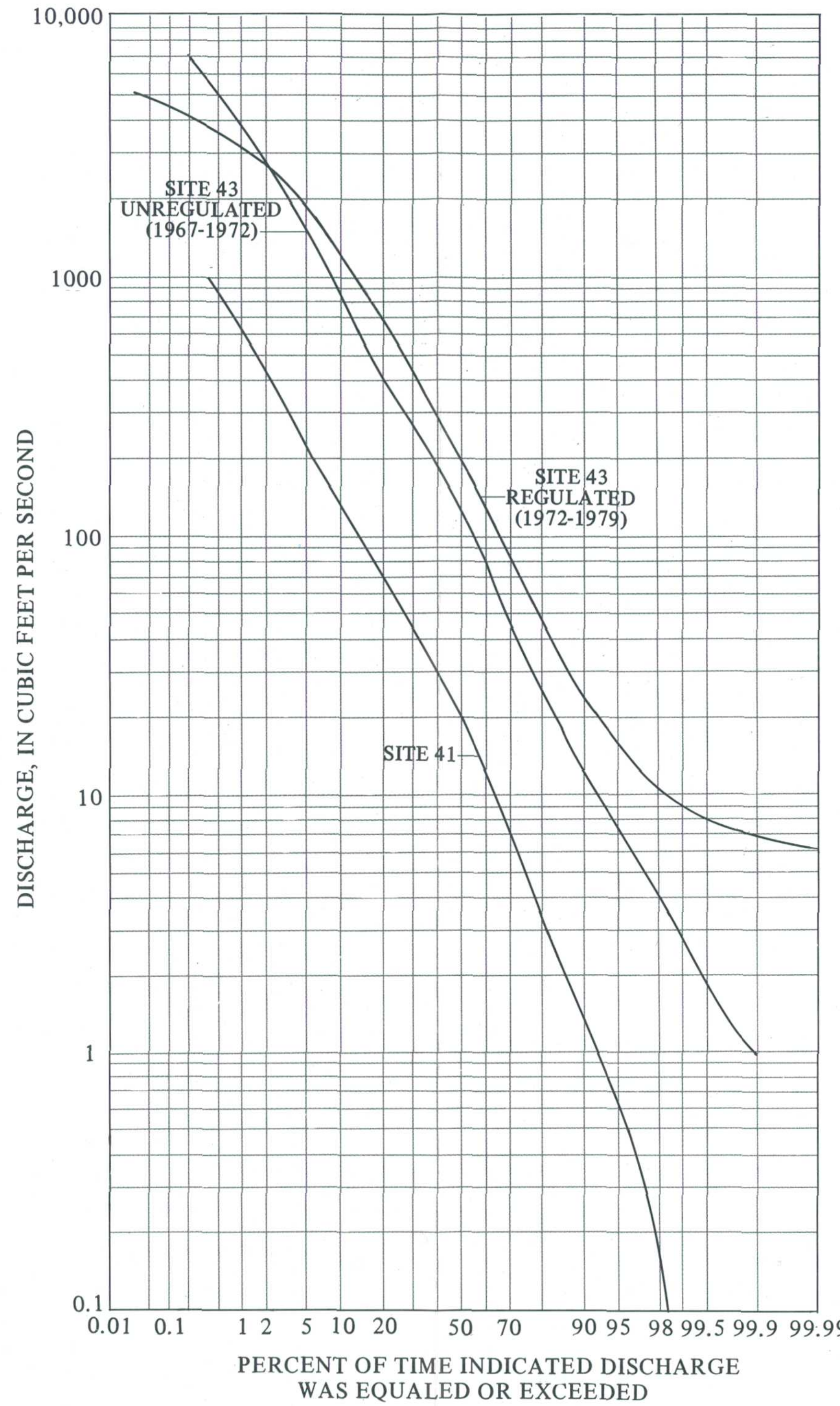


Figure 6.3.4-2 Streamflow duration curves for selected sites.

Table 6.3.4-1 Flow duration for selected sites.

SITE NUMBER	PERIOD OF RECORD	DAILY MEAN DISCHARGE, IN CUBIC FEET PER SECOND, THAT WAS EXCEEDED FOR INDICATED PERIOD OF TIME						
		10	25	50	70	75	90	95
9	1968-80	960	530	260	140	120	67	49
8	1974-79	150	65	23	9.2	6.8	2.7	1.9
14	1974-79	470	230	96	46	37	18	13
27	1962-74	2,400	1,300	550	240	190	99	80
27*	1974-79	3,100	1,600	750	390	340	180	130
32	1930-73	4,000	1,800	670	260	210	95	63
32*	1973-79	4,800	2,600	1,100	560	480	250	170
37	1938-79	720	270	76	20	14	3.1	1.3
41	1964-79	130	55	19	6.3	4.5	1.3	0.6
43	1967-72	810	340	130	45	34	14	7.8
43*	1972-79	1,300	520	200	83	63	23	15

*Regulated period.

Mean Flow in the Area is a Function of Basin and Climate Characteristics and Streamflow Regulation

Streamflow distribution varies seasonally in response to precipitation and evapotranspiration. Mean-monthly streamflow is generally greatest in March and lowest in September or October. Regulation affects streamflow in major streams throughout the area.

Flow in unregulated streams varies with changes in precipitation and evapotranspiration. The hydrograph, illustrating seasonal streamflow variation for the Guyandotte River at Logan (site 27) during the period from October 1, 1973 to September 30, 1974 (prior to regulation), is typical of an unregulated river (fig. 6.3.5-1). The lowest monthly flow, 189 ft^3/s (cubic feet per second), for the period was in October.

Mean-monthly and mean-annual streamflow also varies in response to seasonal and annual precipitation and evapotranspiration variations.

The greatest mean-monthly flows usually occur during March because of snowmelt, increased precipitation, and relatively low evapotranspiration. Streamflow during spring and early summer is usually high because of increased thunderstorm activity. Streamflow decreases during late summer and early fall because of increased evapotranspiration losses and reduced precipitation. During November-December, streamflow usually increases because evapotranspiration decreases and precipitation increases.

Mean-monthly and mean-annual streamflows for selected streams (fig. 6.3.5-2) are given in table 6.3.5-1. As shown in table 6.3.5-1, the Guyandotte River and Twelvepole Creek are regulated streams. Streamflow regulation usually results in increased mean-monthly discharges during dry periods. For example, the lowest mean-monthly discharge at Twelvepole Creek below Wayne (site 43) for the unregulated period was 29.4 ft^3/s and 136 ft^3/s for the regulated period. Mean-monthly flows of regulated streams are generally less variable than those of unregulated streams and do not reflect natural streamflow conditions.

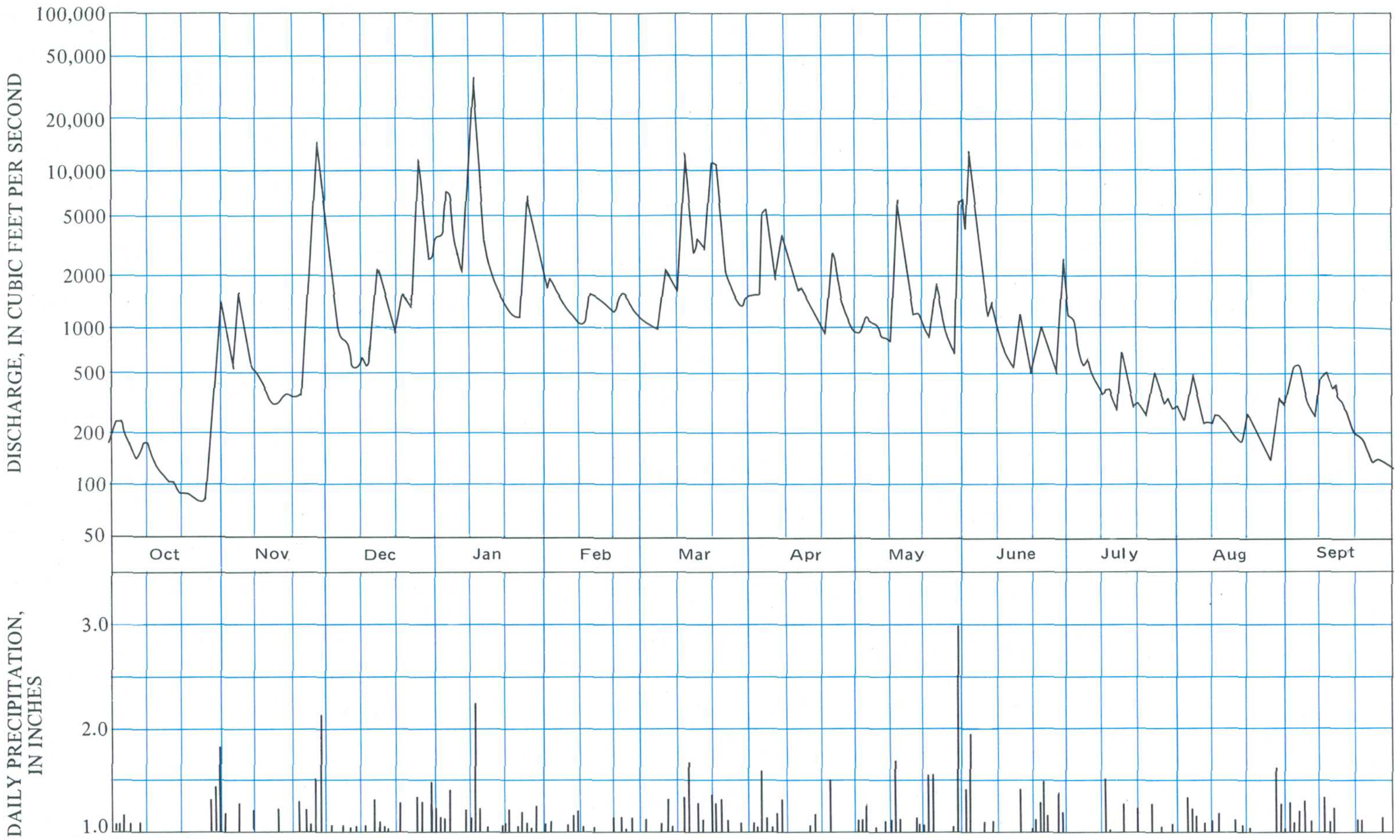


Figure 6.3.5-1 Hydrograph for the Guyandotte River at Logan (site 27) and precipitation at Logan for the 1974 water year.

Table 6.3.5-1 Mean-monthly and mean annual streamflow for selected sites.

SITE NUMBER	STATION NAME	YEARS OF RECORD	PERIOD OF RECORD	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	MEAN ANNUAL
9	Guyandotte River near Baileysville	13	1968-80	758	801	824	818	603	324	215	211	111	190	281	490	466
8	Indian Creek at Fanrock	7	1974-80	106	89.2	133	122	69.8	31.5	25.9	22.7	9.2	35.2	47.3	57.4	62.1
14	Clear Fork at Clear Fork	7	1974-80	411	370	438	314	215	146	78	93.2	54.9	115	147	272	221
27	Guyandotte River at Logan															
	(unregulated period)	15	1960-74	1,815	1,892	2,535	1,797	1,364	663	411	399	302	319	706	1,480	1,140
	(regulated period)	7	1974-80	2,369	2,059	2,796	2,306	1,500	978	774	725	354	714	956	1,422	1,410
32	Guyandotte River at Branchland															
	(unregulated period)	47	1928-74	2,567	3,227	4,024	2,732	1,806	900	689	526	286	279	643	1,641	1,610
	(regulated period)	7	1974-80	3,712	3,154	4,077	3,249	2,250	1,370	1,077	1,074	529	977	1,393	2,483	2,110
37	Mud River near Milton	43	1938-80	476	580	694	505	319	142	117	74.6	60.3	43.4	144	358	289
41	East Fork Twelvepole Creek near Dunlow	17	1964-80	94.1	91.4	116	104	67.8	21.8	18.8	17.4	11.5	14.6	27.7	82.3	55.9
43	Twelvepole Creek below Wayne															
	(unregulated period)	32	1927-31 1946-72	463	707	730	655	628	118	201	115	29.4	724	128	406	354
	(regulated period)	9	1972-80	841	571	874	675	476	242	146	177	136	144	403	791	456

Figure 6.3.5-2 Location of selected stations for mean flow determination.

Water-Quality Investigations are Supported by Laboratory Analytical Services and Quality-Control Program

The U.S. Geological Survey uses field and laboratory analysis to determine water quality. Quality control is maintained by following set standards of techniques and procedures in the laboratories and in the field. Data are stored on computer discs for retrieval through WATSTORE and STORET files.

Water quality is assessed by the U.S. Geological Survey using a variety of instrumentation and techniques. Parameters subject to rapid change after collection are measured on site by electrometric or physical methods as shown in table 6.4.1-1. Parameters determined on site include pH, specific conductance, water temperature, dissolved-oxygen concentration, alkalinity, acidity, and biological parameters such as fecal coliform and fecal streptococci density. Chemical methods are described in Skougstad and others (1978). Biological methods are described in Greeson and others (1977).

Quality control of field and laboratory analytical techniques is maintained by a series of reference samples, analysis of replicate samples, and by review of analytical results. The quality-assurance program is maintained by a section of the laboratory in Denver and by individual district offices responsible for sample collection and field determinations.

Table 6.4.1-1 is a partial listing of water-quality parameters determined at sites shown in figures 6.1-1 and 6.2-1 during 1979 and 1980. Not all parameters were determined at all sites.

Chemical determinations were performed for dissolved as well as for total (dissolved plus suspended) concentrations of constituents in water. The term "dissolved" refers to material that passes through a 0.45 μm (micrometer) pore-size membrane filter. It is recognized that some water samples may contain colloidal material that will pass through a 0.45 μm filter. "Total" (dissolved plus suspended) concentration of a constituent refers to the summation of the concentrations of dissolved and particulate components. "Suspended" refers to that material which is retained by a 0.45 μm pore filter.

