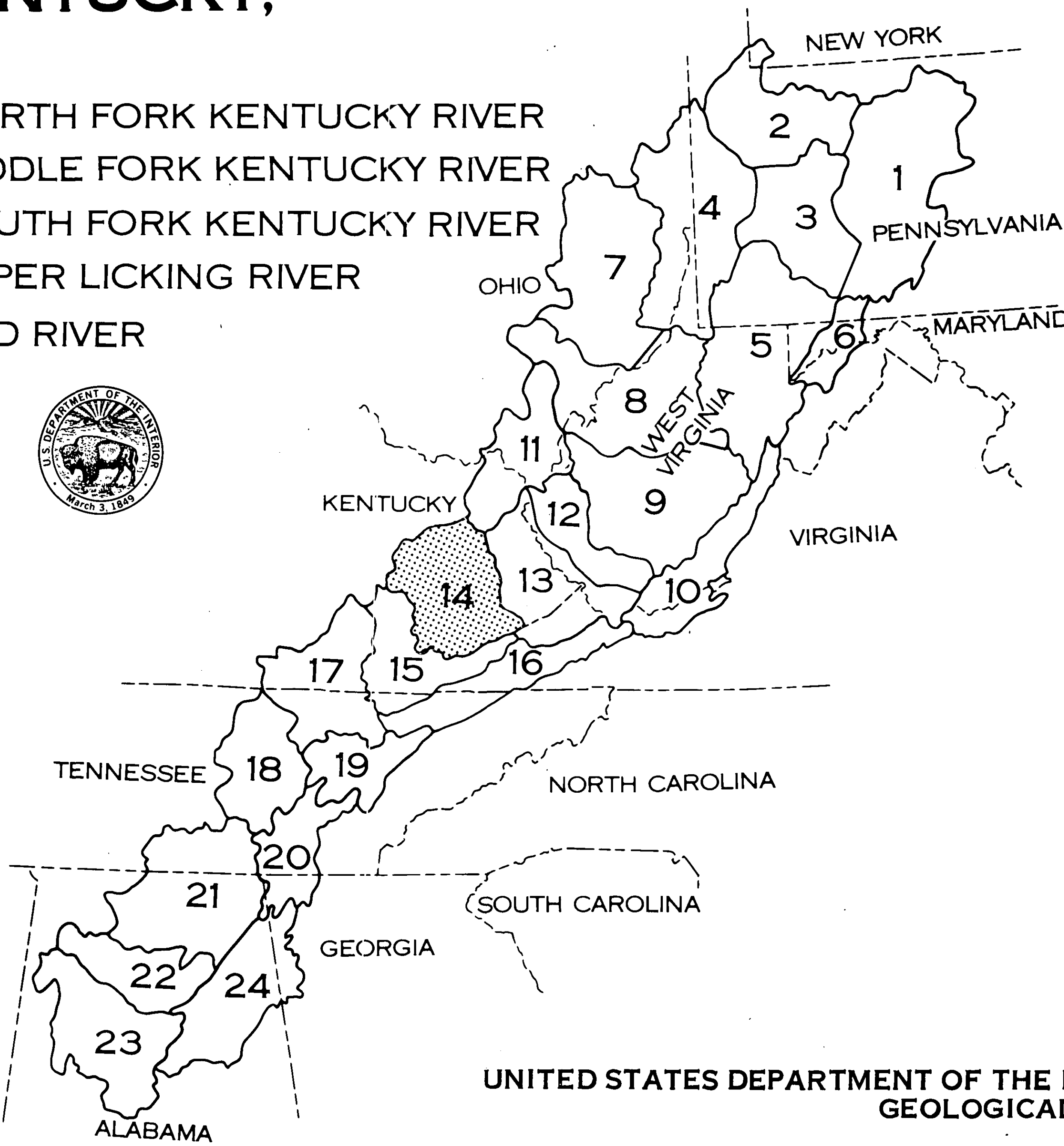
HYDROLOGY OF AREA 14, EASTERN COAL PROVINCE, KENTUCKY,

- NORTH FORK KENTUCKY RIVER
- MIDDLE FORK KENTUCKY RIVER
- SOUTH FORK KENTUCKY RIVER
- UPPER LICKING RIVER
- RED RIVER



UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 81-137

HYDROLOGY OF AREA 14, EASTERN COAL PROVINCE, KENTUCKY

BY
FERDINAND QUINONES, DONALD S. MULL, KAREN YORK, AND VICTORIA KENDALL

U.S. GEOLOGICAL SURVEY
WATER RESOURCES INVESTIGATIONS 81-137

LOUISVILLE, KENTUCKY
AUGUST 1981

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, *SECRETARY*

GEOLOGICAL SURVEY

Doyle G. Frederick, *Acting Director*

For additional information write to:

U.S. Geological Survey
Room 572, Federal Building
Louisville, Kentucky 40202

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 2.54	millimeters per hour (mm/h) 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)
acres	4047.	square meters (m^2)
acre-feet (acre-ft)	1233.	cubic meters (m^3)
gallons per minute (gal/min)	0.06309	liters per second (L/s)
million gallons per day (mgal/d)	0.04381 3785.	cubic meters per second (m^3/s) cubic meters per day (m^3/d)
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)
cubic feet per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meters per second per square kilometer [$(m^3/s)/km^2$]
pounds	453.6	grams (g)
tons (short)	0.9072	metric tons
tons per square mile ($tons/mi^2$)	0.03753	metric ton per square kilometer (metric ton/km^2)

ABSTRACT

The Eastern Coal Province is divided into 24 separate hydrologic reporting areas. The division is based on hydrologic factors, location, size, and mining activity. Hydrologic units (drainage basins) or parts of units are combined to form each area. A separate report will be published for each area and is designed to be useful to mine owners and operators and consulting engineers by presenting information about existing hydrologic conditions and by identifying sources of hydrologic information. General hydrologic information is presented in a brief text and illustrations on each water-resources related topic.

Area 14 is in the central part of the Eastern Coal Province, in the Eastern Coal Field in Kentucky. It includes parts of the Kentucky and Licking River basins, and the Red River basin, draining an area of 4,423 square miles.

Most of Area 14 is underlain by coal-bearing rocks of Pennsylvanian age, subdivided into the Lee and Breathitt Formations. The Lee Formation crops out mainly along the western edge of the area and in Letcher County. The Breathitt Formation crops out in most of the remaining area. Most of the coal occurs in the Breathitt Formation at depths of as much as 2,500 feet.

The principal rivers in the area are the South, Middle, and North Forks of the Kentucky River, the upper Licking River, and the Red River. All streams except the Licking River flow into the Kentucky River. The Kentucky and Licking Rivers flow into the Ohio River and the water eventually reaches the Gulf of Mexico by way of the Mississippi River.

The main soils in Area 14 are derived from siltstones, shales, and sandstones. They are subject to a high rate of erosion as a result of the steep slopes, and especially with the removal of the vegetal cover. The principal land uses in the area are forest and pasture.

Coal mining in Area 14 has shifted gradually from underground to surface operations. Coal production during 1978 was 38 million tons, of which 21 percent was from Perry County.

Precipitation averages range from 41 to 54 inches per year. The 10-year 24-hour rainfall averages 4.3 inches.

Water-use data for 1975 show that domestic and public supply account for 77 percent of the water withdrawals. Most of the water is obtained from streams and lakes because ground-water sources are generally inadequate or undeveloped.

Hydrologic data are available from a network of 64 surface-water sites. The data show that streamflow varies seasonally with precipitation and evapotranspiration. Most of the streams draining less than 100 square miles go dry occasionally. Flooding, however, is severe as a result of intense precipitation and rapid runoff. The magnitude and frequency of floods are affected by the drainage area, topography and geology. Maps defining flood-prone areas are available for 35 stream reaches in Area 14.

Additional hydrologic data are collected at 3 long-term ground water monitoring sites. Miscellaneous information on domestic and industrial wells is available.

The chemical and physical characteristics of the waters in streams draining Area 14 are directly related to mining activities. In streams draining mined areas, dissolved solids such as sulfate, iron, manganese, and some trace metals, are much higher than in streams not affected by mine drainage. Lowering of the pH in streams receiving mine drainage is not readily evident. Acid waters are partly neutralized close to their sources and most stream waters have pH values ranging from 6.2 to 8.3 units. Limited suspended-sediment data from mined areas show tenfold increases in the suspended sediment load as compared to non-mined areas.

Most of the ground water in Area 14 occurs in the sandstone aquifers of the Breathitt and Lee Formations. Water levels fluctuate seasonally in response to precipitation and evapotranspiration. Well yields range from 1 to 325 gallon per minute. The quality of ground water is variable, with generally high iron concentration and salty and saline water below 300 feet below land surface.

The hydrologic data available in Area 14 are now being augmented from an expanded network of streamflow, suspended-sediment, and chemical-quality stations. These stations were implemented in response to the Surface Mining Control and Reclamation Act of 1977 (Public Law 95-87).

AREA 14 REPORT TO AID IN PREPARING AND APPRAISING MINE PERMIT APPLICATIONS

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

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 a large sub-basin in the eastern coal area of Kentucky (see figure 1.1-1). This report, which is for Area 14, 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.

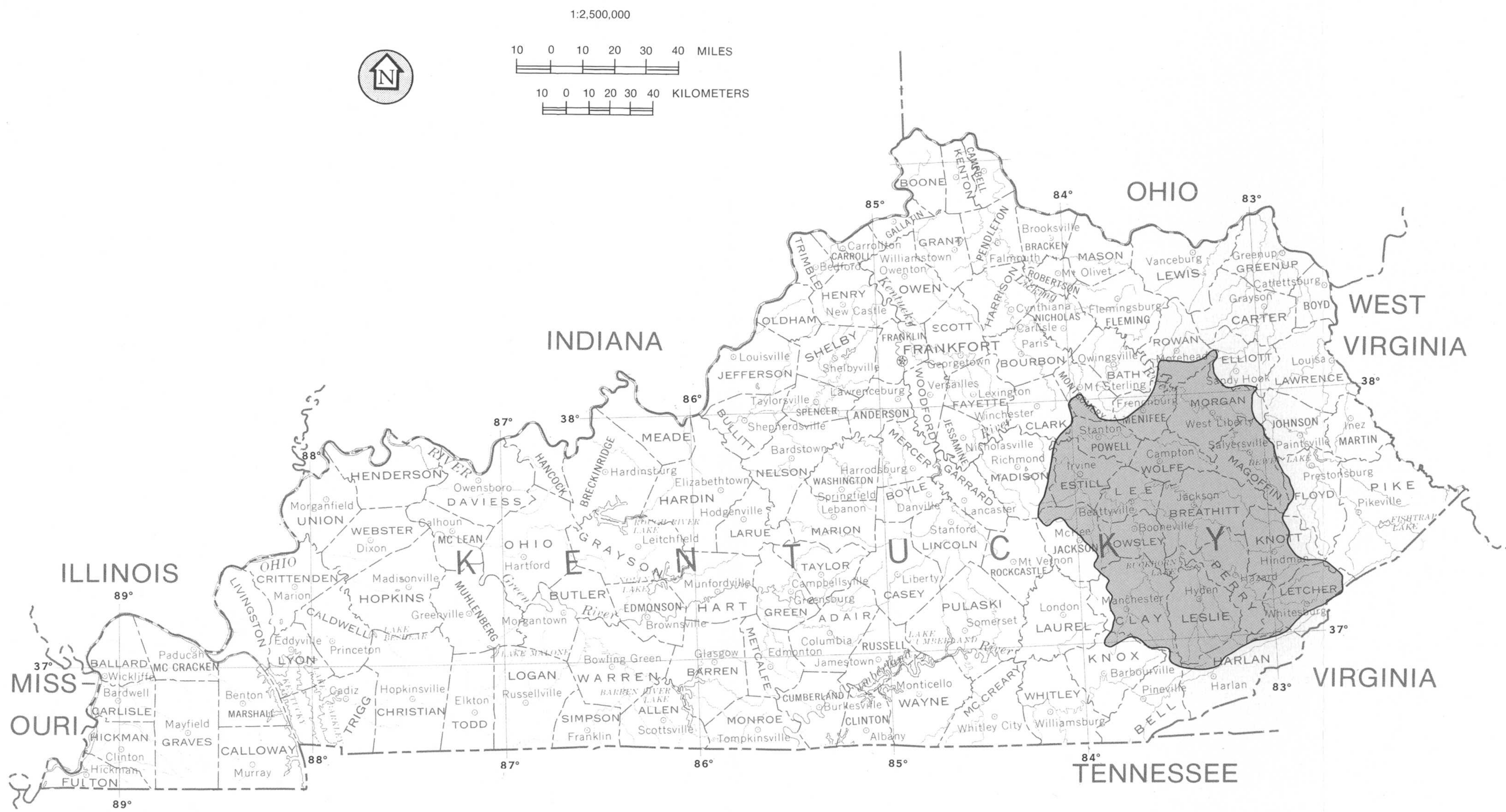


Figure 1.1-1 Location of area 14.

1.0 INTRODUCTION

1.1 OBJECTIVE

AREA LOCATED IN CENTRAL PART OF EASTERN COAL PROVINCE

Area 14 includes 4,423 square miles in the Kentucky, Licking, and Red River basins in Eastern Kentucky.

The Eastern Coal Province has been divided into 24 hydrologic reporting areas. The divisions are based on drainage boundaries, location, size, hydrology, and mining activities (see cover). Several hydrologic units (drainage basins) or parts of units are combined to form one reporting area (fig. 1.2-1).