Laboratory and field analyzed water-quality data are stored in WATSTORE and STORET computer files and can be retrieved through terminals having access to these files (see sections 7.1, 7.2, and 7.3 for further information).

Table 6.4.1-1 Field measurements and laboratory analyses used to describe water-quality conditions.

FIELD MEASUREMENTS	METHOD	REFERENCE	WATSTORE CODE
specific conductance	electrometric	Skougstad and others, 1979	00095
pH	do	do	00400
water temperature	thermometric or electrometric	do	00010
dissolved oxygen	electrometric, polarographic probe	do	00300
alkalinity	electrometric titration	do	00410
acidity	do	do	71825
LABORATORY ANALYSES			
Major ions (dissolved)			
calcium	atomic absorption spectrometric	Skougstad and others, 1979	00915
magnesium	do	do	00925
sodium	do	do	00930
bicarbonate	normally calculated from field alkalinity	do	00440
carbonate	normally calculated from field alkalinity	do	00445
sulfate	automated colorimetric	do	00945
chloride	do	do	00940
silica	ICAP (inductively coupled argon plasma)	Garbarino and Taylor, 1979	00955
Minor ions (dissolved)			
barium	ICAP	Garbarino and Taylor, 1979	01005
beryllium	do	do	01010
cadmium	do	do	01025
cobalt	do	do	01035
copper	do	do	01040
iron	atomic absorption spectrometric	Skougstad and others, 1979	01046
lead	ICAP	Garbarino and Taylor, 1979	01049
lithium	do	do	01130
manganese	atomic absorption spectrometric	Skougstad and others, 1979	01056
molybdenum	ICAP	Garbarino and Taylor, 1979	01060
strontium	do	do	01080
vanadium	do	do	01085
zinc	do	do	01090
Minor elements in water (total)			
iron	atomic absorption spectrometric	Skougstad and others, 1979	01045
manganese	do	do	01055
Minor elements in bottom material (total)			
arsenic	atomic absorption spectrometric	Skougstad and others, 1979	01003
cadmium	do	do	01028
chromium	do	do	01029
cobalt	do	do	01038
copper	do	do	01043
iron	do	do	01170
lead	do	do	01052
manganese	do	do	01053
mercury	do	do	71921
selenium	do	do	01148
zinc	do	do	01093
Organic constituents			
total organic carbon	carbon organic wet oxidation	Fredericks, 1968	00680
coal in bottom material	gravimetric	Skougstad and others, 1979	82301
Physical properties of water			
dissolved residue on evaporation at 180°C	gravimetric	Skougstad and others, 1979	70300
suspended sediment	gravimetric	Guy, 1969	80154
turbidity	nephelometric	Skougstad and others, 1979	00076

Specific Conductance of Surface Water Greater in the Upper Guyandotte River Basin

The mean specific conductance of surface water at synoptic sites was 254 micromhos per centimeter at 25°C. The most important activity influencing specific conductance is underground coal mining in the upper Guyandotte River basin.

Specific conductance is an expression of the measured ability of water to carry an electrical current, and is reported in µmhos/cm (micromhos per centimeter) at 25°C. Specific conductance is proportional to the quantity of ionized minerals and is used as a general indicator of water quality.

Rainfall in the basin generally has a specific conductance of less than 20 µmhos/cm. Salt water and brines commonly have values ranging from 50,000 to 250,000 µmhos/cm. Many environmental conditions influence specific conductance. In undisturbed areas, the solution of surface rocks is a major influence on specific conductance in surface water. Streams draining rocks such as sandstone typically have very low specific conductance, whereas drainage from more soluble rocks such as limestone and dolomite usually has higher specific conductance. Municipal and industrial wastewater discharges frequently have a high specific conductance. Drainage from underground mines, coal preparation plants, and mine spoil piles is the largest source of high specific conductance water in Area 12. Duration and intensity of precipitation also influence the specific conductance of surface water. In general, the specific conductance of surface water was lowest during periods of high flow and highest during periods of low flow. Streamflow during the synoptic sampling periods in 1979 and 1980 was generally low to moderate.

Specific conductance of streams in Area 12 ranged from 40 to 1,500 µmhos/cm and had a mean of 254 µmhos/cm. Mean values and ranges of specific conductance in streams draining Area 12 are shown in figures 6.4.2-1 and 6.4.2-2. The mean specific conductance of streams in the upper Guyandotte River basin (335 µmhos/cm) differed significantly from the streams in the lower Guyandotte River basin (165 µmhos/cm) and from streams in Twelvepole Creek basin (105 µmhos/cm). Essentially all active coal mines (99 percent) are located in the upper Guyandotte River basin.

Previous studies indicated that underground coal mining has a significant effect on specific conductance of surface water in the Guyandotte River basin. Chisholm (Bader and others, 1980) reported that streams draining subsurface mining areas in the basin had specific conductance values two to five times greater than those draining other areas.

Drainage from active underground mines affects the specific conductance of surface water in small, intensely mined basins during periods of low streamflow. James W. Borchers (written communication, 1981) found that drainage from 22 active underground coal mines in the upper Guyandotte River basin had a mean specific conductance of 735 µmhos/cm, again two to five times greater than the specific conductance of water in streams draining unmined basins. The quantity of drainage from active mines can be substantial. For example, in two small basins (<10 mi^2) in the upper Guyandotte River basin active mines contributed 14 to 34 percent of their basin's total streamflow during a period of low flow (James W. Borchers, written communications, 1981).

Past and present surface mining in Area 12 totals less than 7 percent of the land area. The effect of surface-mine drainage on specific conductance of receiving streams probably is considerably less when compared to that from underground mines.

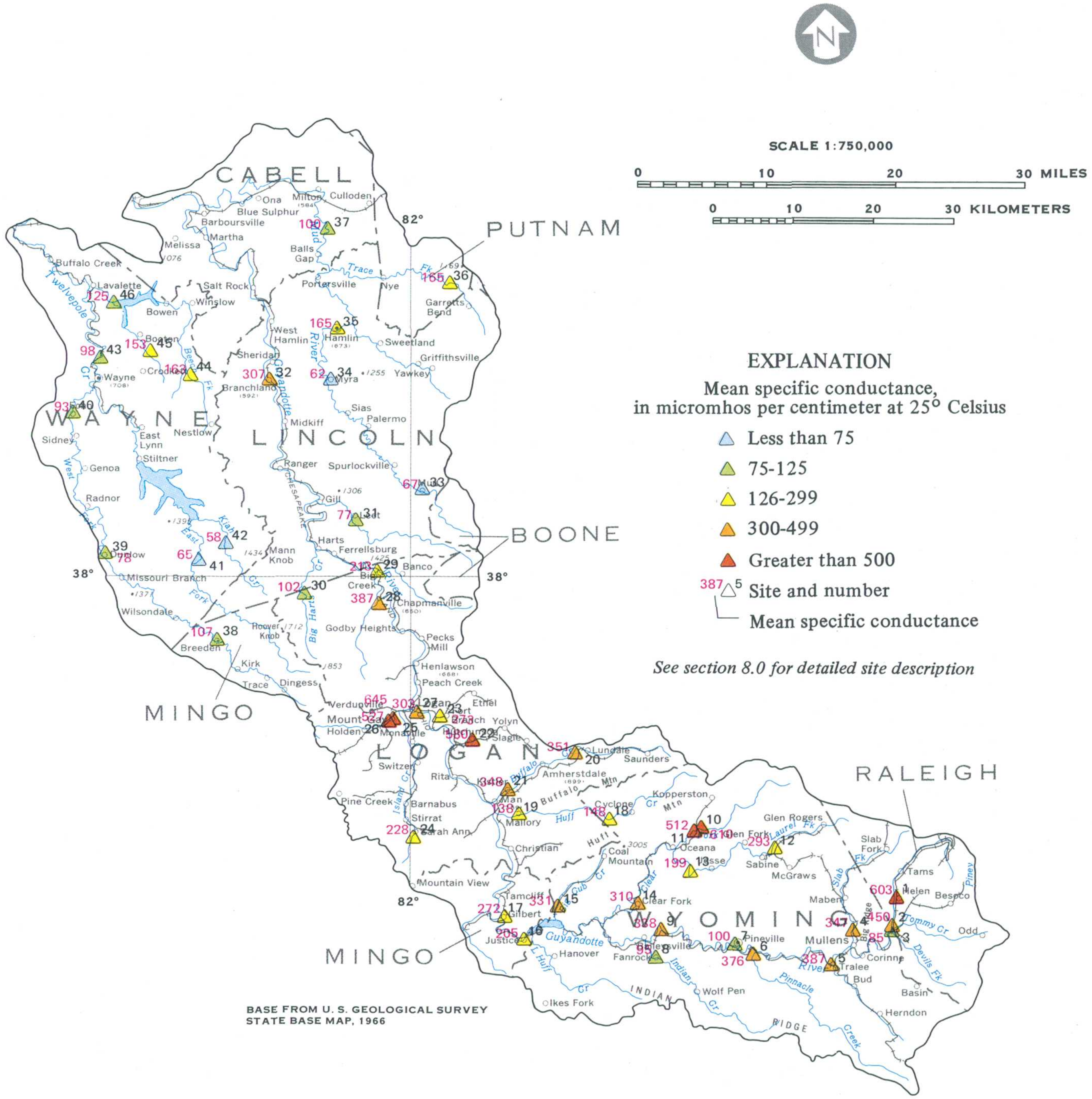


Figure 6.4.2-1 Mean specific conductance at surface-water sites.

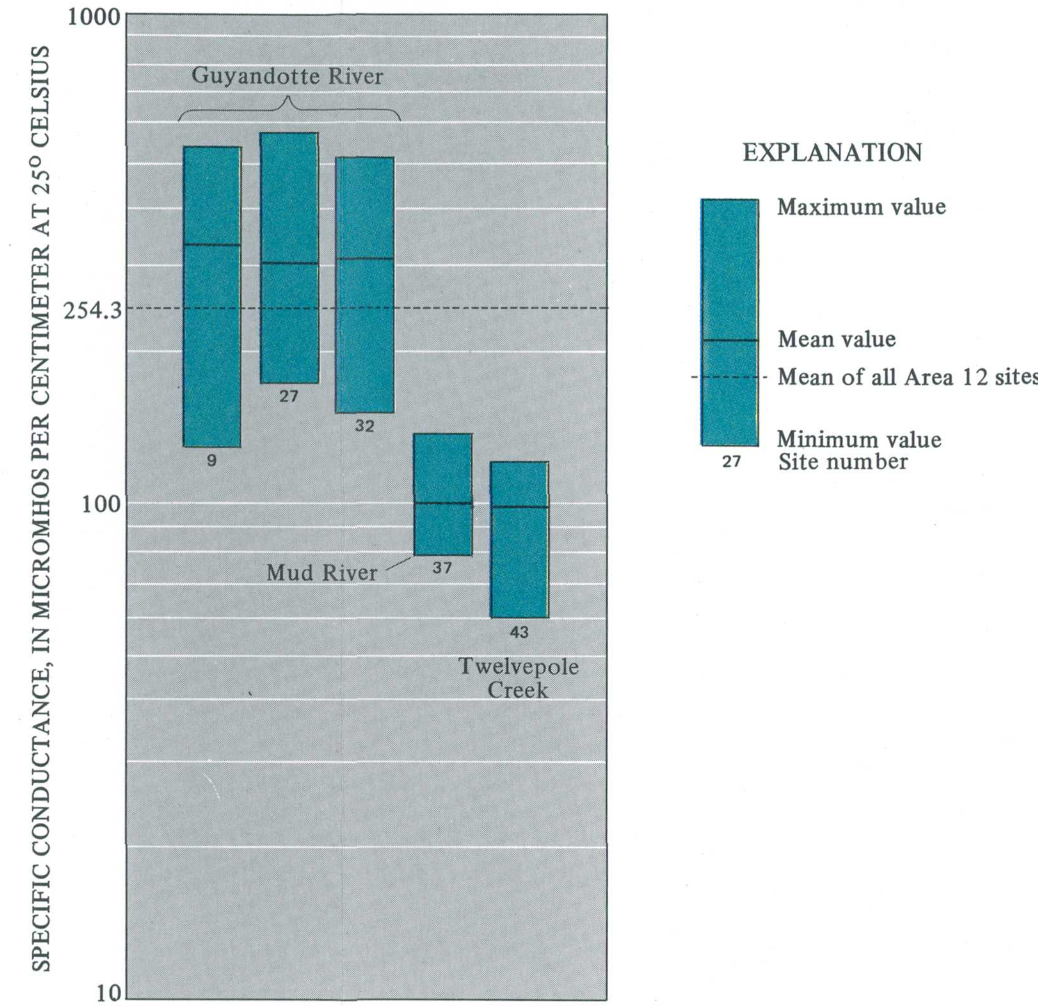


Figure 6.4.2-2 Range of specific conductance at selected surface-water sites.

The pH of Most Surface Waters in Area 12 is Alkaline

The pH of surface water at synoptic sites ranged from 5.7 to 8.9 and had a median value of 7.2. The pH of surface water is determined largely by the hydrolysis and solution of carbonate and pyrite.

"pH" is a measure of the hydrogen ion (H^+) activity in water. The hydrogen ion activity is expressed in logarithmic units and pH is the negative logarithm to the base of 10 of the hydrogen ion activity in moles per liter. Thus a solution with [H^+] of 1×10^{-7}M has a pH of 7. The pH 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). Neutral water (pH 7.0) is uncommon because the solution of minerals and gases in water affects the pH. Atmospheric carbon dioxide (CO_2) plus other natural and man-made materials dissolved in precipitation results in rainfall with a pH from 4.0 to 5.6 and thus is acidic. The dissolution of limestone ($CaCO_3$) in water raises the pH towards alkaline levels (pH >7.0).