Area 14 is in the central part of the Eastern Coal Province in eastern Kentucky. The area is part of the Appalachian Plateaus physiographic province in Kentucky (fig. 1.2-2) and includes 4,423 mi^2 within the Kentucky, Licking and Red River basins . Most of the area is within the mountainous terrain of the Eastern Coal Field, and includes all or parts of Breathitt, Clay, Estill, Jackson, Knott, Lee, Letcher, Leslie, Magoffin, Menifee, Morgan, Owsley, Perry, Powell, and Wolfe counties. The population density in Area 14 ranges from 19 to 52 per square mile, averaging about 30 (Karan and Mather, 1977). The principal cities are Booneville, Campton, Hazard, Hyden, Jackson, Manchester, and Salyersville.

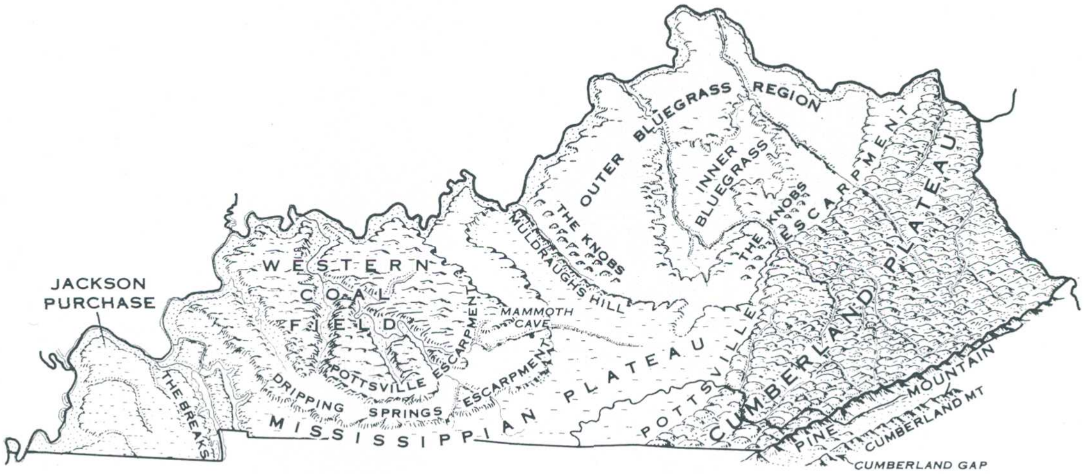


Figure 1.2-2 Physiographic diagram of Kentucky.

(Kentucky Geological Survey).

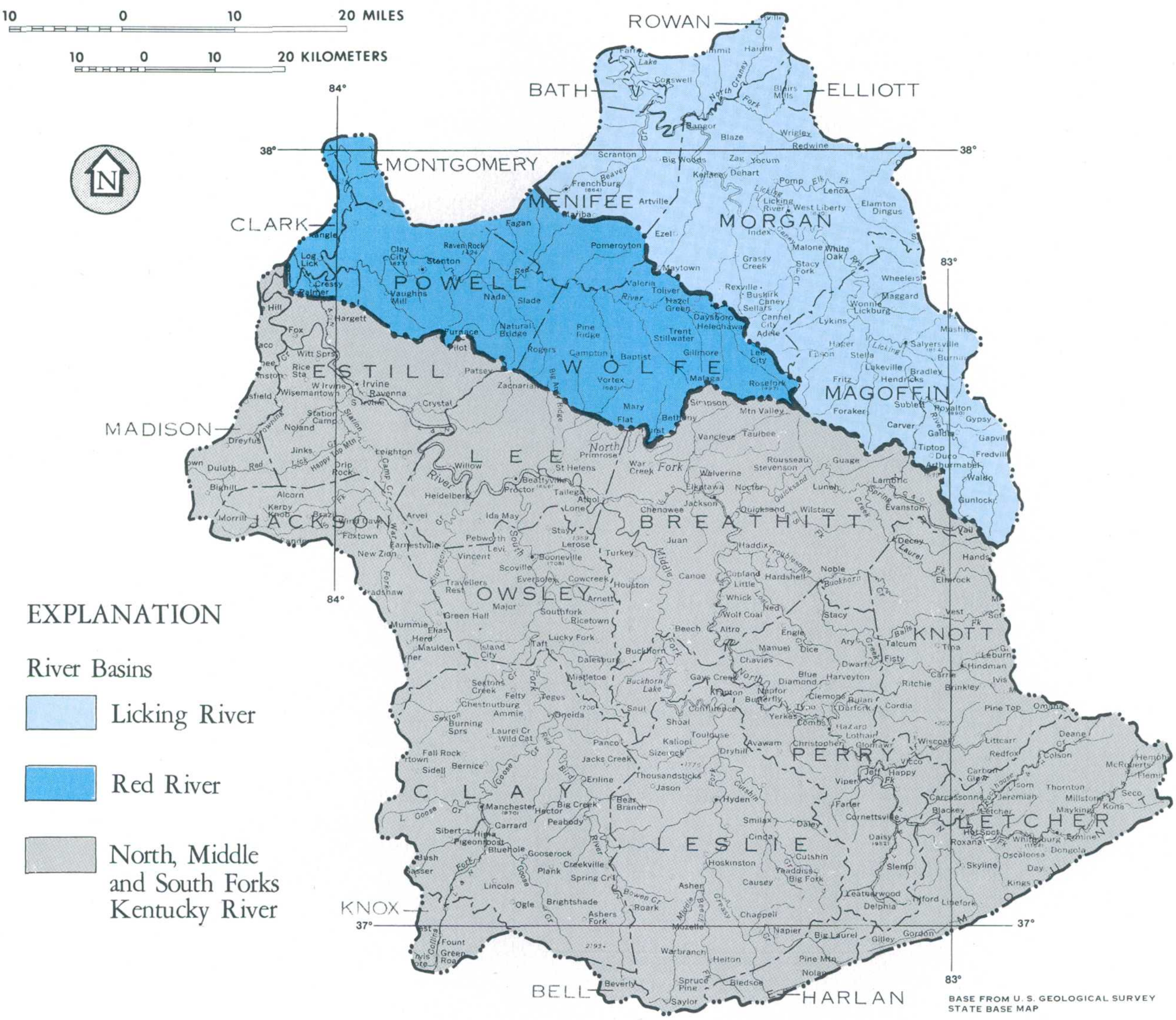


Figure 1.2-1 Drainage basins.

HYDROLOGIC ENVIRONMENT CAN BE ADVERSELY ALTERED BY SURFACE COAL MINING

Erosion, sedimentation, decline in water levels, and degradation of water quality are typical problems associated with surface coal mining.

Surface mining drastically alters the environment of undisturbed areas and may cause detrimental changes to the natural environment. Mining activities such as the removal of vegetation, excavation, and dumping of large volumes of unconsolidated spoil materials create unstable areas of loose earth and rock which erode easily and contribute additional sediment to surface streams, channels, and flood plains. If the mined area is reclaimed during mining, or after mining is completed, some of the detrimental environmental effects can be decreased or prevented.

Adverse effects associated with erosion and increased sedimentation include excessive sediment deposition in streams and reservoirs which in turn increases the cost of maintaining navigation channels and treating water for industrial and domestic uses. Other adverse effects include destruction of life habitat, increased flooding due to filling of the stream channels and flood plains by sediment, and reduction of aesthetic value in recreation areas.

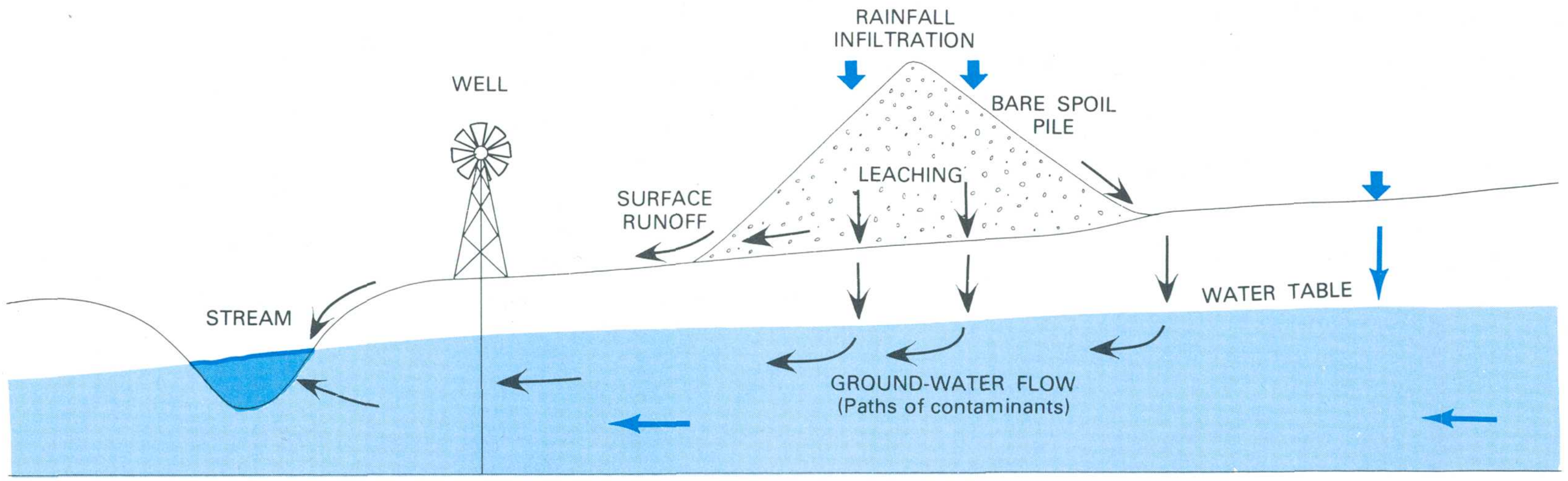
Along with increased sedimentation, another common and troublesome water-quality problem is acid-mine drainage. After mining, accelerated weathering of iron bearing minerals (pyrite and marcasite, for example) exposed in spoil materials and coal beds produces sulfuric acid and accelerates the dissolution of minerals. Water draining such a mined area generally has low pH values (2.5-5.0 units), and increased sulfate and dissolved-solids concentrations. The acidic water reacts with other minerals increasing trace element concentrations such as aluminum, copper, lead, iron, manganese, and zinc. Adverse effects associated with acidic and highly mineralized mine drainage may include reduction of aquatic life, increased corrosiveness of water, limitations on the use of water for domestic and industrial purposes, and reduction of aesthetic value and recreational use.

The adverse effects are most apparent on and near the mine site. The receiving stream for surface and seepage drainage at the mine site usually is most affected. Suspended sediment, mineral content, and pH will usually diminish in severity downstream from the mine due to settling out of the sediment, and the increased buffering and dilution capacity of the stream.

The decline of ground-water levels can occur in and near surface-mining areas when excavation extends below the water table causing some wells and springs to go dry (fig. 1.3-1). The quality of ground water can also be affected even though the effects may take much longer to detect at points remote from mining activities.

The magnitude of the effects of surface mining on the surrounding hydrologic environment depends on several physical and chemical factors. The more influential factors include mining and reclamation methods, topography, geology, climate, rate of water movement and volumes, the distance to the mine site, and the time elapsed since mining began.

Some chemical and physical relations and trends that can result from surface coal mining are shown in figure 1.3-2. No proportion, ratio, or linearity is implied by these diagrams.



From SYNTHETIC FUELS DEVELOPMENT by U.S. Dept. of Int. and U.S.G.S.

Figure 1.3-1 Toxic substances leaching from soils.

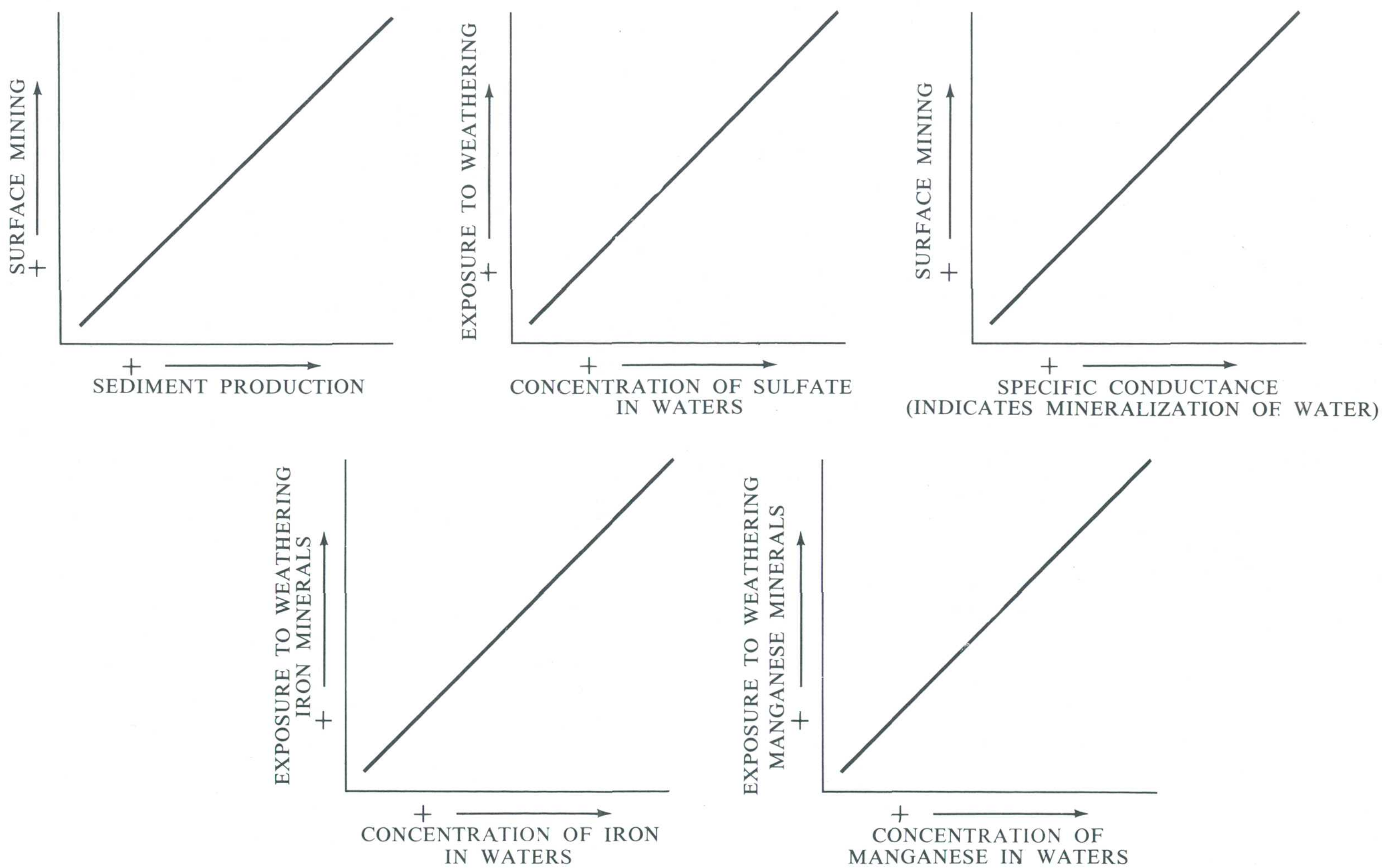


Figure 1.3-2 Example relations and trends that can result from surface coal mining.

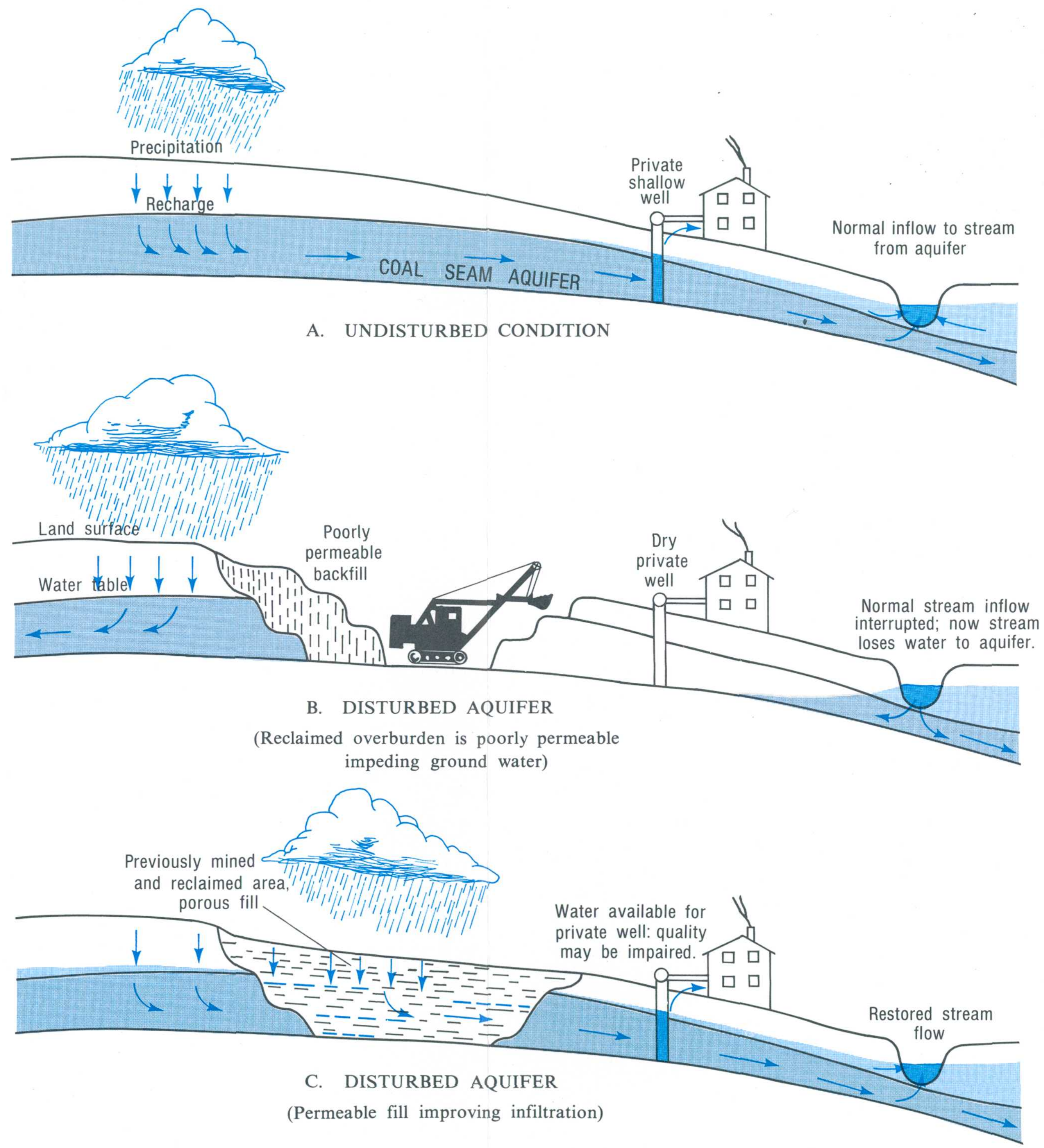


Figure 1.3-3 Possible impacts of mining aquifers.

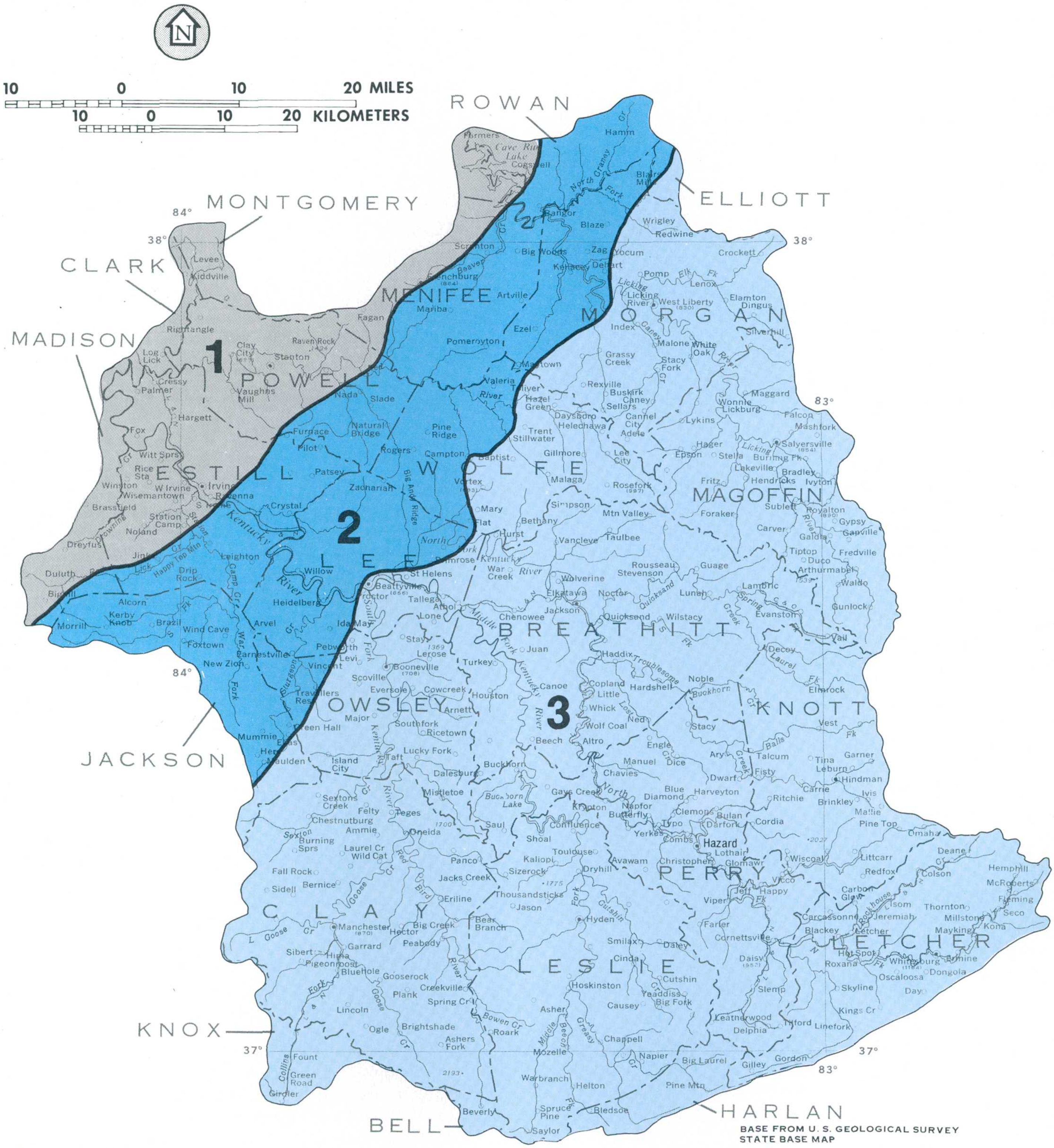
AREA WITHIN THREE PHYSIOGRAPHIC REGIONS

The Knobs, Cumberland Plateau, and Kanawha sections in Area 14 lie within the Appalachian Plateaus and the Interior Low Plateau.

Most of Area 14 lies within the Applachian Plateaus physiographic province which is subdivided into the Kanawha and Cumberland Plateau sections (fig. 2.1-1). The greater part of the area lies within the Kanawha section which is a dissected plateau characterized by narrow, crooked valleys, and narrow, irregular steep-sided ridges. This section is underlain by sandstone, siltstone, and shale of Pennsylvanian age and is drained by the North, Middle, and South Forks Kentucky River and the Licking River.

The Cumberland Plateau section borders the Kanawha section on the northwest. It is a broad plateau of moderate relief. Along its western margin it is intricately dissected into very narrow ridges which are bordered by deep valleys having precipitous walls. The surface of the upland is developed on shale and sandstone of Pennsylvanian age, and the valleys are cut into shale and limestone of Mississippian age.

The Knobs section of the Interior Low Plateau province borders the Cumberland Plateau section on the northwest. The Knobs section is characterized by conical hills that are separated by wide valleys or lowlands. The hills are erosional remnants of the Cumberland Plateau section to the southeast and consist of shale, limestone, and sandstone of Mississippian and Pennsylvanian age. Broad valleys in the northwestern part of the area are developed in shale of Devonian age.



EXPLANATION
PHYSIOGRAPHIC SECTIONS

1 Knobs

2 Cumberland Plateau

3 Kanawha

Figure 2.1-1 Physiographic sections.

THREE MAJOR ROCK UNITS UNDERLIE AREA 14

The rocks are subdivided into the Breathitt and Lee Formations of Pennsylvanian age, and the underlying rocks of Mississippian to Ordovician age. Coal occurs in the Pennsylvanian rocks.