The pH of surface-water samples at synoptic sites ranged from 5.7 to 8.9 and had a median of 7.2. The samples were collected during low to medium flow in 1979 and 1980. Median pH values for each synoptic site are shown in figure 6.4.3-1 and the range of pH values at selected stations is shown in figure 6.4.3-2. Streams in the upper Guyandotte River basin were generally the most alkaline with a median pH of 7.5 at synoptic sites. This may be due in part to alkaline drainage from coal mines in the upper Guyandotte River basin. Streams in the lower Guyandotte River basin and Twelvepole Creek basin generally had lower pH values (median pH values were 6.9 and 6.8 respectively).

Chisholm (Bader and others, 1980) reported a median pH value of 7.8 for streams in the Guyandotte River basin for the period 1975 to 1976. Most streams in the upper Guyandotte River basin had pH values of 6.6 or greater. Some streams having a low pH in 1975 (sites 10 and 26) still had among the lowest median pH values in 1979 and 1980.

The major chemical reactions affecting pH in streams draining the area are the solution and hydrolysis of carbonates and the oxidation of sulfur minerals, mainly pyrite. Acidic rain may affect surface-water pH also, but these effects are largely unknown at this time.

The solution and hydrolysis of carbonates cause the pH of surface water to increase. The reaction which occurs is generalized for limestone but would also occur for other forms of carbonate:

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

and

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

Carbonate minerals occurring in Area 12 include limestone ($CaCO_3$) and siderite ($FeCO_3$). Other carbonate minerals occur less frequently. Few limestone beds are found in Area 12. Most of the limestone beds found are in the Kanawha Formation of the Pottsville Group. Hennen and Gawthrop (1915) list limestone beds totaling 12 feet in thickness in an 1,830-foot thick section of the Kanawha Group (Kanawha Formation, modern designation according to Cardwell and others, 1968) in Wyoming County. Most limestone occurs as thin lenses between beds of sandstone, shale, and coal. Iron carbonate (siderite) occurs in shale and sandstone strata throughout Logan and Wyoming Counties.

Underground-mining techniques affect the pH of surface water. Mining regulations require that underground-mine surfaces be coated with powdered limestone to reduce the potential for coal dust explosions. Water dissolves part of this limestone, thus drainage from active mines often is alkaline.

The oxidation of sulfides causes the pH of affected streams to become acidic. The most common sulfide in the area is pyrite, FeS_2. It commonly

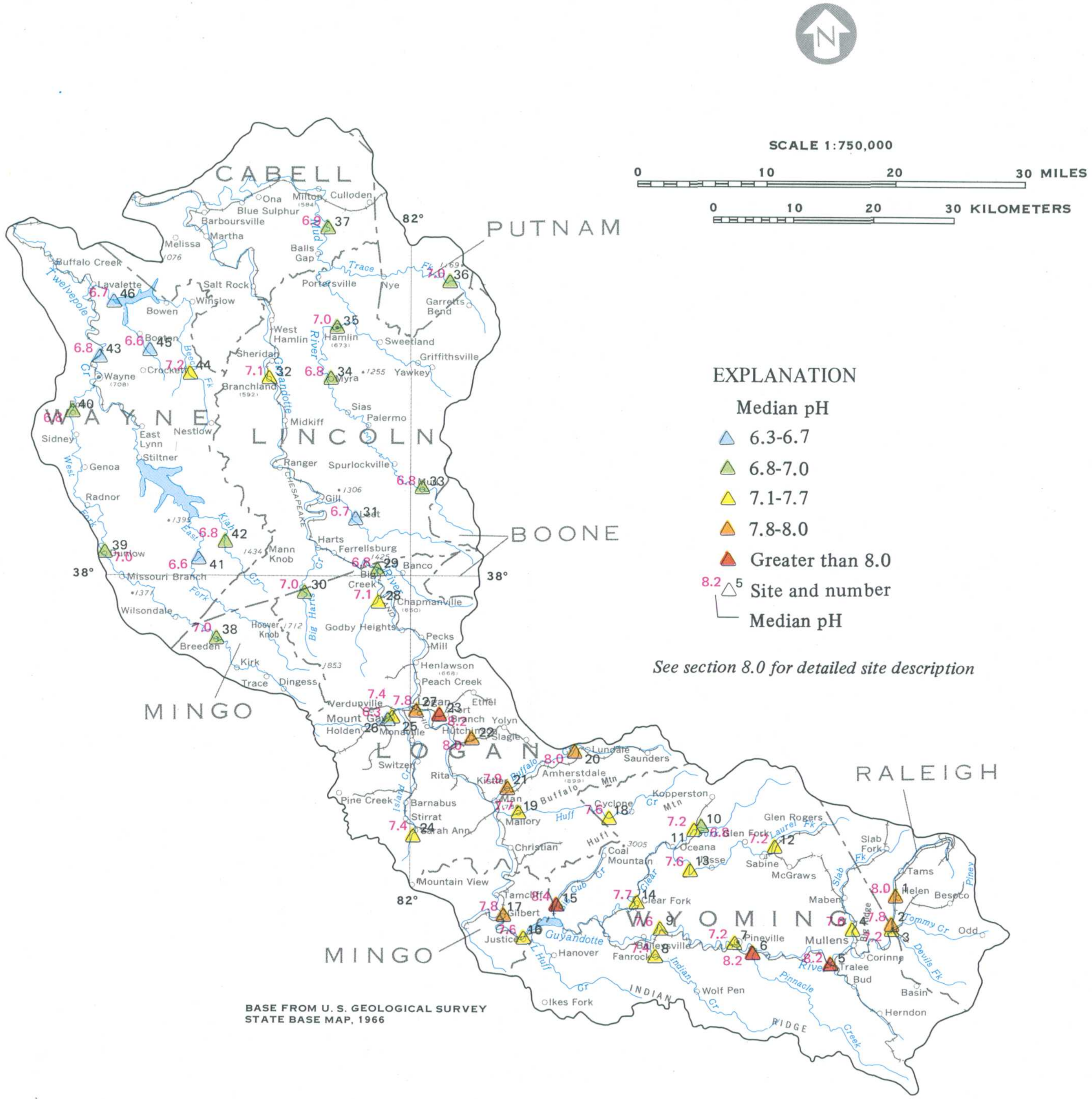


Figure 6.4.3-1 Median pH at surface-water sites.

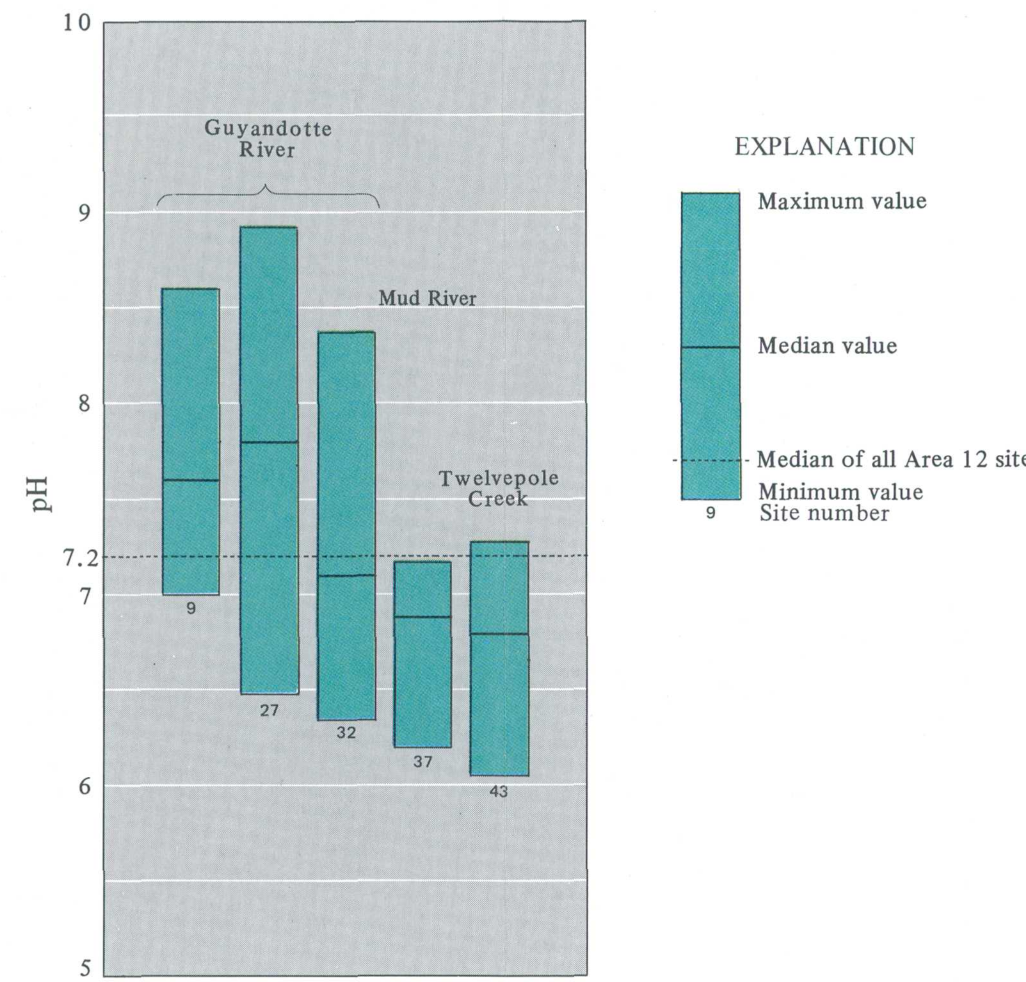


Figure 6.4.3-2 Range of pH at selected surface-water sites.

occurs with coal, shale, and sandstone. Pyritic minerals in mine refuse piles and in active and abandoned coal mines are oxidized when exposed to oxygen, moisture, and autotrophic bacteria (Thiobacillus). The reaction rate occurs as follows:

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

The distribution of sulfides in the rocks underlying Area 12 is unknown, but the occurrence of sulfides in coal is well documented (Barlow, 1974). In general, the sulfur content is lower in coals of the older rocks such as the Pocahontas Formation and greater in the younger rocks such as the Allegheny Formation and Conemaugh and Monongahela Groups which overlie the Pocahontas Formation. The younger rocks are exposed in northern portions of Area 12. Water draining from these rocks may result in some reduction in the pH of surface water in the lower Guyandotte River and Twelvepole Creek basins.

Highest Alkalinity Values Occur in Upper Guyandotte River Basin

The mean alkalinity of surface water at synoptic sites in Area 12 was 43 milligrams per liter. The carbonate content of rock strata underlying the area and underground coal mining affect surface water alkalinity.

Alkalinity is the ability of water to resist pH change brought about by addition of strong acid and is a measure of the buffering capacity of water. Alkalinity is due to the presence of carbonate, bicarbonate, and hydroxyl ions in water. Surface water in the area varies widely in its alkalinity content. Rainfall has almost no buffering capacity, alkalinity typically less than 1 mg/L (milligram per liter), while surface water draining undisturbed regions in Area 12 generally has alkalinity values ranging from 10 to 30 mg/L. Ground water in the area generally has the highest alkalinities because of high bicarbonate and carbonate content and can have alkalinity values exceeding 300 mg/L.

The alkalinity in surface water at synoptic sites ranged from 4 to 246 mg/L and had a mean value of 43 mg/L. The mean alkalinity value at each site is shown in figure 6.4.4-1 and the range of alkalinity at selected sites is shown in figure 6.4.4-2. Streams in the upper Guyandotte River basin had the highest mean alkalinity, 55 mg/L, and streams in Twelvepole Creek basin had the lowest, 23 mg/L. The range of alkalinity in streams draining the upper Guyandotte River basin was much greater than the range of alkalinity in streams draining the lower Guyandotte River and Twelvepole Creek basins.

The major factors influencing the alkalinity of surface water in the area are the carbonate content of the rocks and the influence of underground coal mining. Carbonate minerals found in Area 12 include limestone ($CaCO_3$) and siderite ($FeCO_3$). Limestone is uncommon in the area but there are some beds in the Kanawha Formation. Hennen and Gawthrop (1915) list limestone beds totaling 12 feet in thickness in an 1,830-foot thick section of the Kanawha Group (Kanawha Formation, modern designation according to Cardwell and others, 1968) in Wyoming County. Most limestone occurs as thin lenses between beds of sandstone, shale, and coal. Iron carbonate also occurs in shale and sandstone in the Kanawha Formation. Iron hydroxides are another possible source of alkalinity but are less soluble than carbonates.

Drainage from underground mines affects the alkalinity of surface water in the upper Guyandotte River basin. Mining regulations require that underground mine surfaces be coated with powdered limestone to reduce the potential for coal dust explosions. The solution of the limestone powder can make drainage or pumpage from active underground mines highly alkaline. For example, the mean alkalinity of drainage from 22 active underground mines in the upper Guyandotte River basin was 182 mg/L, about 3 times the mean alkalinity of streams unaffected by mining (James W. Borchers, written communication, 1981). The quantity of water contributed to streams throughout Area 12 by underground mines is variable but substantial. In two small (less than 10 square miles) basins in the upper Guyandotte River basin, active mines contributed 14 to 34 percent of their basin's total streamflow during a period of low flow (James W. Borchers, written communications, 1981).

Figure 6.4.4-1 Mean alkalinity at surface-water sites.