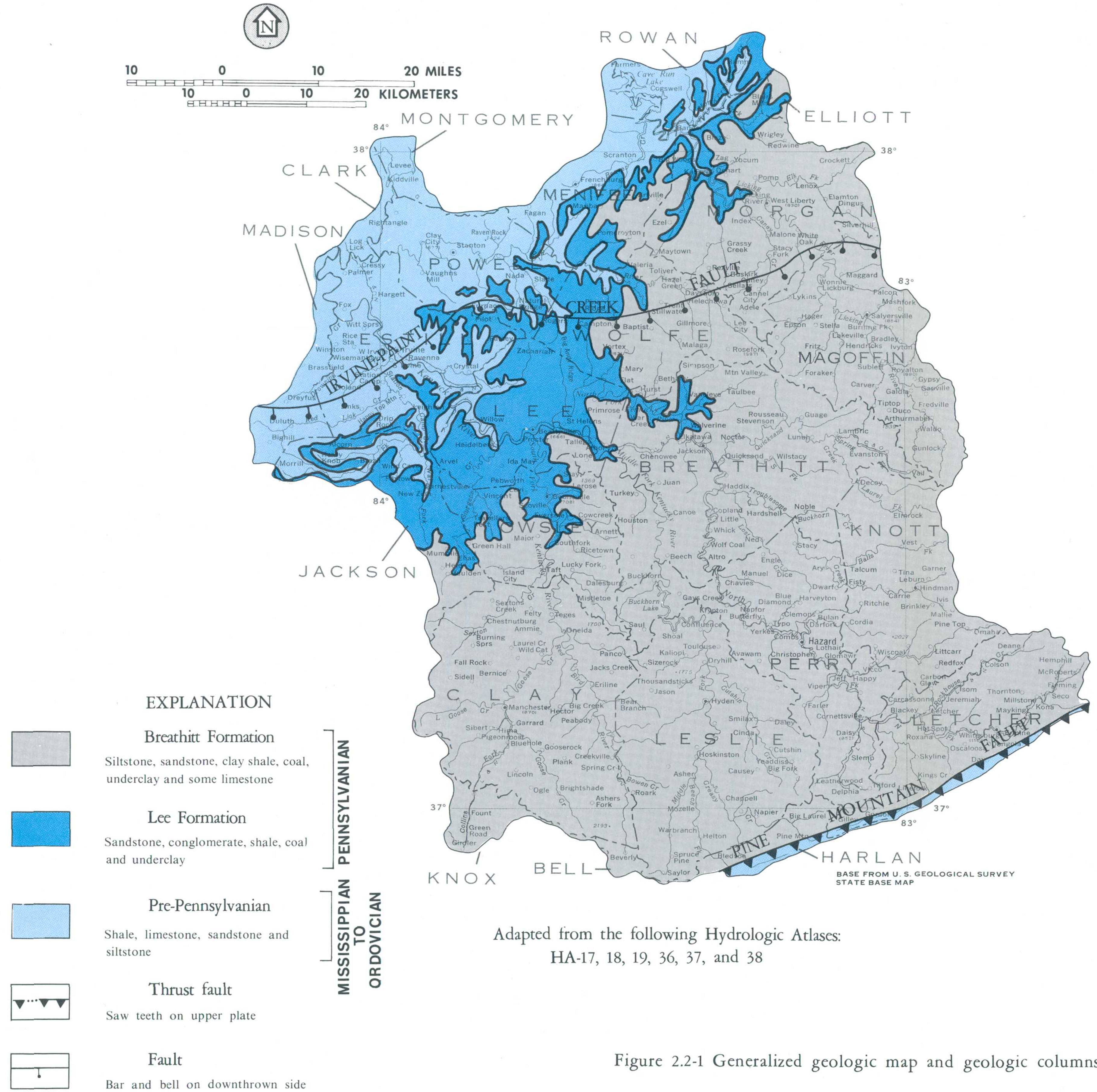
The Breathitt Formation crops out in most of Area 14 and contains most of the mineable coal. The maximum thickness of the formation, about 2,500 feet, occurs in southern Leslie County. The Breathitt Formation consists of siltstone and clay shale, sandstone, coal, ironstone, and limestone. Siltstone and clay shale generally intergrade. As many as 30 coal beds or coal zones are present in the formation and range in thickness from less than 6 inches to as much as 19 feet. The coal beds are irregular in shape. The thickest beds tend to be elongate toward the north and east. Individual beds may be thin or absent locally and commonly may grade horizontally into other sediments such as black shale or siltstone. Individual sandstone beds range from 30 to 120 feet in thickness and commonly show rapid lateral changes in lithology. Thus regional correlation of individual beds is difficult. Limestone is present as thin, discontinuous beds or as concretions which commonly occur above coal beds. At least one zone of limestone and calcareous shale, the Magoffin Member is widespread.

The Lee Formation is overlain by the Breathitt Formation except in the western part of Area 14. Although not shown because of the scale of the geologic map in figure 2.2-1, the Lee Formation crops out in the valleys of the major streams in Clay and Owsley Counties. The formation is characterized by massive orthoquartzite that locally contains lenses of conglomerate; in places, sandstone makes up more than 80 percent of the formation. The sandstone beds commonly intertongue with or grade laterally into siltstone or shale. It also contains shale beds ranging from less than 20 feet to as much as 40 feet in thickness. Carbonaceous shale, siltstone, and coal are frequently interbedded and are more common in the upper part of the formation. The Lee Formation also contains coal beds that are markedly lenticular and discontinuous. The formation varies in thickness from about 300 feet along the northwestern border of its outcrop to about 1,200 feet in Letcher County.

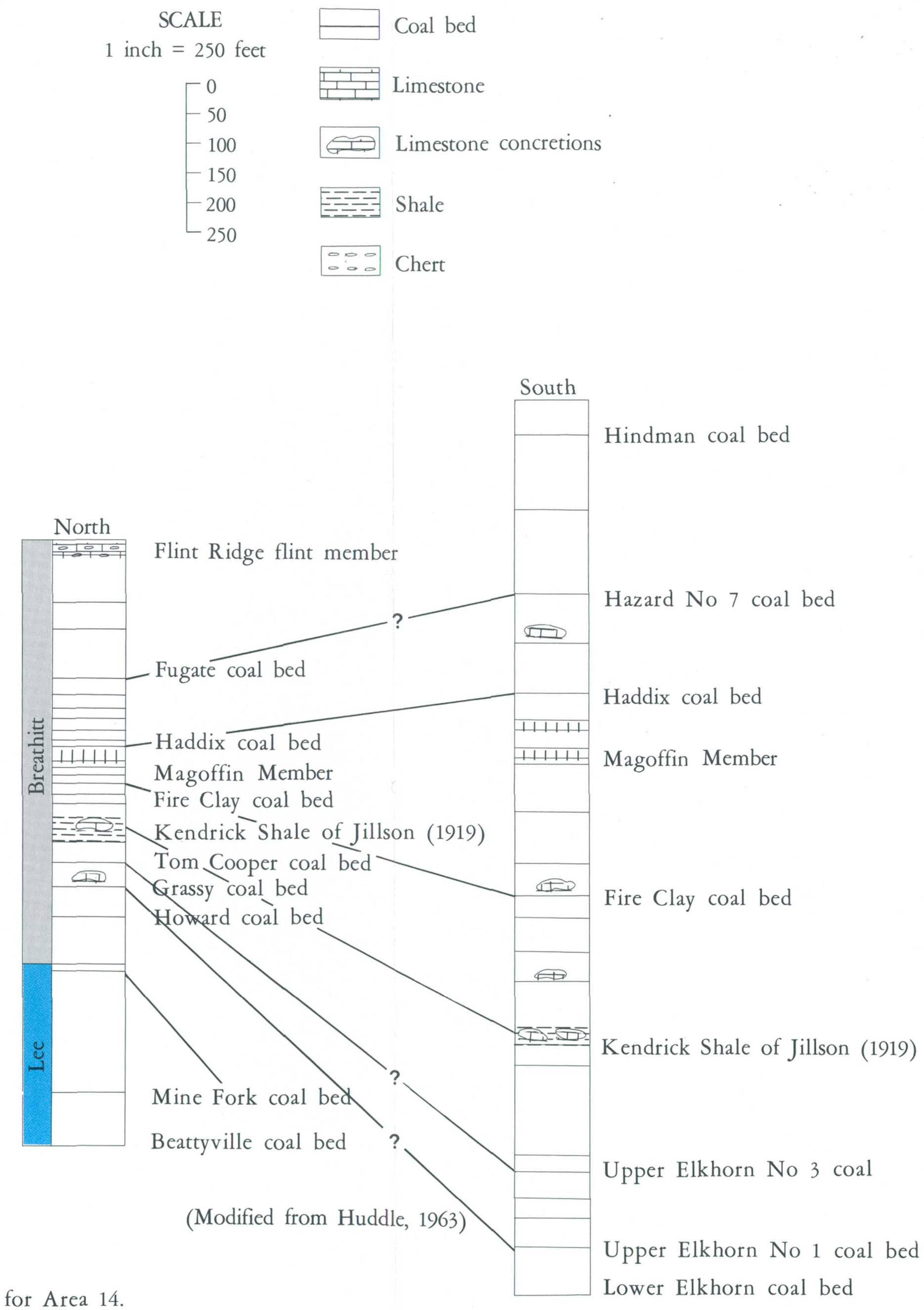
Pre-Pennsylvanian rocks of Mississippian to Ordovician age are undifferentiated for the purpose of this report. These rocks are exposed along Pine Mountain in Letcher County and in the northwestern part of the area. They consist of shale, limestone, and sandstone and range in thickness from about 700 feet to 2,600 feet.

All formations are relatively flat-lying and thicken toward the southeast. The major structural features in Area 14 are the Irvine-Paint Creek fault system, and the Pine Mountain Fault, which is the northwest border of the Cumberland overthrust block. Geologic structure has little effect on mining except in the vicinity of major faults where the coal beds are too discontinuous to mine.

The geologic map of Area 14 shown in figure 2.2-1 is highly generalized. Detailed geology of the area is available on 7½ minute geologic-quadrangle maps (Appendix 1). Each map has a geologic columnar section and most have a geologic cross section that shows the stratigraphic relation of coal beds and surrounding rocks.



Adapted from the following Hydrologic Atlases:
HA-17, 18, 19, 36, 37, and 38



(Modified from Huddle, 1963)

Figure 2.2-1 Generalized geologic map and geologic columns for Area 14.

FIVE RIVERS DRAIN MOST OF AREA 14

The South, Middle and North Forks Kentucky River drain about 60 percent of the area. Other major streams include the Licking and Red Rivers.

The South, Middle and North Forks Kentucky River are the main streams in Area 14, draining nearly 60 percent of the area (fig. 2.3-1). The North and Middle Forks join upstream from the city of Beattyville, in Lee County, to form the Kentucky River. The South Fork flows into the Kentucky River a short distance downstream from Beattyville. Troublesome and Quicksand Creeks, upstream from the city of Jackson, are the main tributaries to the North Fork. Cutshin and Greasy Creeks are the principal tributaries to the Middle Fork, while Red Bird River, Goose Creek, and Sexton Creek are the main branches of the South Fork. The Kentucky River is regulated by a series of navigation dams downstream from Heidelberg and the confluence with the South Fork.

The Red River flows westerly from Lee City in Wolf County toward the city of Hazel Green and enters the Kentucky River downstream from Clay City between Estill and Clark Counties. The principal tributaries of the Red River are Stillwater Creek, Middle Fork Red River, and Lulbegrud Creek.

The Licking River flows from Salyersville northwest to Cave Run Lake. Caney Fork and Elk Fork are the principal tributaries to the Licking River, flowing into it downstream from the city of West Liberty.

There are three reservoirs in Area 14. Buckhorn Lake (Middle Fork Kentucky River) downstream from Hyden; Carr Fork Lake (Carr Fork) near Sassafrass; and Cave Run Lake (Licking River) near Farmers serve both for flood control and recreational purposes. The drainage area and maximum capacity of each reservoir are as follows:

Reservoir	Drainage Area mi^2	Capacity acre-ft
Buckhorn Lake	408	168,000
Carr Fork Lake near Sassafrass	58	47,700
Cave Run Lake near Farmers	826	614,100

Altitudes in the upper Kentucky River basin range from about 800 to 2,000 feet, and from 600 to 1,400 feet in the Licking River basin. The basins of the three Forks of the Kentucky River are characterized by rugged topography. The Licking River basin is similar although the relief and slopes are more gradual.

Drainage areas of the principal rivers in Area 14 are as follows:

Name	Drainage Area mi^2
South Fork Kentucky River at mouth	748
Middle Fork Kentucky River at mouth	559
North Fork Kentucky River upstream from the Middle Fork	1,319
Red River at mouth	487
Mainstem Kentucky River between South Fork and Red River	606
Licking River at Bangor	704
	4,423

Drainage areas for other selected locations in Area 14 are available from:

U.S. Geological Survey
Water Resources Division
Room 572
600 Federal Place
Louisville, KY 40202