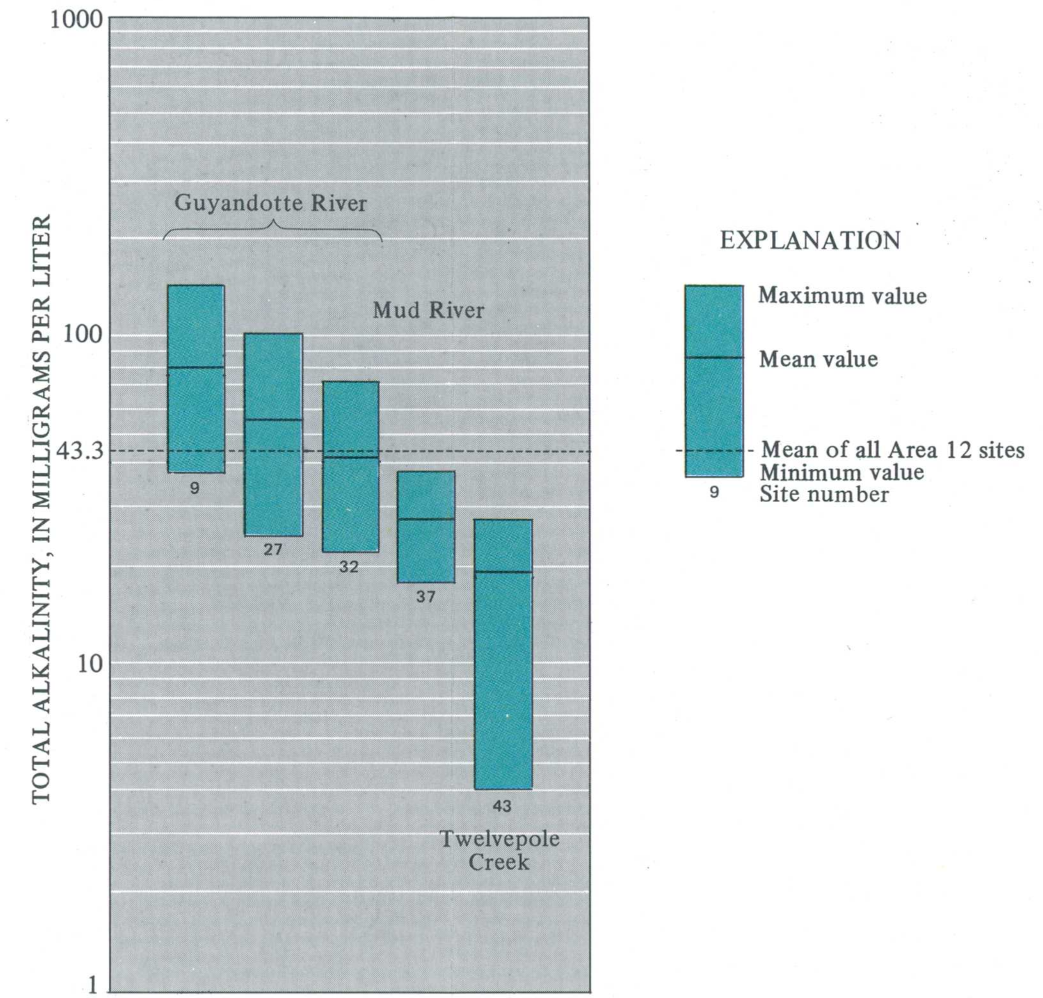


Figure 6.4.4-2 Range of alkalinity at selected surface-water sites.

Highest Sulfate Concentrations Occur in the Upper Guyandotte River Basin

The mean concentration of sulfate in surface water at synoptic sites was 79 milligrams per liter. Streams in the upper Guyandotte River basin had the highest mean sulfate concentration, 109 milligrams per liter. The oxidation of pyritic minerals in mine spoils is a major source of sulfate.

The concentration of sulfate in surface water at synoptic sites throughout Area 12 ranged from 6.6 to 400 mg/L (milligrams per liter) and had a mean value of 79 mg/L. Streams in the upper Guyandotte River basin had the highest mean sulfate concentration (109 mg/L), whereas streams draining the lower Guyandotte River basin had a much lower mean sulfate concentration (45 mg/L). Streams draining the Twelvepole Creek basin had the lowest mean sulfate concentration (19 mg/L). The range of sulfate concentration was greatest (9.3 to 400 mg/L) in the upper Guyandotte River basin where most coal mining occurs. The mean concentration of sulfate at each site is shown in figure 6.4.5-1. The range of sulfate concentrations at selected sites is given in figure 6.4.5-2. Streamflow conditions during 1979 and 1980 sampling periods were generally in the low to moderate flow range.

A major source of sulfate is the oxidation of sulfides, mainly pyrite (FeS_2), contained in coal, shale, and sandstone throughout the area. Pyritic minerals in mine-refuse piles and in active and abandoned coal mines are oxidized when exposed to oxygen, moisture, and autotrophic bacteria (Thiobacillus). Sulfate concentrations in leachate from mine spoil have been reported to range from 58 to 4,220 mg/L (Lindorff, 1980). The reaction rate occurs as follows:

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

Drainage from underground coal mines and abandoned surface-mined areas has a significant effect on the sulfate concentration in surface water in Area 12. The majority of coal mines and mine-waste piles are located in the upper Guyandotte River basin. Statistical analysis indicates that sulfate concentrations are significantly higher (at the one percent level of significance) in streams draining the upper Guyandotte River basin than those in streams draining the lower Guyandotte River -Twelvepole Creek basins. Similarly, data from a study of small basins in the upper Guyandotte River basin indicated that sulfate concentrations of streams draining heavily mined areas were 8 to 12 times higher than those of streams draining predominantly unmined basins (James W. Borchers, written communications, 1981).

The amount of water contributed to streams from mined areas is variable but substantial. In two small basins (less than 10 square miles) in the upper Guyandotte River basin, active mines contributed 14 to 34 percent of their basin's total streamflow during a period of low flow (Borchers, written communication, 1981). For this reason, drainage from coal mines increases the sulfate concentration in surface water in the upper Guyandotte River basin.

The occurrence of pyrite in the rocks of Area 12 has not been documented, but the occurrence of pyrite in coal is well known (Barlow, 1974). The sulfur content is lowest in older rocks such as the Pocahontas Formation, ranging from 0.5 to 1.5 percent sulfur. Coals in younger rocks such as the Allegheny Formation and Conemaugh and Monongahela Groups which overlie the Pocahontas Formation have a higher sulfur content. The coal beds have a progressively higher sulfur content towards the north (fig. 6.4.5-3).

Another source of sulfate is precipitation. The average concentration of sulfate in rainfall in Area 12 is 6.8 mg/L (P. E. Zurbuch, personal communication, 1981). This suggests that precipitation supplies a small, but measurable amount of sulfate to surface water in the area.

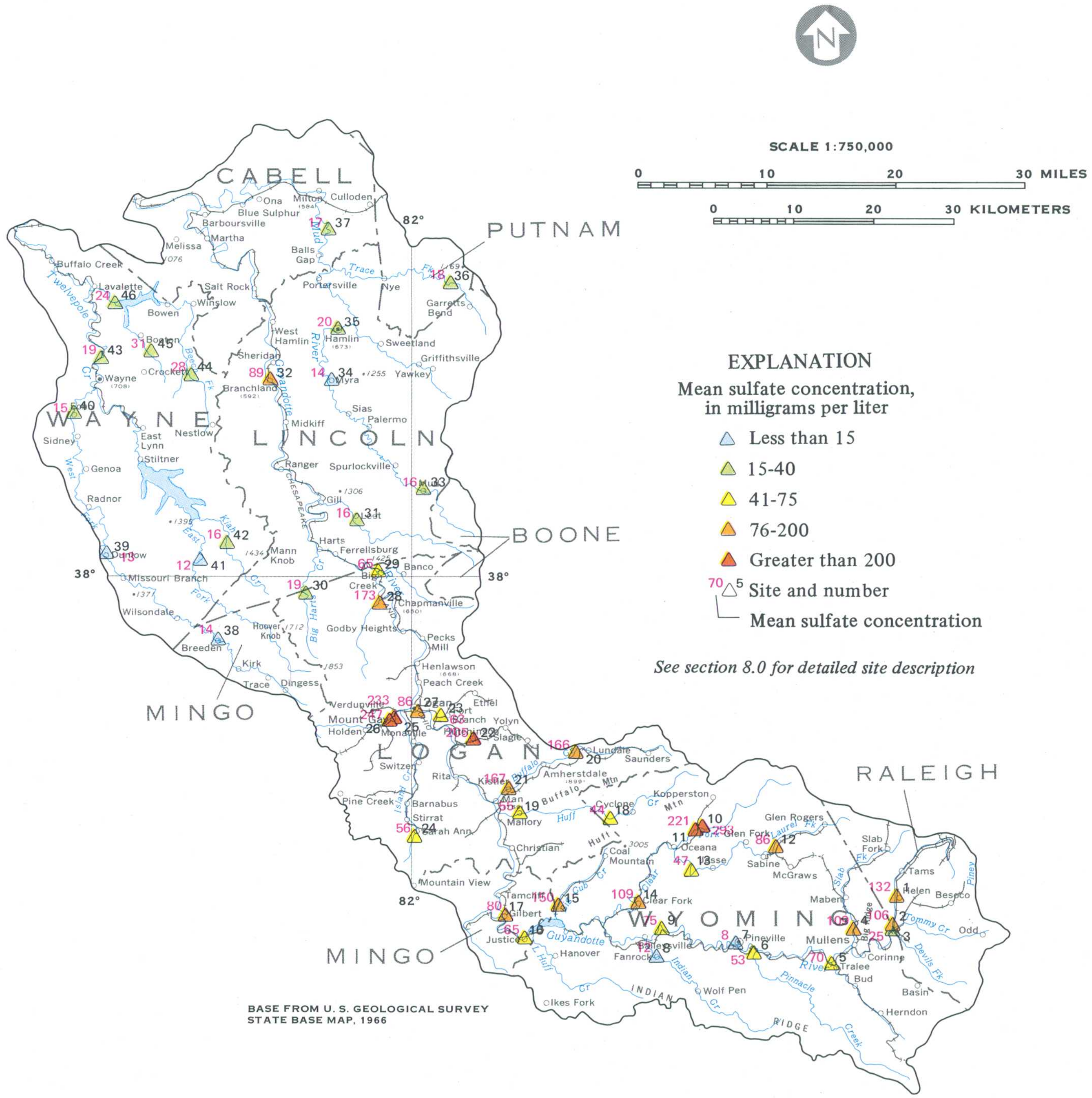


Figure 6.4.5-1 Mean sulfate concentrations at surface-water sites.

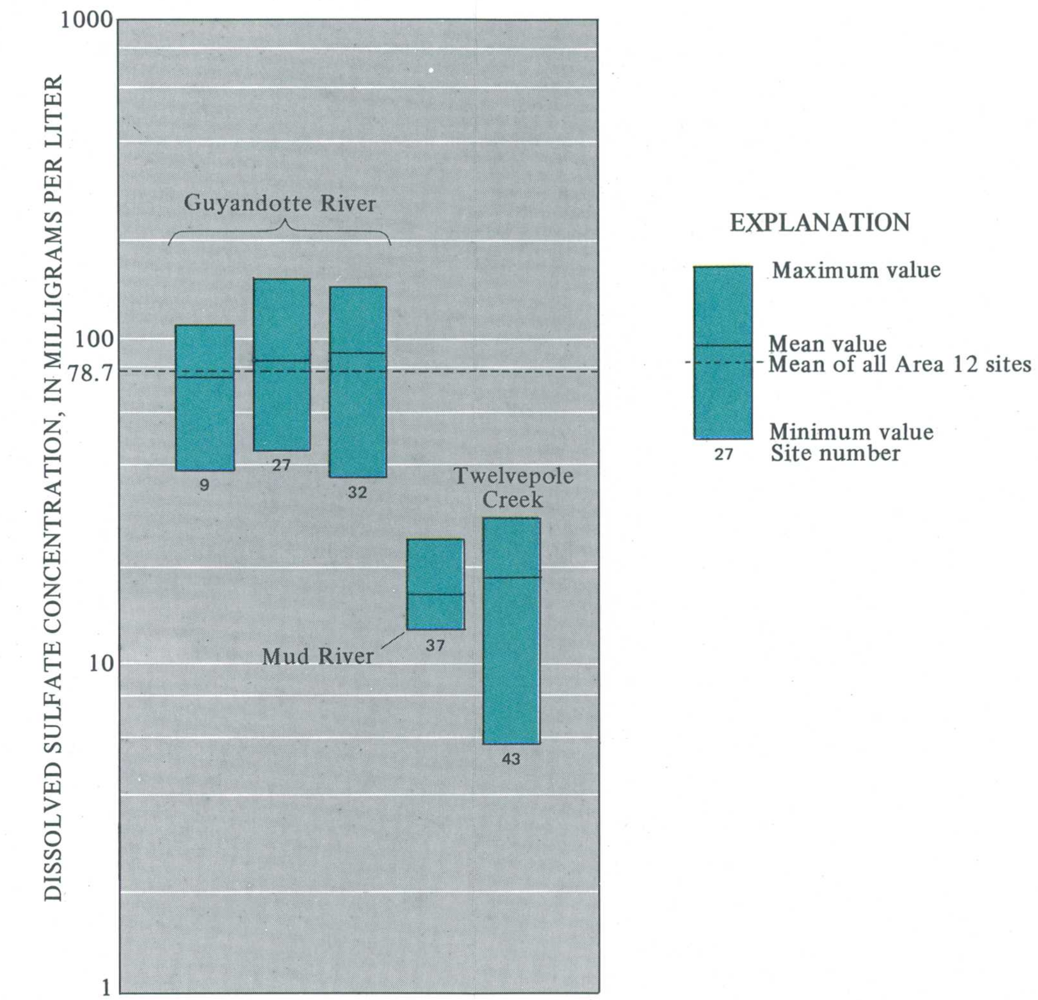


Figure 6.4.5-2 Range of sulfate concentrations at selected surface-water sites.