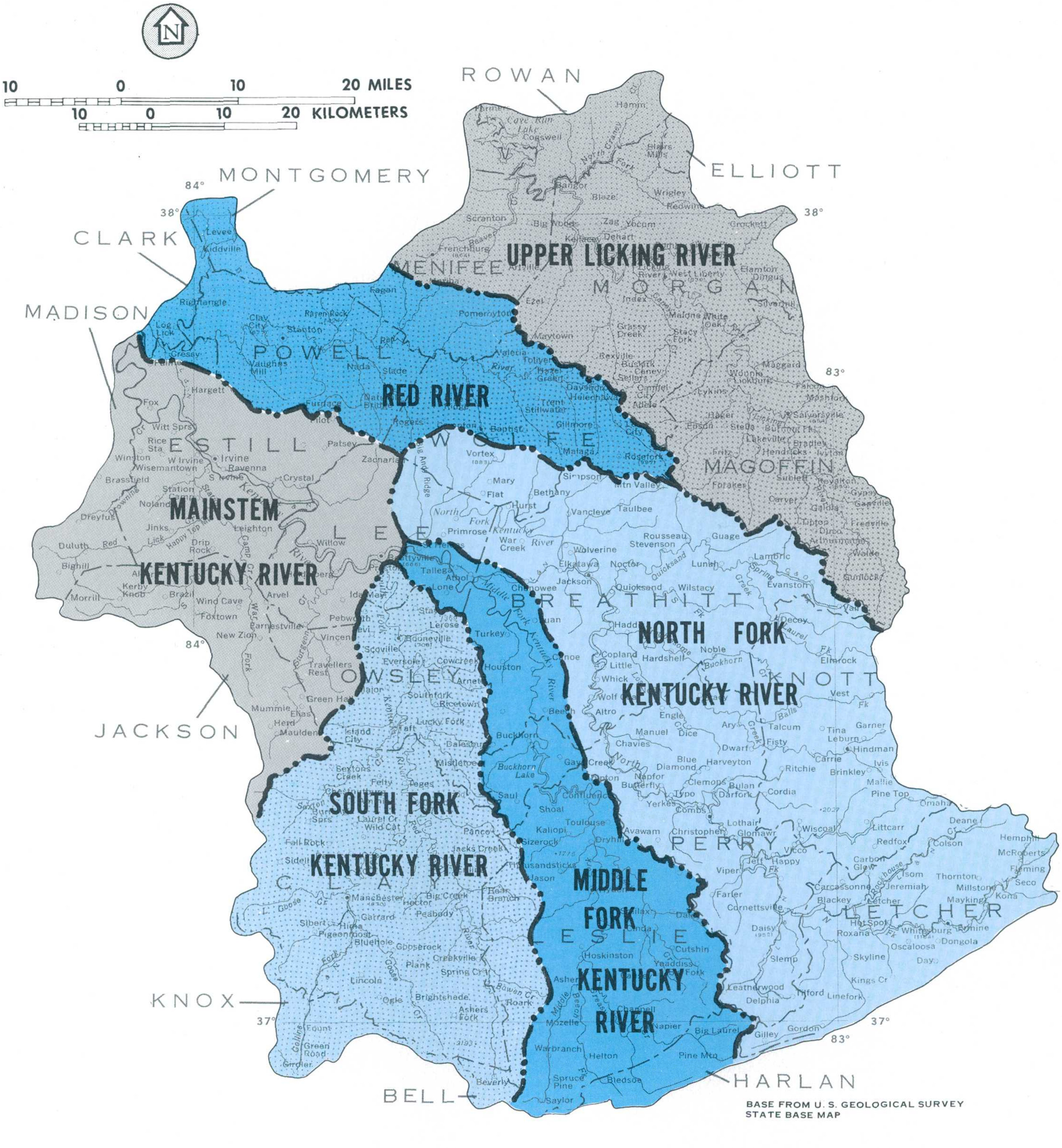


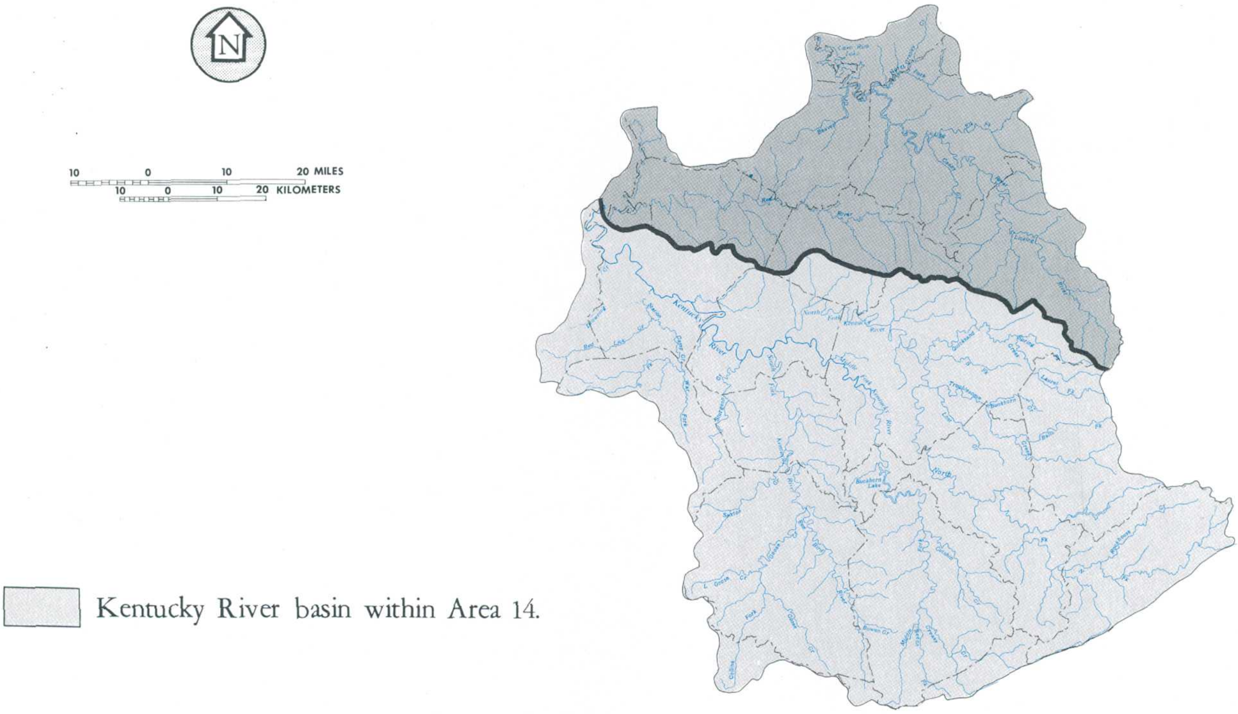
Figure 2.3-1 River Basins.

FORESTS COVER MOST OF AREA 14

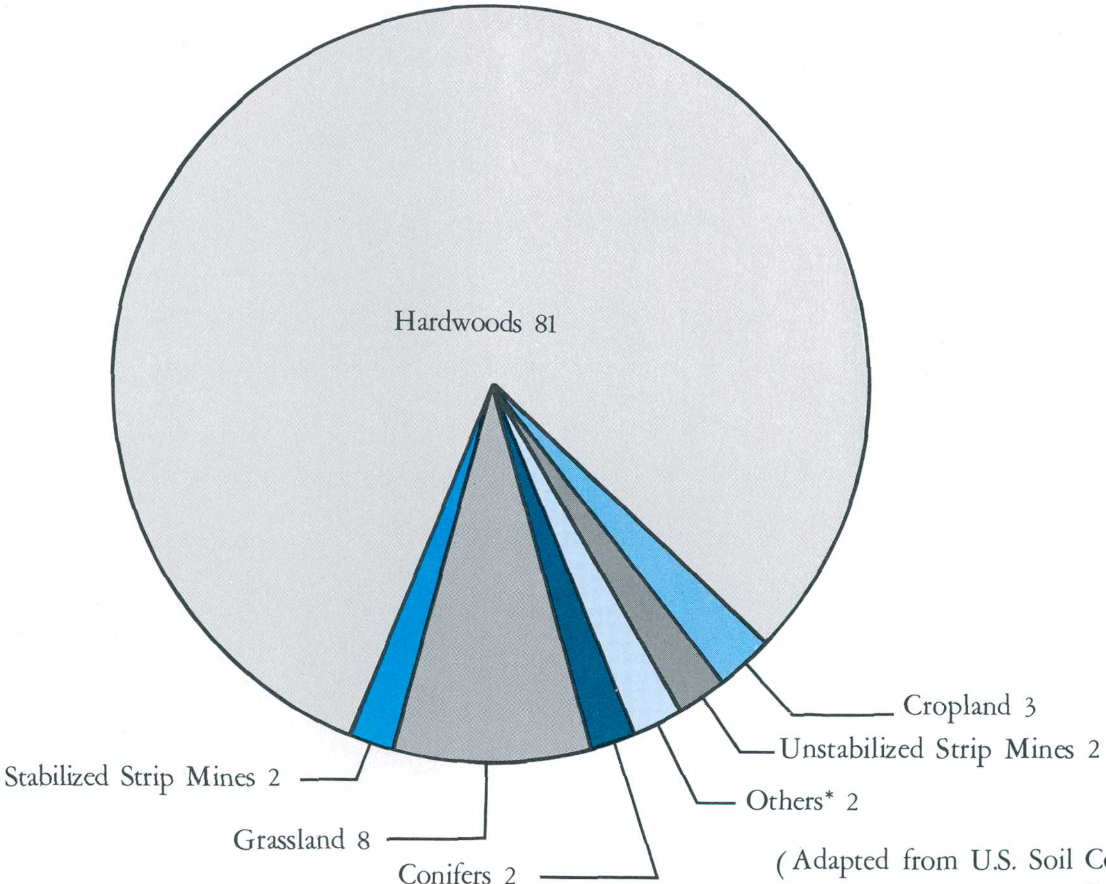
Complete land-use data are available for only the upper Kentucky River basin. Data show that of about 2.2 million acres, 83 percent was forested and 4 percent was used for mining.

A detailed survey of land use in the Kentucky River basin was completed using 1974-75 Landsat satellite data. The acreage was prorated to include only the upper Kentucky River basin (Appendix 2).

Hardwood and conifer forests account for about 83 percent of the acreage in the upper Kentucky River basin, Area 14. In Perry County, the principal coal producing county, contour strip mines account for about 14 percent of the acreage, compared to only about 4 percent for the entire upper Kentucky River basin. The area of stabilized and unstabilized strip mines is about equal.



LAND USE IN THE UPPER KENTUCKY RIVER BASIN, PERCENTAGE.



(Adapted from U.S. Soil Conservation Service, 1978)

Figure 2.4-1 Land use in the upper Kentucky River basin.

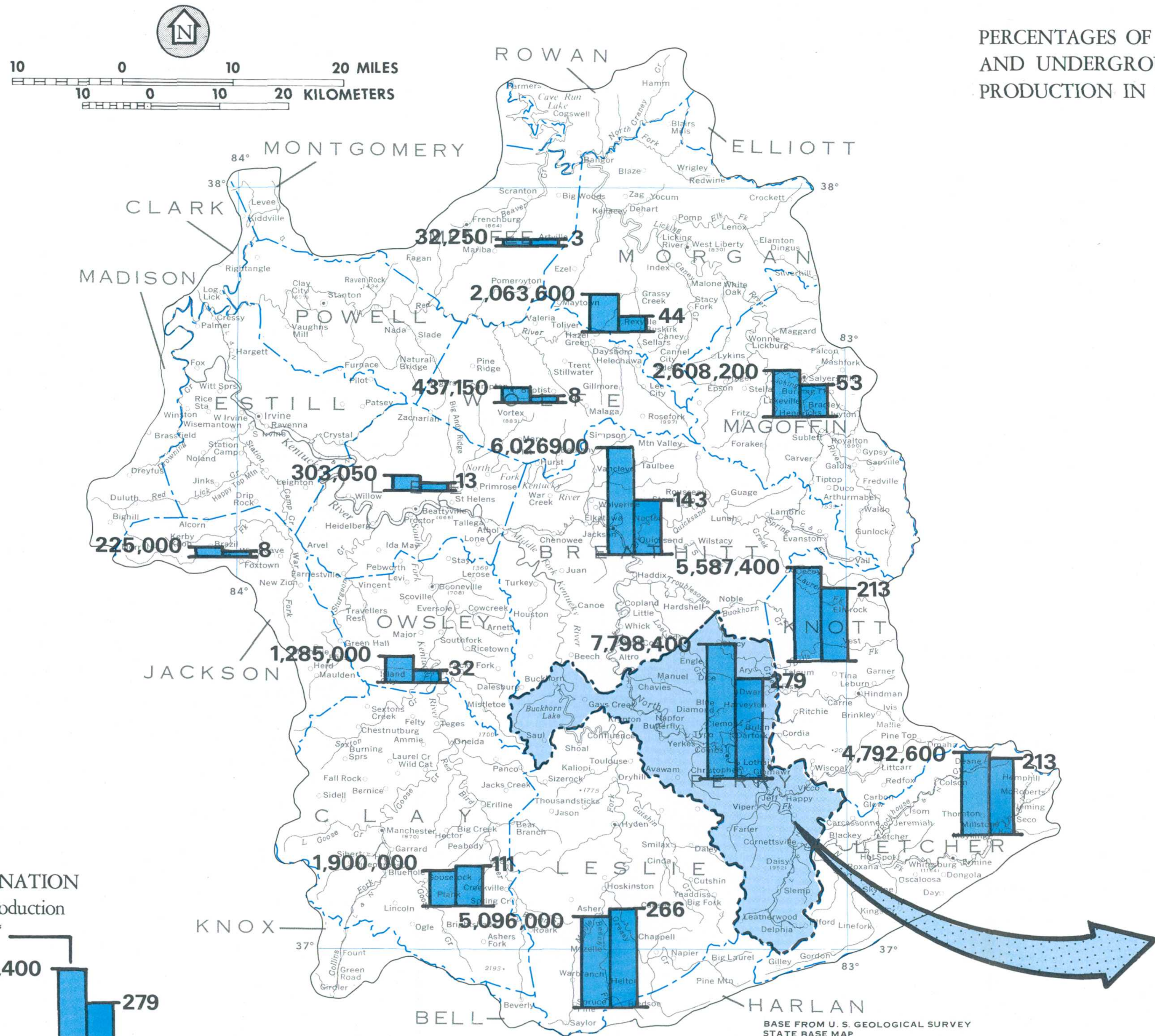
*Urban, water, unclassified.

COAL PRODUCTION IN 1978 WAS 38 MILLION TONS

Surface mining accounts for 65 percent of total production from Area 14. Perry County was the principal producer of coal during 1978, with about 8 million tons.

Coal production in Area 14 is concentrated in the drainage basins of the Middle and North Forks Kentucky River. The combined production in Breathitt, Knott, Perry, Letcher, and Leslie Counties was about 29 million tons in 1978, or nearly 76 percent of the total 38 million tons produced in the area (fig. 2.5-1). Perry County was the principal producer, with nearly 8 million tons from 279 mines (Kirkpatrick, 1979). Coal production in 1979 was about 7 percent less than during 1978 when 755 surface and 661 underground mines were active.

During the period from 1950-78 there was a gradual shift in the mining operations from underground to surface mines, although underground mining still accounts for about 35 percent of the total production. Production figures for both types of mines for Perry County during this period are shown in figure 2.5-2.