Iron Concentrations in Streams Draining the Guyandotte River Basin and the Twelvepole Creek Basin are Similar

The mean concentration of total iron in surface water at synoptic sites was 1,300 micrograms per liter. The mean concentrations of total iron in streams draining the Guyandotte River basin and Twelvepole Creek basin were similar.

Iron is common in streams throughout Area 12. High iron concentrations add a disagreeable taste to the water and can clog pipes and stain fixtures. High iron concentrations also affect fish and other aquatic life. In-stream water-quality standards (West Virginia State Water Resources Board, 1980) set a maximum of 1,000 μg/L (micrograms per liter) total iron (sum of dissolved and suspended concentrations) for most streams in the area, but only 500 μg/L for trout streams. These limits are presently exceeded in many streams throughout the area.

The concentration of total iron in surface water at synoptic sites throughout Area 12 ranged from 90 to 27,000 μg/L and had a mean of 1,300μg/L. Mean dissolved and total iron concentrations for each measuring site are shown in figures 6.4.6-1 and 6.4.6-2. Mean concentrations of dissolved and total iron in streams in the upper Guyandotte River basin were 112 and 1,426 μg/L, respectively; those for streams in the lower Guyandotte River basin were 116 and 1,221 μg/L, respectively. Mean dissolved and total iron concentrations for streams in Twelvepole Creek basin were 155 and 1,167 μg/L, respectively. Mean concentrations of dissolved as well as total iron for all sites in the upper and lower Guyandotte River and Twelvepole Creek basins were similar. The range of concentrations was greatest in the upper Guyandotte River basin. Most of the iron (91 percent) transported in streams during the 1979 and 1980 measuring period was in the suspended phase. Streamflow conditions generally ranged from low to moderate.

In a previous study, Chisholm (Bader and others, 1980) reported that in 1975 and 1976 most streams in the Guyandotte River basin contained mean dissolved iron concentrations of less than 150 μg/L. This was still true in 1980, although two streams (sites 12 and 26) contained mean concentrations in excess of 500 μg/L.

Iron is abundant in the Pottsville Group. It occurs mainly as pyrite (FeS_2), siderite ($FeCO_3$), oxide (Fe_2O_3), and hydroxide [$Fe(OH)_3$] in coal, sandstone and shale. Weathering of rock outcrops containing these minerals probably accounts for much of the iron in surface water. Iron, like most metals, becomes more soluble as the pH of water decreases.

Mining influences the concentration of iron in surface water in several ways; it creates large quantities of spoil material which are deposited on the land surface in large piles. Drainage from these spoil piles can contain iron concentrations in excess of 1,000 mg/L (milligrams per liter) (1×10^6 μg/L) (Krothe and others 1980). When the drainage from spoil areas enters a stream, the dissolved iron is oxidized from the ferrous (Fe^{+2}) to the much less soluble ferric (Fe^{+3}) state. The iron precipitates as a yellowish-red deposit in the stream channel. In Area 12 the majority of the mine-refuse (spoil) piles are located in the upper Guyandotte River basin.

Drainage from active mines is another source of high iron concentrations. The mean concentration of dissolved iron from 22 active underground mines in the upper Guyandotte River basin was 1,400 μg/L, or about 9 to 28 times the mean dissolved iron concentration of streams draining undisturbed areas (James W. Borchers, written communication, 1981). The amount of water contributed to streams in Area 12 from mines and mine refuse piles is variable but substantial. In two small (less than 10 square miles) basins in the upper Guyandotte River basin, active mines contributed 14 to 34 percent of their basin's

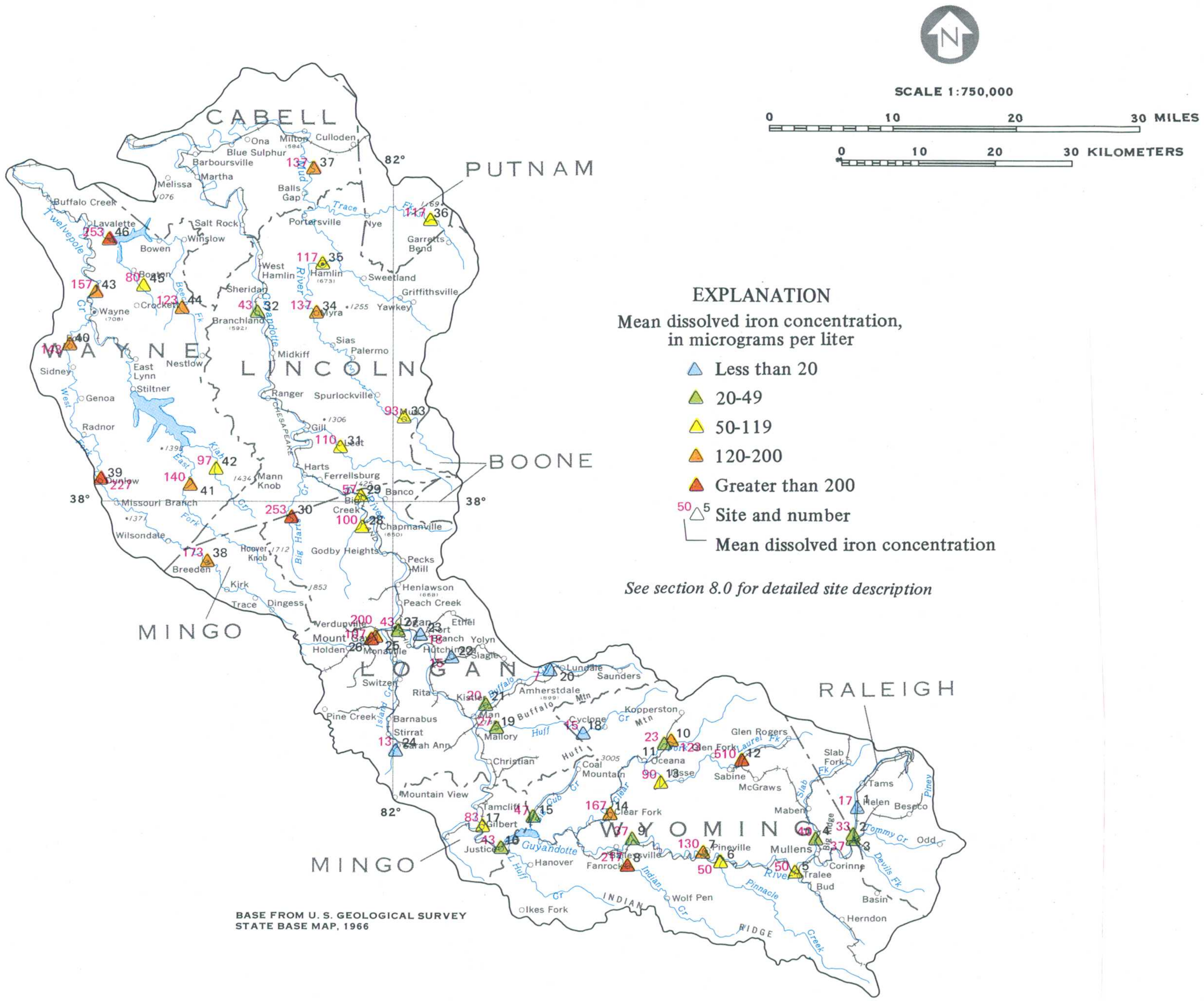


Figure 6.4.6-1 Mean concentrations of dissolved iron at surface-water sites.

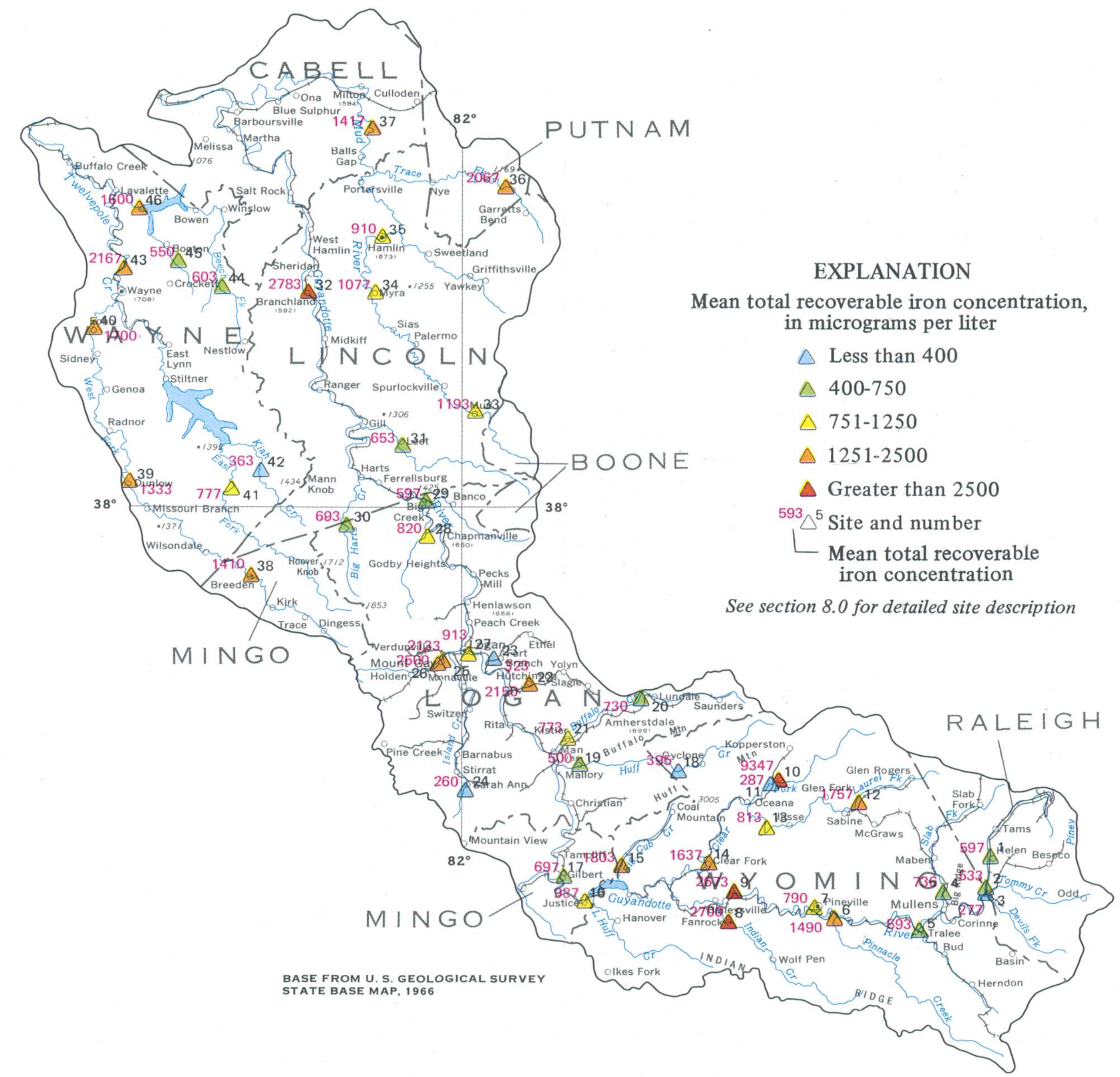


Figure 6.4.6-2 Mean concentrations of total recoverable iron at surface-water sites.

total streamflow during a period of low flow. For this reason, the contribution of iron from mines and mine refuse piles to surface water in the upper Guyandotte River basin may be substantial.

Manganese Concentrations Greatest in the Upper Guyandotte River Basin

The mean concentration of dissolved manganese in surface water at synoptic sites was 166 micrograms per liter. The sources of manganese include the natural weathering of rocks containing manganese and drainage from mines and mine-refuse piles.

Manganese is a common trace element in surface and ground water throughout Area 12. Manganese is an essential element for plants and animals but is reportedly toxic at high concentrations. For example, a mean concentration of 5,700 μg/L (micrograms per liter) was found to be lethal to 50 percent of a study group of fresh-water crustaceans (*Daphnia magna* - water flea) in a 3-week test period (Biesinger and Christensen, 1972). The most important mechanism of toxic action is thought to be the poisoning of enzymes (Bowen, 1966). The West Virginia instream water-quality standards for all surface water in the area limit manganese concentration to 1,000 μg/L (West Virginia State Water Resources Board, 1980).

The mean concentration of dissolved manganese in surface water at synoptic sites throughout the area was 166 μg/L.

Streams in the upper Guyandotte River basin contained the greatest mean dissolved manganese concentration, an average of 207 μg/L from 27 sites. The range of dissolved manganese concentrations was also greatest in the upper Guyandotte River basin (10 to 2,100 μg/L). Streams draining Twelvepole Creek basin contained the lowest mean dissolved manganese concentration, an average of 106 μg/L at 9 sites. Mean dissolved manganese concentration at each site is shown in figure 6.4.7-1. Most of the manganese (77 percent) was transported in the dissolved phase during the streamflow conditions encountered (low to medium flow) at the time of sampling in 1979 and 1980.

Manganese occurs in the rocks as oxide (MnO_2) and hydroxide [$Mn(OH)_2$] forms, and as rhodochrosite ($MnCO_3$). Manganese enters surface water by the weathering of these minerals, but also is often present in high concentrations in drainage from mine areas. Anderson and Youngstrom (1976) reported that the mean concentration of manganese in coal-pile drainage can be as high as 17,000 μg/L. James W. Borchers (written communication, 1981) found that the mean concentration of dissolved manganese in drainage from 22 active underground mines in the upper Guyandotte River basin was 1,300 μg/L, or about 3 to 10 times the dissolved manganese concentration of streams draining undisturbed areas. The amount of water contributed to streams throughout the area from these sources is variable but substantial. In two small (less than 10 square miles) basins in the upper Guyandotte River basin, active mines contributed 14 to 34 percent of their basin's total streamflow during a period of low flow (James W. Borchers, written communication, 1981). For this reason, drainage from underground coal mines may substantially increase the concentration of manganese in surface water in the upper Guyandotte River basin.

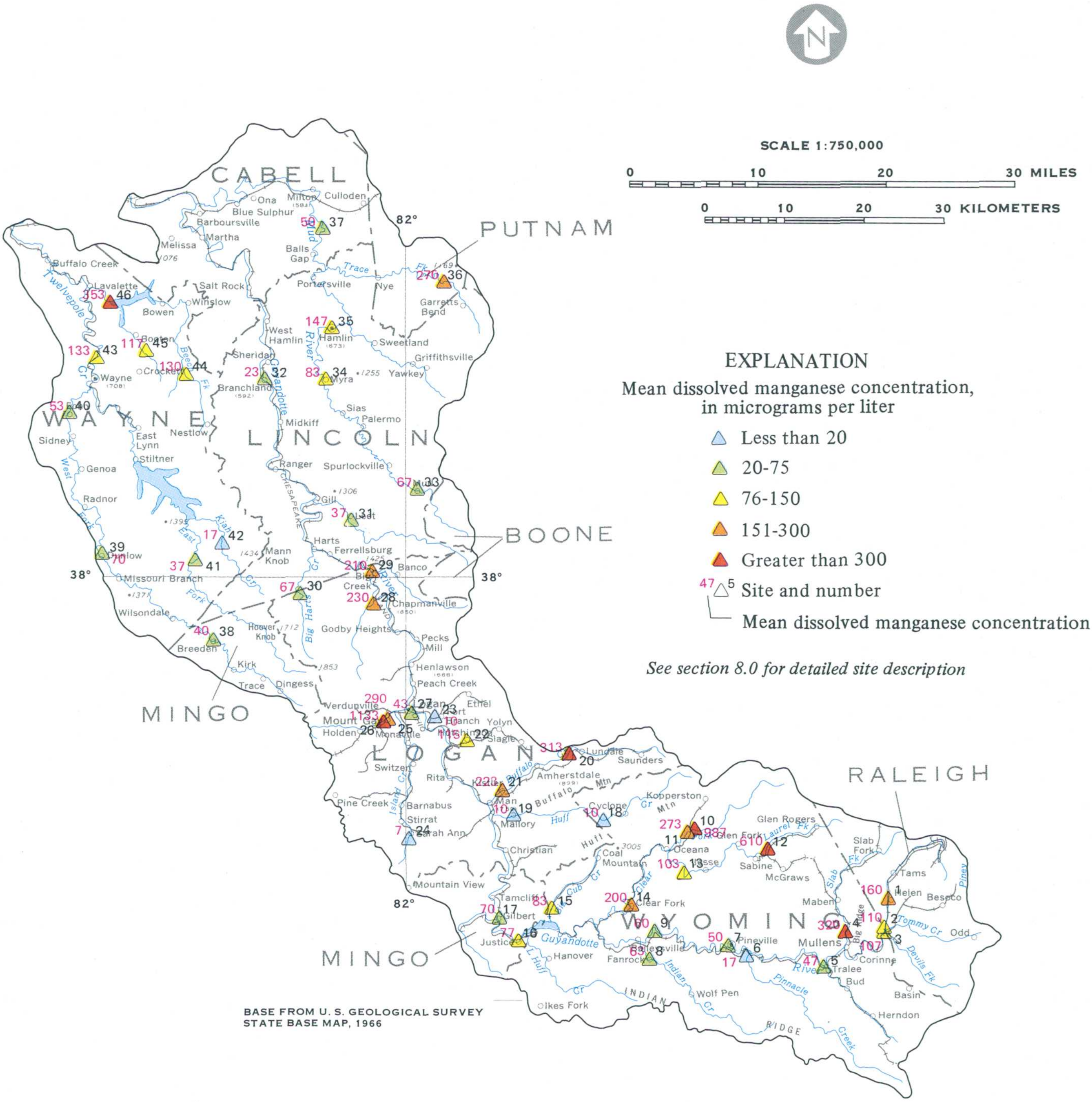


Figure 6.4.7-1. Mean dissolved manganese concentrations at surface-water sites.

Sediment Yields Range from 23 to 452 Tons Per Square Mile Per Year

Sediment yields from selected streams in Area 12 are relatively low and range from 23 to 452 tons per square mile per year. The majority of sediment loads are transported during high-flow periods.

Average annual sediment yields of selected streams draining Area 12 are relatively low and range from 23 to 452 (tons/mi^2)/yr (tons per square mile per year). Most of the area is characterized by hilly terrain with moderate to steep slopes and easily erodible soils. These characteristics produce rapid runoff with high erosion potential. Most of the area, however, has dense forest cover that aids in the protection of the soil from erosion.

Land-use activities such as forest clearing, cultivation, road construction, and surface mining drastically alter natural sediment yields. Eckhardt (1976) reported that sediment yields from highway construction can be as high as 66,000 (tons/mi^2)/yr. During surface mining, large volumes of exposed unconsolidated materials generally are a major source of sediment. Although sediment yields associated with surface mining can be high, they can be reduced by effective reclamation.

Suspended-sediment concentration ranges, estimated average-annual sediment yields, period of record, and drainage areas for sites shown in figure 6.4.8-1 are given in table 6.4.8-1. Other data for these sites are given in section 8.0. The sites are located in an area of similar climate and topography and are primarily underlain by the Pottsville, Conemaugh, and Monongahela Groups. Most of the suspended-sediment loads were transported during high-flow periods. During the 1979 water year, the amount of suspended sediment transported during the ten days of highest flow at sites 51, 49, 50, 47, 9, and 48 averaged 76 percent and ranged from 60 to 85 percent of the annual sediment load.

Suspended-sediment yield curves for selected streams (sites 49 and 51) are shown in figure 6.4.8-2. Site 49 drains a relatively undisturbed basin, whereas site 51 drains a basin with considerable surface-mined area (20 percent). The difference in land use between the basins is reflected by the relative positions of their sediment-yield curves (fig. 6.4.8-2).

Particle-size distribution of suspended sediment transported during high flows at sites 51, 50, 47, 9, and 37 was predominantly in the clay and silt range, finer than 0.062 mm (millimeters). The particle-size distribution for all sites averaged 80 percent clay and silt and 20 percent sand, 0.062-2.0 mm; clay and silt size fractions of the distributions ranged from 55 to 96 percent, whereas sand ranged from 4 to 45 percent.

Bedload, the sediment transported along and immediately adjacent to the streambed, is unmeasured and not included in reported sediment yields.

Figure 6.4.8-1 Suspended sediment sampling sites.

Table 6.4.8-1 Summary of suspended-sediment data for selected sites.

SITE NUMBER	STATION NAME	DRAINAGE AREA (MI²)	PERIOD OF RECORD *	SUSPENDED-SEDIMENT CONCENTRATION RANGE (MG/L)	ESTIMATED AVERAGE ANNUAL SEDIMENT YIELD [(TONS/MI²)/YR]
6	Pinnacle Creek near Pineville	56.9	1975-76	0 - 92	23
8	Indian Creek at Fanrock	40.7	1974-76	1 - 1660	80
9	Guyandotte River near Baileysville	308	1969-76	0 - 2710	370
14	Clear Fork at Clear Fork	124	1974-76	1 - 984	248
27	Guyandotte River at Logan	836	1975-76	4 - 1750	204
32	Guyandotte River at Branchland	1226	1975-76	0 - 3780	280
37	Mud River near Milton	256	1975-76	1 - 988	203
47	Bearhole Fork at Pineville	6.27	1977-79	0 - 728	240
48	Milam Fork at McGraws	6.64	1977-79	0 - 794	170
49	Marsh Fork at Maben	4.85	1977-79	0 - 1450	160
50	Still Run at Itmann	7.12	1977-79	0 - 2190	350
51	Allen Creek at Allen Junction	8.43	1977-79	0 - 1440	210
52	Mud River at Barboursville	360	1975-76	1 - 555	135
53	Mud River at Palermo	51.1	1975-76	1 - 418	180
54	Buffalo Creek at Man	45.6	1975-76	7 - 22,900	452
55	Island Creek at Logan	103	1975-76	20 - 584	296

*Period for which these computations were made.

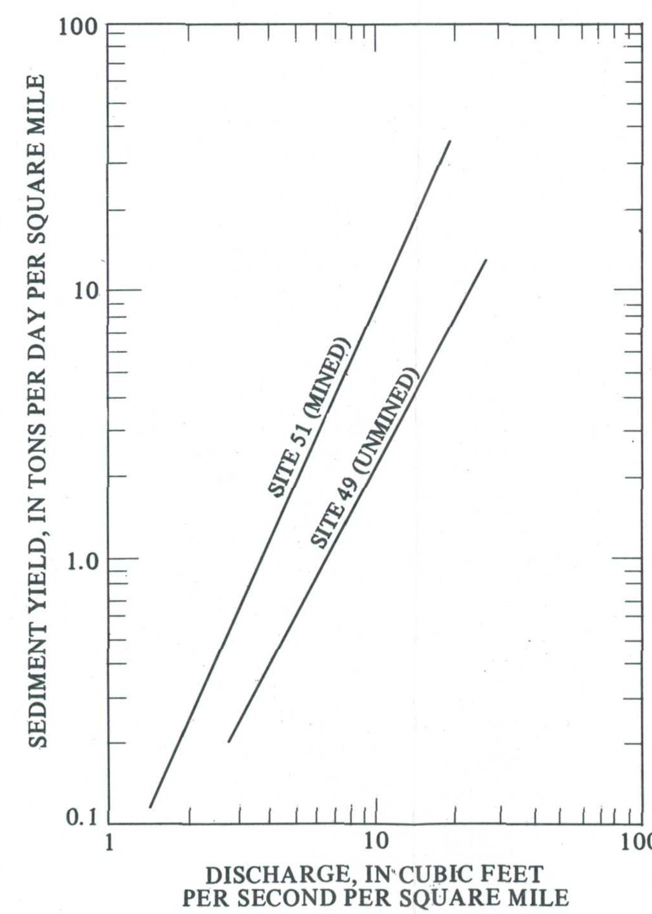


Figure 6.4.8-2 Relation of suspended sediment to stream discharge in mined and unmined areas.

Iron Transported Primarily by Suspended Sediment

Suspended sediment is the major transport mechanism for iron in surface water throughout Area 12. Most of the iron is transported during high flows, which occur during several days each year.

Suspended sediment is the major transport mechanism for iron in Area 12 because of the low solubility of iron in surface water. Chemical analyses of water samples collected indicate the predominance of iron in the particulate 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 the sediment particles in suspension. The surface area per unit weight of sediment increases as the particle size decreases. The inverse relation 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 coarser fractions of suspended sediment (Feltz, 1980). Rickert and others (1977) and Wilber and Hunter (1975) also reported that the concentration of metals in bottom material was strongly dependent on the particle-size distribution of the sample. In general, the quantity of metals on bottom-material samples increases as the sediment particle size decreases.

Using data for the sampling period of August 18-22, 1980, a least-squares fit (regression analysis) of the suspended sediment and total iron concentration resulted in the relationship shown in figure 6.4.9-1. The regression equation and the coefficient of determination (r^2) are expressed as follows:

$$[Fe] = 99.45\,[S]^{0.78}$$
$$r^2 = 0.91$$

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

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

r^2 is the proportion of the total variation of [Fe] explained by the variable [S].

The relation shown in figure 6.4.9-1 may be used for estimating total iron loads leaving basins in Area 12; however, it should not be used beyond the suspended-sediment concentration range shown in the graph. Although significant quantities of iron can be transported over long periods of time when suspended-sediment concentrations are very low, the majority of the total iron load is transported with suspended sediment during a few high-flow periods each year. This load is primarily precipitated and sorbed iron which has accumulated in bottom material over an extended period between high flows. Daily suspended-sediment loads in the Guyandotte River at Baileysville (site 9) indicate that the majority of the annual suspended-sediment load during 1979 (84,700 of 137,363 tons or 62 percent of the annual load) was transported during 10 days of high streamflow ranging from 2,130 to 7,170 ft^3/s (cubic feet per second). A total of 57,300 tons (42 percent of the annual load) was transported during a 3-day period. During a 284-day period of low streamflow ranging from 23 to 1,090 ft^3/s, less than 1 percent of the total annual suspended-sediment load was transported. It is estimated that about 3,138 tons of iron was similarly transported in suspension at site 9 in 1979, most of it (1,749 tons) during a 10-day period.

Suspended sediment in the Guyandotte River (site 32) consists mostly of fine material. During the period of 1977-1980, most suspended sediment (59 percent) consisted of particles finer than 0.062 mm (millimeters) in diameter. During the year from October 1, 1976 to September 30, 1977, an estimated 28,740 tons (79 tons per day) of total iron was transported past site 32. This estimate is based on the relation shown in figure 6.4.9-1 and mean-annual discharge and sediment concentration at site 32. The greatest quantity of iron (17,795 tons) was transported during the months of February, March, and April. About 22 percent of the annual total iron load was transported during a 3-day period.