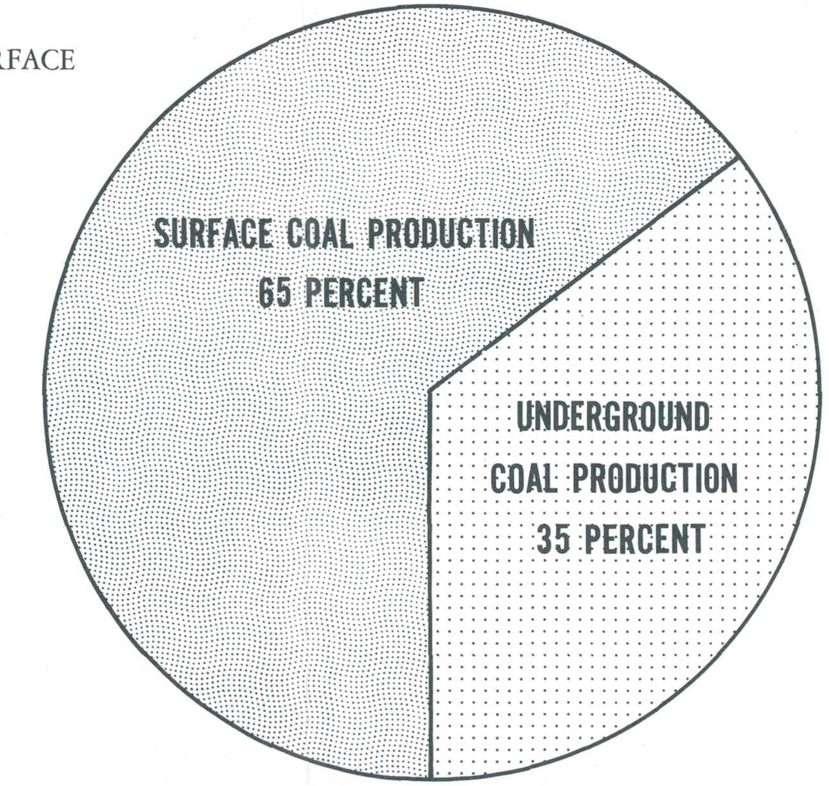
EXPLANATION
Coal production in tons*
7,798,400
279
Number of mines, undifferentiated. (Surface and underground)

Figure 2.5-1 Coal production and number of mines in 1978.

*Production figures show total tonnage for the indicated counties.

(Adapted from Kirkpatrick, 1979.)

PERCENTAGES OF THE OVERALL SURFACE AND UNDERGROUND COAL PRODUCTION IN 1978 FOR AREA 14.



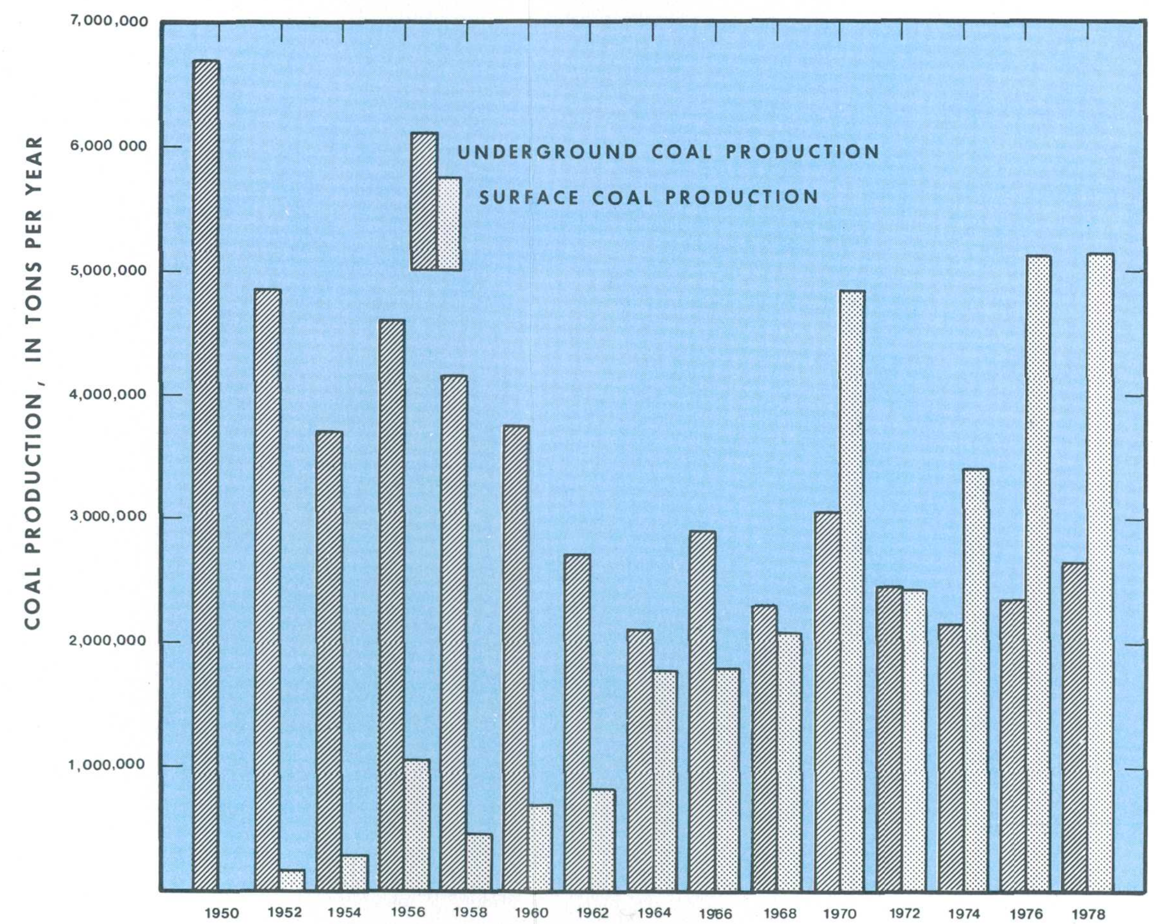


Figure 2.5-2 Coal production from underground and surface mines in Perry County, Kentucky, 1950-78.

SOILS ARE DERIVED FROM SILTSTONES, SANDSTONES AND SHALES

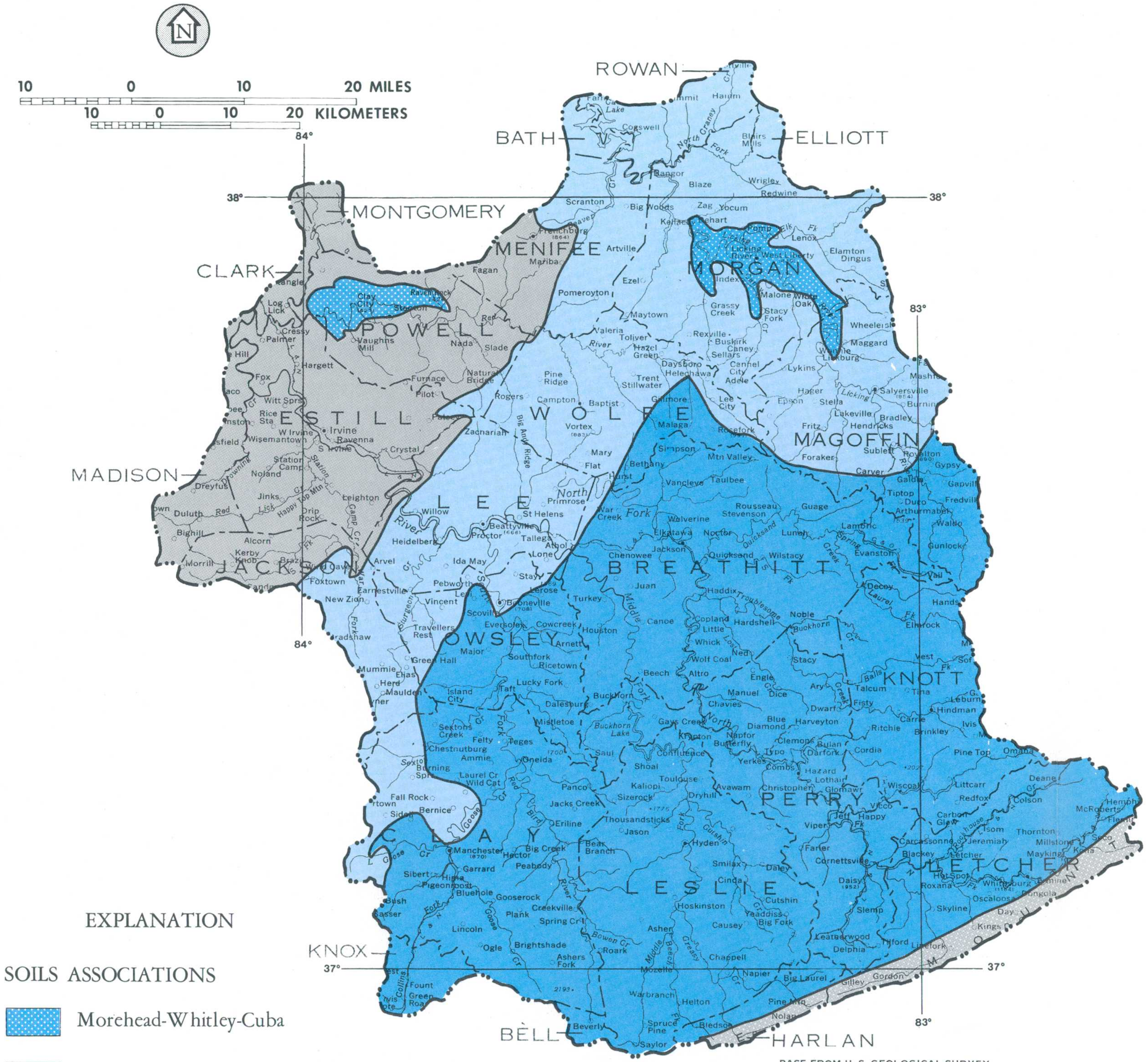
Most of the soils in Area 14 are derived from siltstones, sandstones, and shales. The principal soil associations are the Jefferson-Shelocta and Lathan-Shelocta.

About 80 percent of the soils in the study area are associations of the Jefferson-Shelocta and the Lathan-Shelocta soils (fig. 2.6-1). These are deep, well drained soils formed from siltstones, shales, and sandstones. The slopes in the area range from 20 to 60 percent, making the land poorly suited for agriculture.

A band of the Shelocta-Brookside soils extends across the northwestern part of the basin. These soils are very similar to the Jefferson-Shelocta and Lathan-Shelocta associations but contain mostly clayey colluvium derived from limestone.

Two narrow bands of the Morehead-Whitely-Cuba association are in the flood plains of the Kentucky and Licking Rivers. These soils are deep, well drained, and composed of loamy alluvium. Although they are excellent agricultural soils, their use is limited by the potential for flooding.

The general characteristics of the soils in Area 14 are shown in table 2.6-1. The suitability of soils for use in agriculture and growth media are described in table 2.6-2.



(Adapted from Soil Conservation Service, 1978)

EXPLANATION

SOILS ASSOCIATIONS

- Morehead-Whitley-Cuba
- Lathan-Shelocta
- Jefferson-Shelocta
- Jefferson-Dekalb
- Shelocta-Brookside

Figure 2.6-1 Generalized soil associations.

Table 2.6-1 Soil association features

Soil Association	Physical Description	Soil Depths (inches)	Depth to bedrock (feet)	pH	Permeabilty (inches/hour)	Available water capacity (inches/inch)	Slope (percent)
Morehead-Whitely-Cuba	Terraces and flood plains of major mountain streams	0 - 74	3.5 - 10	4.5 - 5.5	0.6 - 2.0	.10 - .23	0 - 12
Latham-Shelocta	Steep side slopes with narrow ridge tops and flood plains in the Cumberland Mountains	0 - 38	4 - 8	4.5 - 5.5	.63 - 2.0	.11 - .19	20 - 50
Jefferson-Shelocta	Steep side slopes with narrow ridge tops and flood plains in the Cumberland Mountains	0 - 50	5 - 8	4.5 - 6.5	.63 - 6.3	.10 - .18	20 - 60
Jefferson-Dekalb	Steep side slopes of higher mountains with narrow ridge tops and flood plains of Cumberland Mountains	0 - 30	1.5 - 8	4.5 - 5.5	.2 - 6.3	.06 - .18	20 - 60
Shelocta-Brookside	Steep side slopes with narrow ridge tops and flood plains in the Cumberland Mountains	0 - 60	4 - 9	4.5 - 7.3	.2 - 2.0	.09 - .17	20 - 60

Soil Conservation Service, 1978

Table 2.6-2 Suitability rating of soil (to a depth of 1 meter) for use as a plant growth medium in drastically disturbed land reclamation

Factors affecting use	Degree of suitability		
	Good	Fair	Poor (essentially unsuitable)
Electrical conductivity EC (umhos/cm)	<8	8 - 16	>16
Sodium adsorption ratio SAR	<2	2 - 12	>12
Exchangeable-sodium-percentage ESP*	<2	2 - 15	>15
pH	5.0 - 8.5	3.5 - 5.0	<3.5;>8.5
Coarse fragments over 3-inch diameter (percent by volume)	< 15	15 - 35	>35
Intermediate textural group	medium moderately fine moderately coarse	fine	coarse
Available water capacity (inches/inch)	>0.1	0.1 - 0.05	< 0.05
Depth to bedrock or cemented pan	> 40 inches	20 - 40 inches	<20 inches
Slope (percent)	<8	8 - 15	>15

* Rate 2:1 Clay texture poor if over 10; sand texture if over 20

Modified from U. S. Department of the Interior (1977)

ANNUAL PRECIPITATION AVERAGES 47 INCHES

Precipitation data at 16 long-term stations in Area 14 show averages ranging from 41 to 54 inches per year. The 10-year 24-hour rainfall averages 4.3 inches.

Kentucky lies within the path of moisture-laden, low-pressure systems that move from the Gulf of Mexico. Average precipitation throughout the State ranges from 40 to 54 inches (fig. 2.7-1).

Average rainfall throughout Area 14 is fairly uniform, increasing slightly from east to west. Long-term precipitation data are available at 16 sites (fig. 2.7-2). Annual averages range from about 41 to 54 inches per year. Precipitation occurs on about 130 days each year. Although it may occur at any time of the year, monthly averages from January through March are from 20 to 35 percent greater than for August through October (fig. 2.7-3).