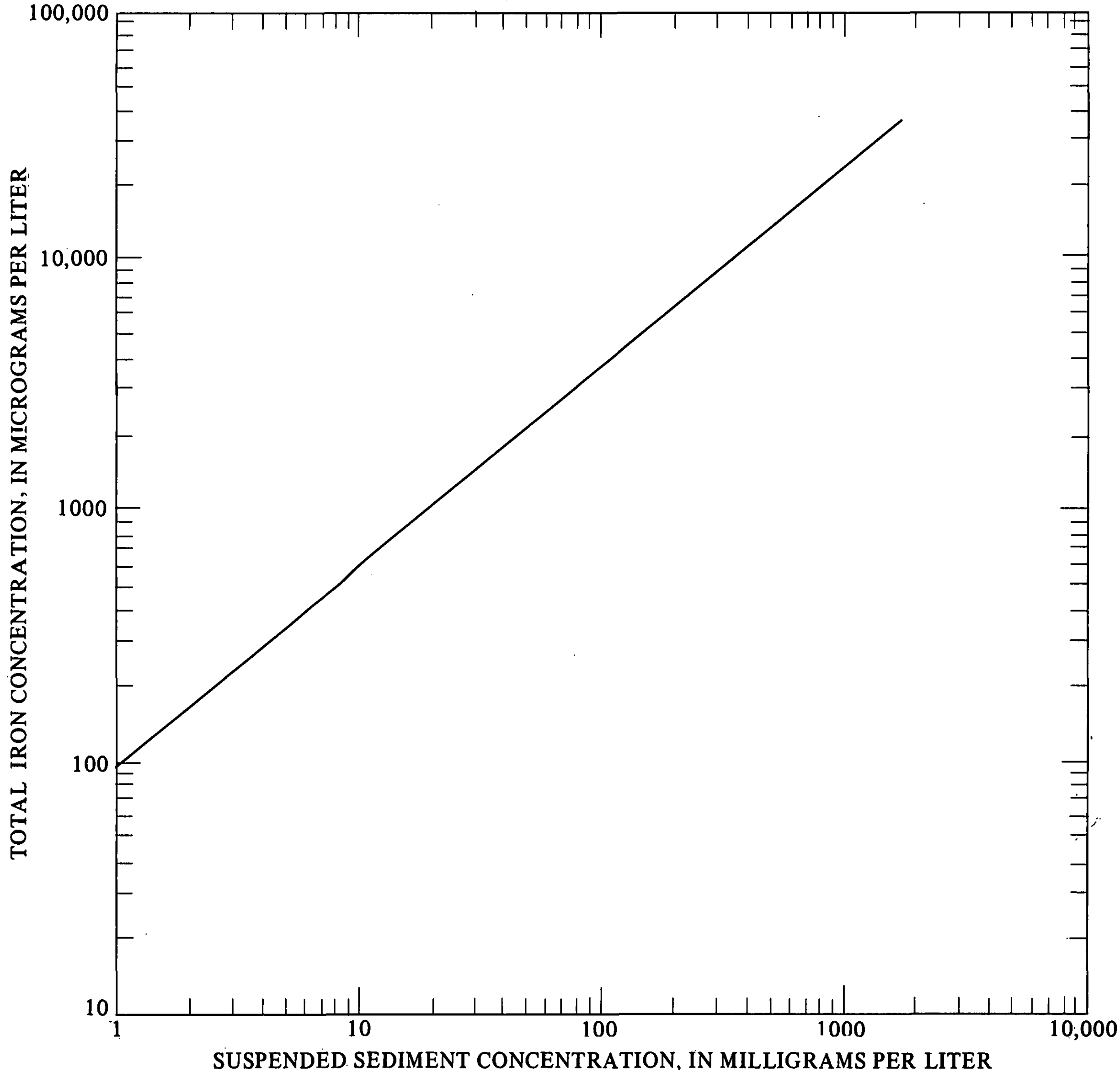


Figure 6.4.9-1 Relation of suspended-sediment concentration to total iron concentration.

NAWDEX, WATSTORE, OWDC Have Water-Data Information

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

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

(1) The National Water Data Exchange (NAWDEX), which indexes the water data available from 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 7.2, 7.3, and 7.4.

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 (fig. 7.2-1). A central Program Office located at U.S. Geological Survey national headquarters in Reston, Virginia, provides data-exchange policy and guidelines for participants. The major functions of the Program Office are to: (1) maintain a computerized Master Water Data Index (fig. 7.2-2) which identifies sites for which data are 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.7.2-3) 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 53 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

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

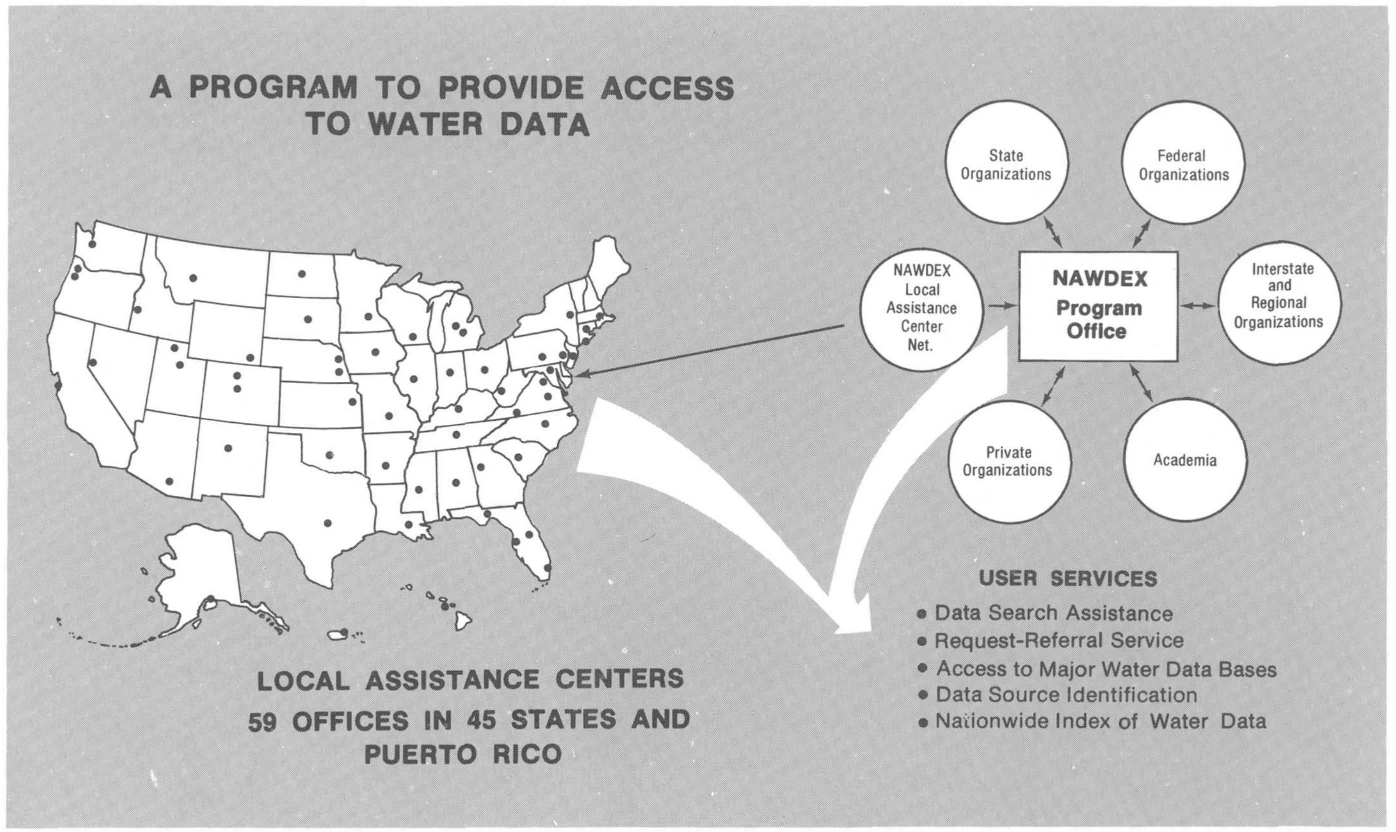


Figure 7.2-1 Access to water data.

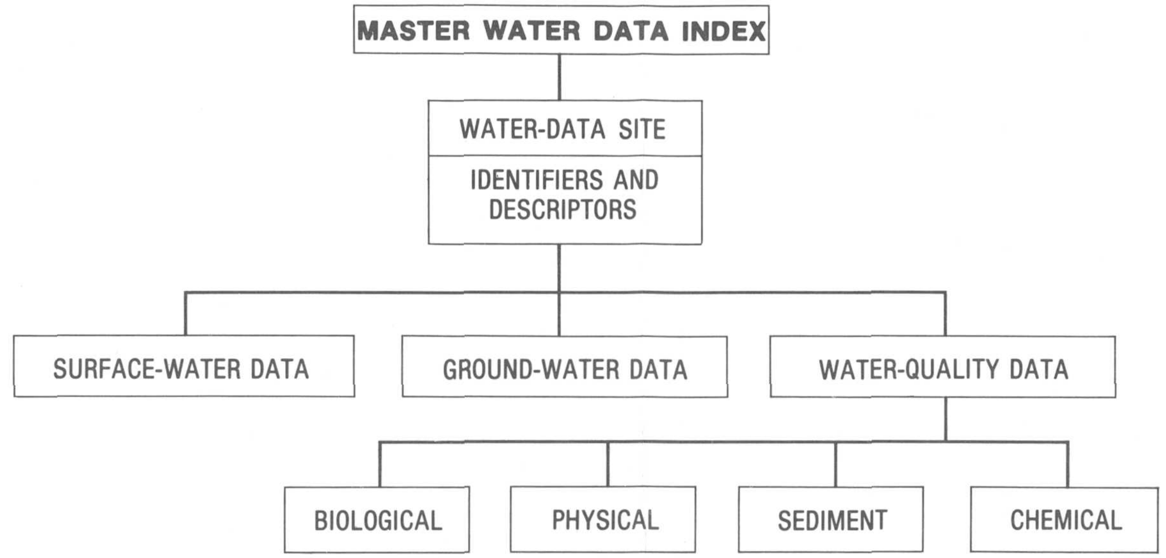


Figure 7.2-2 Master water-data index.

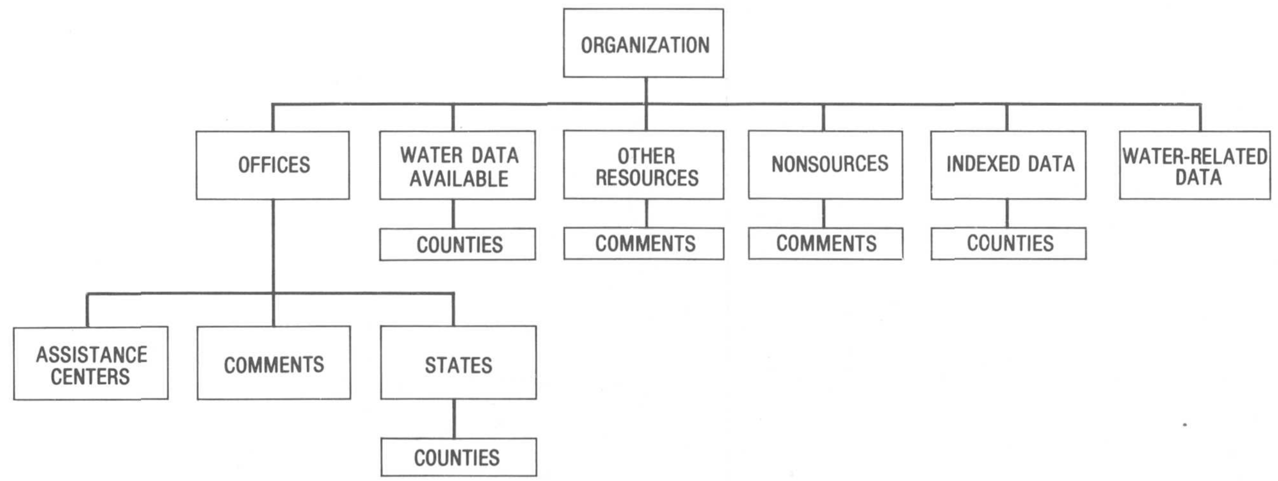


Figure 7.2-3 Water-data sources directory.

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
Federal Building and U.S. Court House
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. 7.3-1). 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 at intervals more frequent than daily are stored in this file. Rainfall, stream discharge, and temperature data are examples of the types of data stored in the Unit Values File.

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

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

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

Digital Transmission Sites: Digital recorders are used at many field locations to record values for parameters such as river stages, conductivity, water temperature, turbidity, wind direction, and chlorides. Data are recorded on 16-channel paper tape, which is removed from a recorder and transmitted over telephone lines to a receiver in Reston, Va. The data are recorded on magnetic tape for use on the central computer. Extensive testing of satellite data collection platforms indicates their feasibility for collecting real-time hydrologic data on a national scale. Battery-operated radios are used as the communication link to the satellite. About 200 data relay stations are being operated currently (1980).

Central Laboratory System: The Water Resources Division's two water-quality laboratories, located in Denver, Colorado, and Atlanta, Georgia, analyze more than 150,000 water samples per year. These laboratories are equipped to automatically perform chemical analyses ranging from determinations of simple inorganic compounds, such as 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, 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.