Snow and sleet averages about 20 inches per year. During extreme years, snow totals exceeding 50 inches can contribute significantly to the winter and spring runoff.

Area 14 is rugged and mountainous and intense local storms are produced by orographic effects. The 10-year, 24-hour, rainfall in the area averages 4.3 inches (fig. 2.7-4). Bar graphs show the uniform distribution of these events. A total of 5.6 inches was recorded in December 1978 during a 24-hour period near West Liberty.

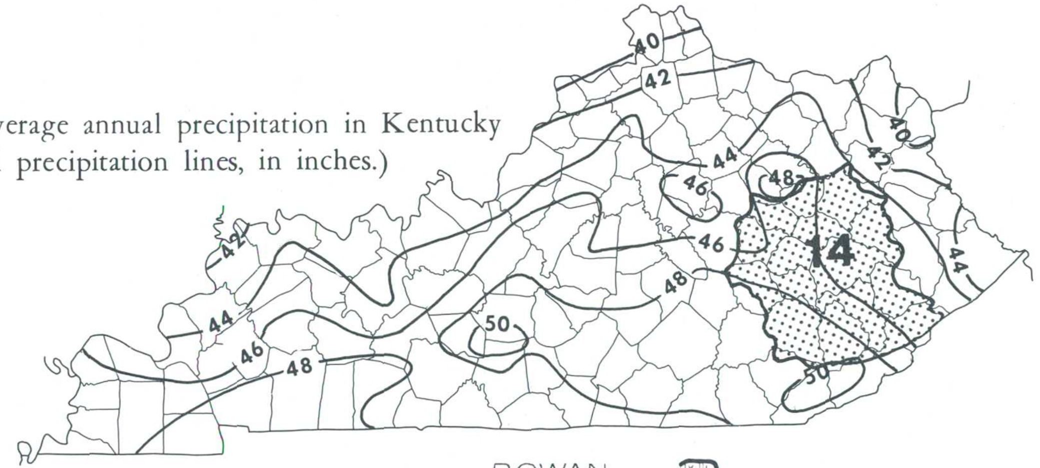


Figure 2.7-1 Average annual precipitation in Kentucky (Equal precipitation lines, in inches.)

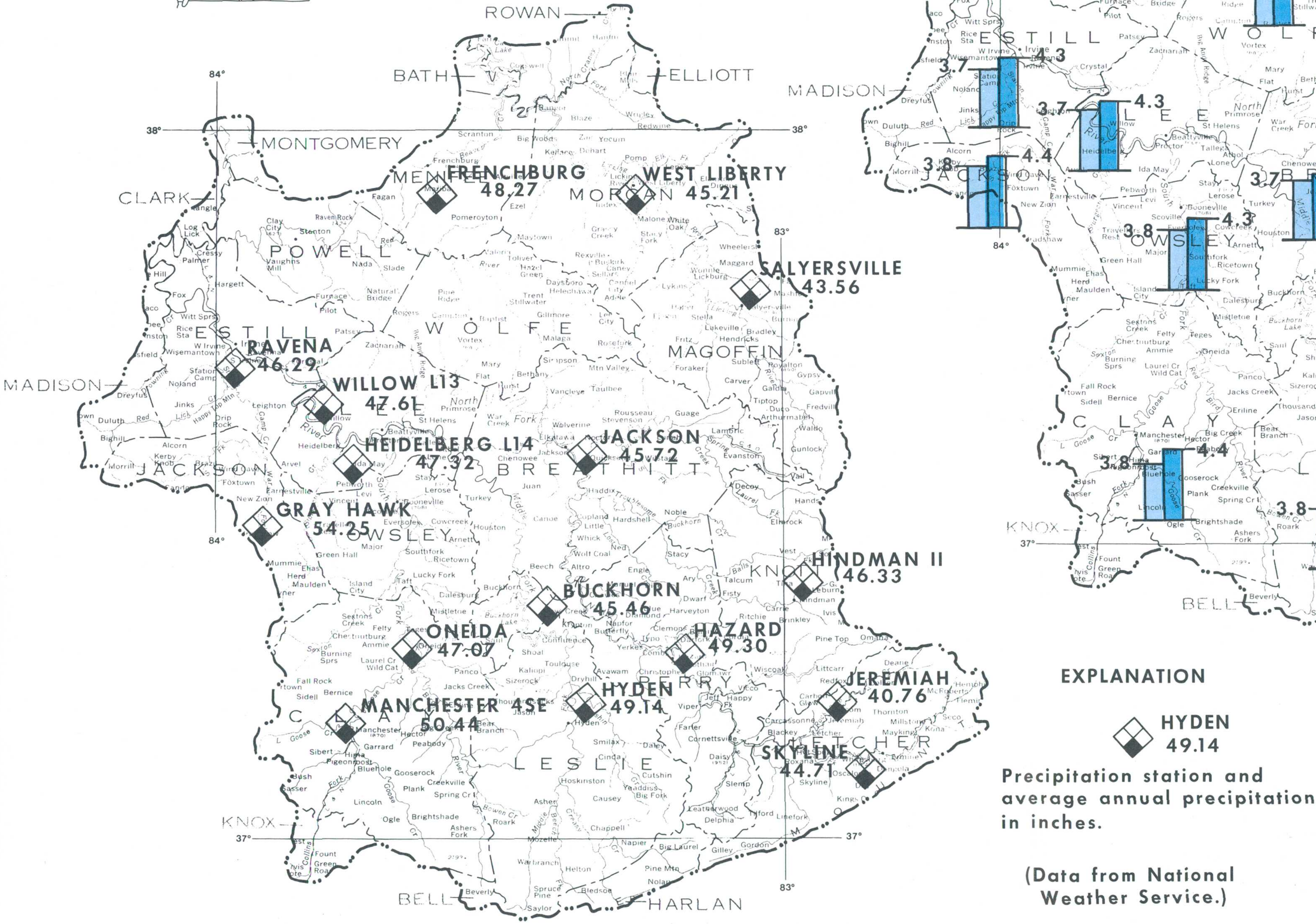


Figure 2.7-2 Precipitation network.

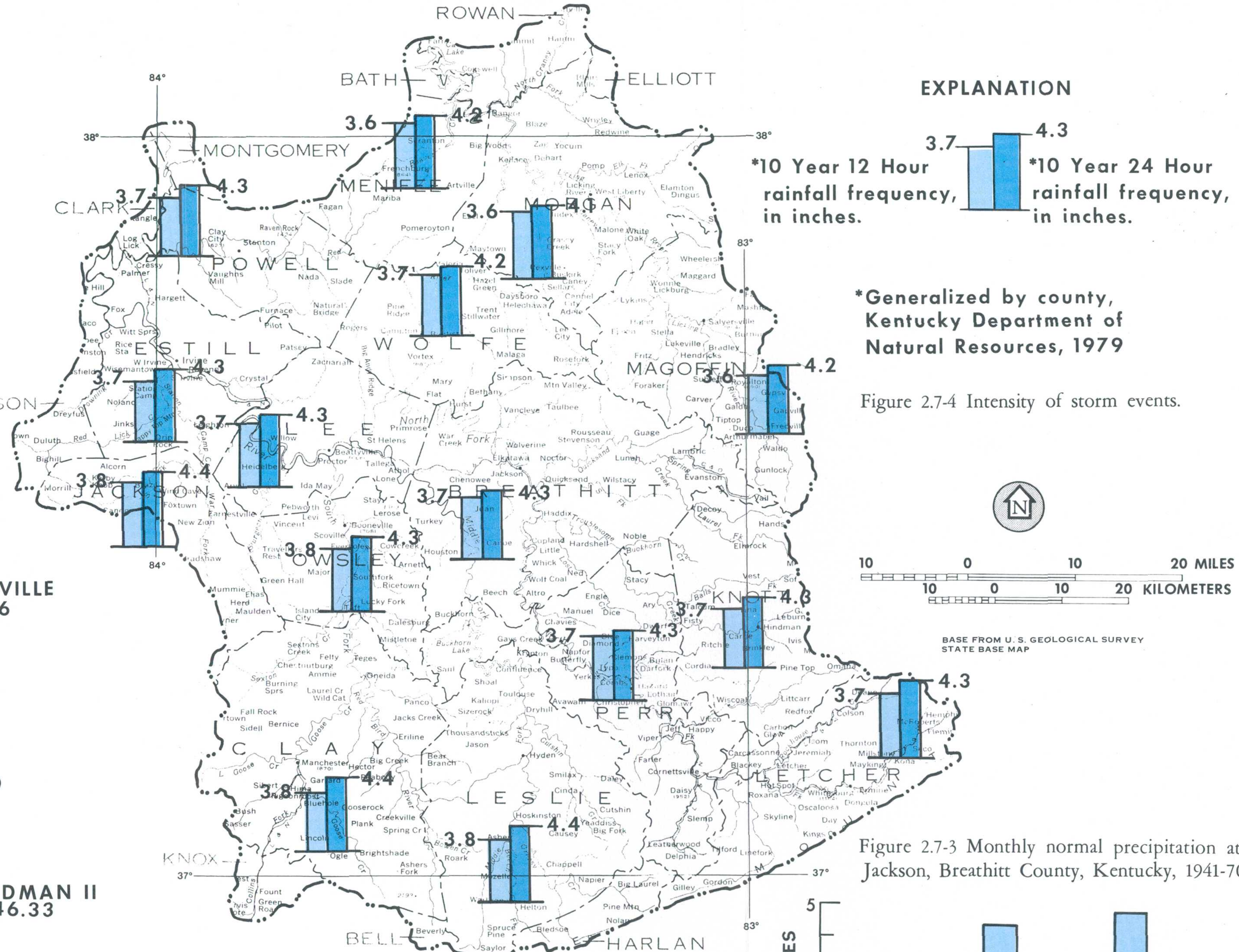
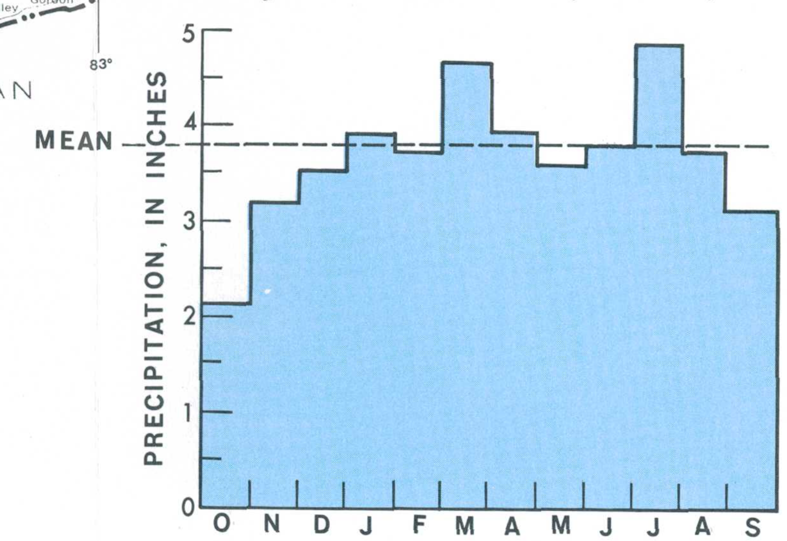


Figure 2.7-4 Intensity of storm events.

Figure 2.7-3 Monthly normal precipitation at Jackson, Breathitt County, Kentucky, 1941-70.