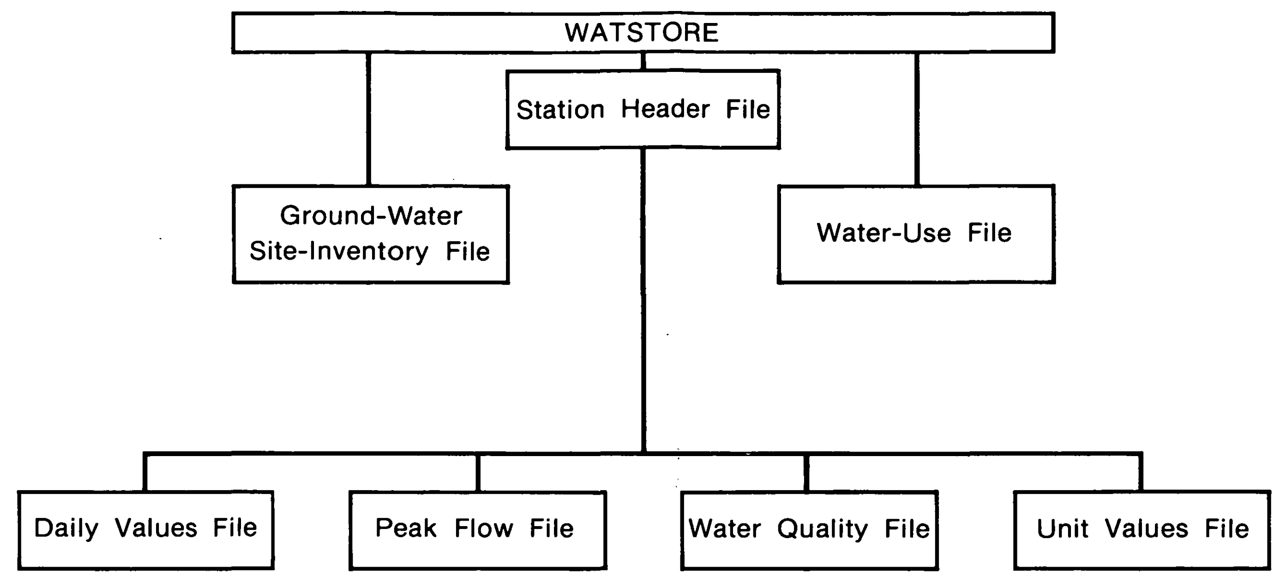


Figure 7.3-1 Index file stored data.

Water Data Indexed for Coal Provinces

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

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

This special index consists of five volumes (fig. 7.4.1): 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 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 7.2).

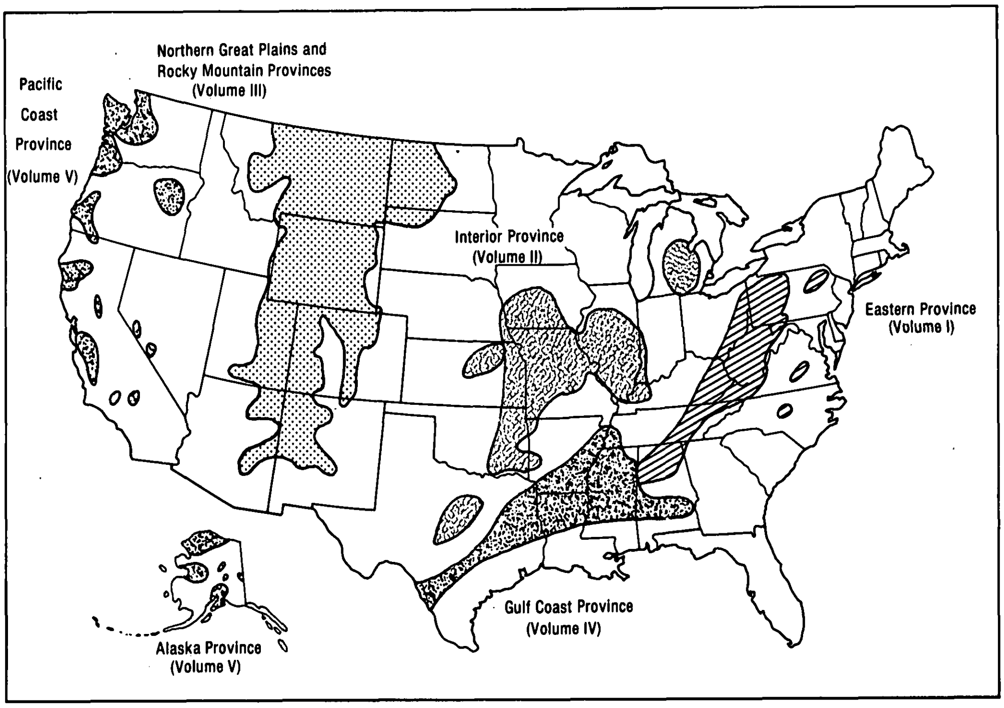


Figure 7.4-1 Index volumes and related provinces.

Station name, location, drainage area, and period of record for surface-water sites in Area 12.

Site number	Station name	Station number	Latitude	Longitude	Drainage area (mi²)	Discharge	Type of data, period of record, and sampling frequency1/: Chemical quality	Sediment
1	Winding Gulf at Highway 16/18 Bridge at Helen	---	37°38'09"	81°18'51"	18.9	I 1979-80	I 1979-80	I 1980
2	Stonecoal Creek at Highway 16 Bridge at Stonecoal	---	37°36'09"	81°19'18"	33.1	I 1979-80	I 1979-80	I 1980
3	Devils Fork at Highway 16 Bridge at Amigo	---	37°35'49"	81°19'14"	23.1	I 1979-80	I 1979-80	I 1980
4	Slab Fork at Highway 54 Bridge at Nuriva	---	37°36'01"	81°22'45"	32.7	I 1979-80	I 1979-80	I 1980
5	Barkers Creek at Bridge at Tralee	---	37°33'22"	81°24'03"	36.4	I 1979-80,	I 1979-80	I 1980
6	Pinnacle Creek at Highway 16 Bridge near Pineville	---	37°34'06"	81°31'58"	56.9	I 1975-76, I 1979-80	I 1975-76, I 1979-80	I 1975-76, I 1979-80
7	Rockcastle Creek at Highway 97 Bridge at Pineville	---	37°35'09"	81°31'55"	13.4	I 1979-80	I 1979-80	I 1980
*8	Indian Creek at Fanrock	03202490	37°34'00"	81°39'10"	40.7	C 1974-80	M 1974-80	D 1974-78, I 1980
*9	Guyandotte River near Baileysville	03202400	37°36'15"	81°38'44"	308	C 1968-80	M 1973-80	D 1973-80 I 1980
10	Clear Fork at Private Bridge at Toney Fork	---	37°42'46"	81°35'13"	24.2	I 1979-80	I 1979-80	I 1980
11	Toney Fork at Highway 2 Bridge at Toney Fork	---	37°42'46"	81°35'49"	8.88	I 1979-80	I 1979-80	I 1980
12	Laurel Fork at Highway 5 Bridge at Ravencliff	---	37°41'22"	81°29'03"	19.2	I 1979-80	I 1979-80	I 1980
13	Laurel Fork at Highway 9/9 Bridge at Matheny	---	37°40'01"	81°36'05"	52.8	I 1979-80	I 1979-80	I 1980
*14	Clear Fork at Highway 16 Bridge at Clear Fork	03202750	37°37'26"	81°42'13"	124	C 1974-80	M 1974-80	D 1974-80, I 1980
15	Big Cub Creek at Highway 6/5 Bridge near Guyan	---	37°37'02"	81°47'24"	16.6	I 1978-80	I 1979-80	I 1980
16	Little Huff Creek at U.S. 52 Bridge at Justice	---	37°35'39"	81°49'43"	40.9	I 1979-80	I 1979-80	I 1980
17	Gilbert Creek at Bridge to School at Gilbert	---	37°37'07"	81°52'54"	26.7	I 1979-80	I 1979-80	I 1980
18	Huff Creek at Private Bridge at Campus	---	37°43'46"	81°43'26"	27.3	I 1979-80	I 1979-80	I 1980
19	Huff Creek at Highway 10/10 Bridge at Mallory	---	37°43'50"	81°50'16"	45.7	I 1979-80	I 1979-80	I 1980
20	Buffalo Creek at Highway 16 By-Pass Bridge at Crites	---	37°47'55"	81°45'48"	21.6	I 1979-80	I 1979-80	I 1980
21	Buffalo Creek at Highway 16/5 Bridge at Kistler	---	37°45'21"	81°51'36"	43.7	I 1979-80	I 1979-80	I 1979-80
22	Rum Creek at Highway 14/1 Bridge at Dehue	---	37°48'33"	81°55'02"	17.6	I 1979-80	I 1979-80	I 1980
23	Dingess Run at Railroad Bridge at Mellville	---	37°50'28"	81°56'57"	23.1	I 1979-80	I 1979-80	I 1980
24	Island Creek at Highway 119 Bridge at Crystal Block	---	37°42'24"	81°59'20"	7.73	I 1979-80	I 1979-80	I 1980
25	Island Creek at Highway 119 Bridge at Mt. Gay	---	37°50'41"	82°00'36"	58.5	I 1979-80	I 1979-80	I 1980
26	Copperas Mine Fork at 119/14 Bridge at Mt. Gay	---	37°50'44"	82°00'52"	45.4	I 1979-80	I 1979-80	I 1980
*27	Guyandotte River at Logan	03203600	37°50'34"	81°58'34"	836	C 1960-80	M 1965, M 1975-76, M 1979-80	D 1975-76, I 1980
28	Crawley Creek at Highway 3/4 Bridge near Chapmanville	---	37°57'45"	82°02'57"	14.4	I 1979-80	I 1979-80	I 1980
29	Big Creek at Highway 2 Bridge near Big Creek	---	38°00'33"	82°01'05"	28.1	I 1979-80	I 1979-80	I 1980
30	Big Harts Creek at Highway 3 Bridge near Shively	---	37°58'40"	82°08'38"	28.1	I 1979-80	I 1979-80	I 1980
31	Big Ugly Creek at Highway 7 Bridge near Leet	---	38°02'59"	82°04'02"	18.1	I 1979-80	I 1979-80	I 1980
*32	Guyandotte River at Branchland	03204000	38°13'15"	82°12'10"	1,226	C 1915-22, C 1928-80	M 1961,1965, M 1975-80	D 1976-77, I 1980
33	Mud River at Highway 46 Bridge at Mud	---	38°05'32"	81°58'06"	14.0	I 1979-80	I 1979-80	I 1980
34	Mud River at Highway 7 Bridge at Myra	---	38°13'19"	82°06'48"	81.2	I 1979-80	I 1979-80	I 1980
35	Middle Fork at Highway 3 Bridge at Hamlin	---	38°16'42"	82°04'30"	50.1	I 1979-80	I 1979-80	I 1980
36	Trace Fork at Highway 37 Bridge near Mt. Moriah	---	38°19'56"	81°58'38"	32.6	I 1979-80	I 1979-80	I 1980
*37	Mud River near Milton	03204500	38°23'15"	82°06'46"	256	C 1938-80	M 1975-77, M 1978-80	D 1975-77, I 1980
38	West Fork Twelvepole Creek at Highway 2 Bridge at Breeden	---	37°55'34"	82°16'12"	24.7	I 1979-80	I 1979-80	I 1980
39	West Fork Twelvepole Creek at Highway 44 Bridge at Dunlow	---	38°01'26"	82°25'55"	65.1	I 1979-80	I 1979-80	I 1980
*40	West Fork Twelvepole Creek at Highway 52/49 Bridge above Wayne at Echo	03206980	38°10'52"	82°28'33"	108	C 1979-80	I 1979-80	D 1979-80

Station name, location, drainage area, and period of record for surface-water sites in Area 12 (continued).

Site number	Station name	Station number	Latitude	Longitude	Drainage area (mi^2)	Discharge	Type of data, period of record, and sampling frequency1/: Chemical Quality	Sediment
*41	East Fork Twelvepole Creek near Dunlow	03206600	38°01'02"	82°17'46"	38.2	C 1964-80	I 1979-80	I 1980
42	Kiah Creek at Highway 33 Bridge near Kiahsville	---	38°02'32"	82°15'23"	18.0	I 1979-80	I 1979-80	I 1980
*43	Twelvepole Creek below Wayne	03207020	38°14'56"	82°26'06"	300	C 1915-22, C 1927-31, C 1946-80	M 1978-80	I 1980
44	Beech Fork Highway 26 Bridge near Gilkerson	---	38°13'51"	82°18'48"	14.3	I 1979-80	I 1979-80	I 1980
45	Millers Fork at Highway 22 Bridge near Crockett	---	38°15'00"	82°22'17"	9.37	I 1979-80	I 1979-80	I 1980
*46	Beech Fork below Beech Fork Dam	03207057	38°18'28"	82°25'28"	80.4	C 1976-80	I 1979-80	I 1980
47	Bearhole Fork at Pineville	03202310	37°35'16"	81°31'12"	6.27	C 1977-79	D 1977-79	D 1977-79
48	Milam Fork at McGraws	03202695	37°40'48"	81°28'27"	6.64	C 1977-79	D 1977-79	D 1977-79
49	Marsh Fork at Maben	03202245	37°38'19"	81°23'38"	4.85	C 1977-80	D 1977-80	D 1977-80
50	Still Run at Itmann	03202255	37°34'51"	81°25'42"	7.12	C 1977-79	D 1977-79	D 1977-79
51	Allen Creek at Allen Junction	03202240	37°35'33"	81°20'48"	8.43	C 1977-79	D 1977-79	D 1977-79
52	Mud River at Barboursville	03205180	38°24'58"	82°17'42"	360	M 1975-76	D 1975-77	I 1975-76
53	Mud River at Palermo	03204250	38°10'10"	82°03'30"	51.1	M 1975-76	M 1975-76	M 1975-76
54	Buffalo Creek at Man	03202990	37°44'34"	81°52'27"	45.6	M 1975-76	M 1975-76	I 1975-76
55	Island Creek at Logan	03203700	37°50'50"	82°00'30"	103	M 1975-77	D 1975-77	M 1975-76
*56	Guyandotte River below R.D. Bailey Dam	03202915	37°35'53"	81°49'46"	535	C 1978-79	I 1978-80	---
*57	East Fork Twelvepole Creek below East Lynn Dam	03206790	38°08'52"	82°23'00"	138	C 1962-80	I 1979-80	---

*Active gaging station (1980)

1/ C - continuous, D - daily, M - monthly, I - intermittent.

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