2.0 GENERAL FEATURES (Continued)

2.7 PRECIPITATION

DOMESTIC USE WAS 77 PERCENT OF WATER USED IN 1975

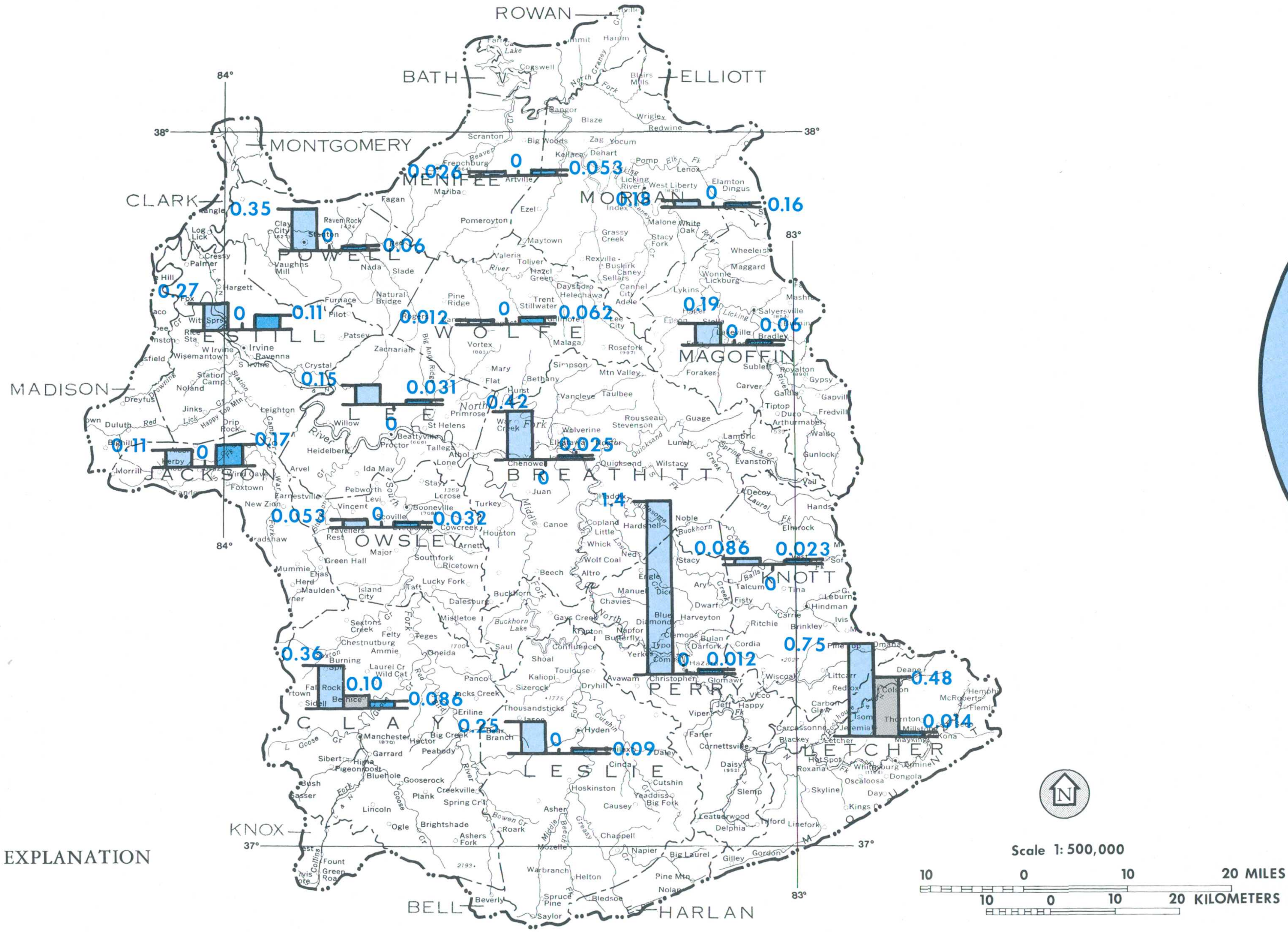
About 6.0 Mgal/d were used in Area 14 during 1975. Nearly 4.6 Mgal/d (77 percent) were for domestic purposes, followed by agricultural uses (0.9 Mgal/d or 15 percent), and industrial uses (0.5 Mgal/d or 8 percent).

During 1975, a total of 6.0 Mgal/d was withdrawn for domestic, agricultural, and industrial uses in Area 14. The distribution in most of the counties in the area is shown in figure 3.0-1. Domestic supply withdrawals were 77 percent of the total, followed by 15 percent for agriculture, and 8 percent for industry (fig. 3.0-2). Nearly all the withdrawals were from streams and lakes. Only small amounts of ground water are withdrawn, mostly from domestic wells. Perry and Letcher Counties accounted for more than 30 percent of the 4.6 Mgal/d withdrawn for domestic purposes.

Water use for agricultural purposes in Area 14 is mostly in Jackson, Estill, and Morgan Counties. Irrigation of tobacco and corn, the principal crops in the area, account for most of the 0.9 Mgal/d used for agriculture.

Industrial activity in the basin is predominantly related to the coal industry. Most of the 0.5 Mgal/d withdrawn in 1975 for industrial purposes was used for coal processing.

The water-use data in this report is contained in "Estimated Use of Water in the United States in 1975," U.S. Geological Survey Circular 765. Data are available through the National Water Data Exchange (NAWDEX). For details about NAWDEX, see section 9 of this report.



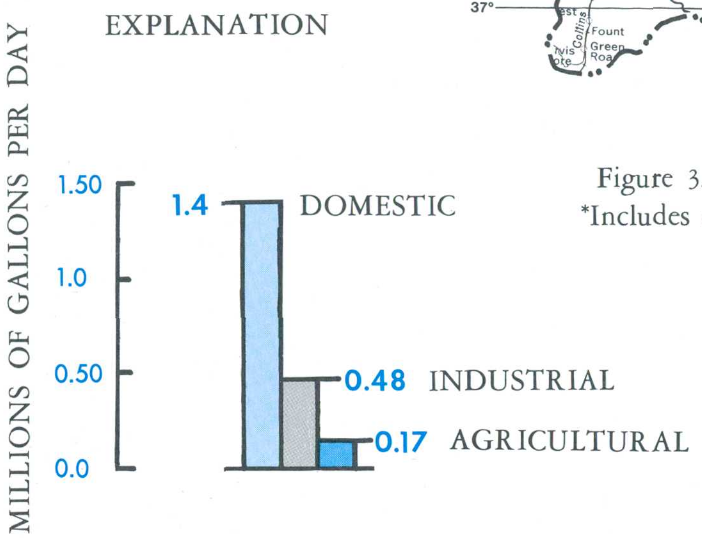


Figure 3.0-1 Water use by counties* in 1975.
*Includes only the principal counties in area 14.

WATER USE, IN MILLION GALLONS PER DAY
(and percentage of total)

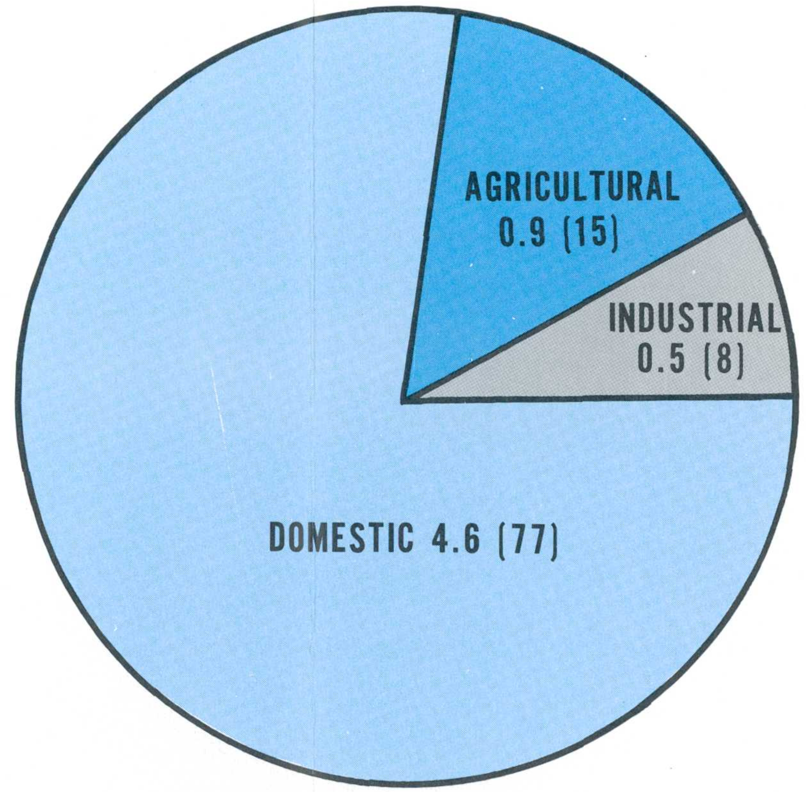


Figure 3.0-2 Water use in 1975.

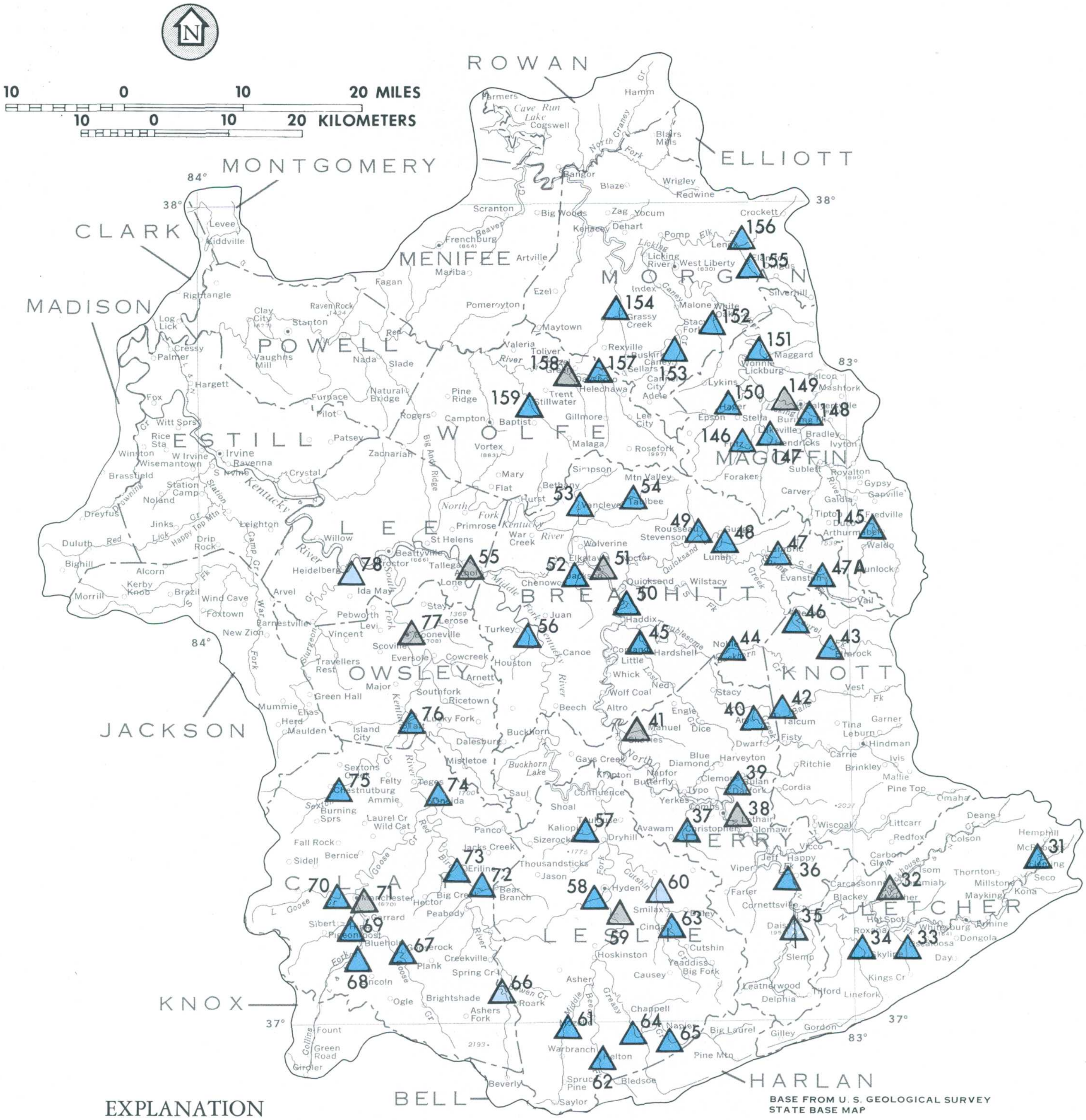
DATA AVAILABLE FOR 64 SITES

The surface-water data-collection network for Area 14 was increased from 12 to 64 quantity and quality sites in 1979 by the U.S. Geological Survey in response to the Surface Mining Control and Reclamation Act of 1977.

Streamflow and water-quality information is available for 64 sites in Area 14. The location and type of stations are shown in figure 4.1-1, with additional information for each station given in Appendix 3.

The existing network consists of several types of stations, including baseline-recording, synoptic, and other-recording. At baseline-recording stations a continuous record of stage and streamflow is obtained. In addition, samples for physical and chemical analyses such as pH, specific conductance, sulfate, iron, manganese, alkalinity, and dissolved solids are collected about every 6 weeks. Suspended-sediment samples are collected several times per week and during high flows in order to define the suspended-sediment load of the streams. At the synoptic stations, streamflow is measured and samples are collected about 4 times per year. At other-recording stations only continuous streamflow data are collected.

The surface-water data collected during 1979, as well as historical data, are published in the annual "Water Resources Data for Kentucky" reports. The information is also available through the National Water Data Exchange (NAWDEX) as described in section 9.0.



EXPLANATION

71 Baseline recording station and number

72 Synoptic station and number

66 Other recording station and number

35 Discontinued recording station and number

NOTE: See Appendix 3 for more detailed explanation on each station.

Figure 4.1-1 Surface-water network.

GROUND-WATER DATA AVAILABLE FOR MANY SITES

Miscellaneous information from a large number of domestic and industrial wells is available. Long-term ground-water information in Area 14 is scarce, with only 3 active monitoring wells. A comprehensive study of the hydrogeology of the Eastern Coal Field, begun in 1980, will provide additional data.

Miscellaneous information from domestic and industrial wells tapping deep formations throughout Area 14 is available (fig. 4.2-1). The types of well (drilled or dug), depth to water, and depth of wells in Breathitt, Floyd, Harlan, Knott, Letcher, and Magoffin Counties as of 1962 are summarized in Hydrologic Atlas 36 (Price and others, 1962). The data for Breathitt County is shown in figure 4.2-1. Other counties in Area 14 are covered in Hydrologic Atlases 37 and 38 (Price and others, 1962A and Kilburn and others, 1962).

Long-term continuous water-level information is available from only 2 wells in Area 14. These wells, located in Letcher County, are shallow and provide information only on the water-table aquifer (fig. 4.2-2). A third well, tapping the Lee Formation in Magoffin County, was sampled for alkalinity in 1935 and has been sampled periodically for chemical and physical analyses since 1951 (Faust and others), with annual samples collected since 1971 (fig. 4.2-2).

A comprehensive study of the hydrogeology of the Eastern Coal Field was begun in 1980 by the Kentucky Geological Survey. The study, which includes Area 14, will gather data on the aquifers in the area, will develop a data base to help implement a ground-water monitoring program, and will establish a network of observation wells.

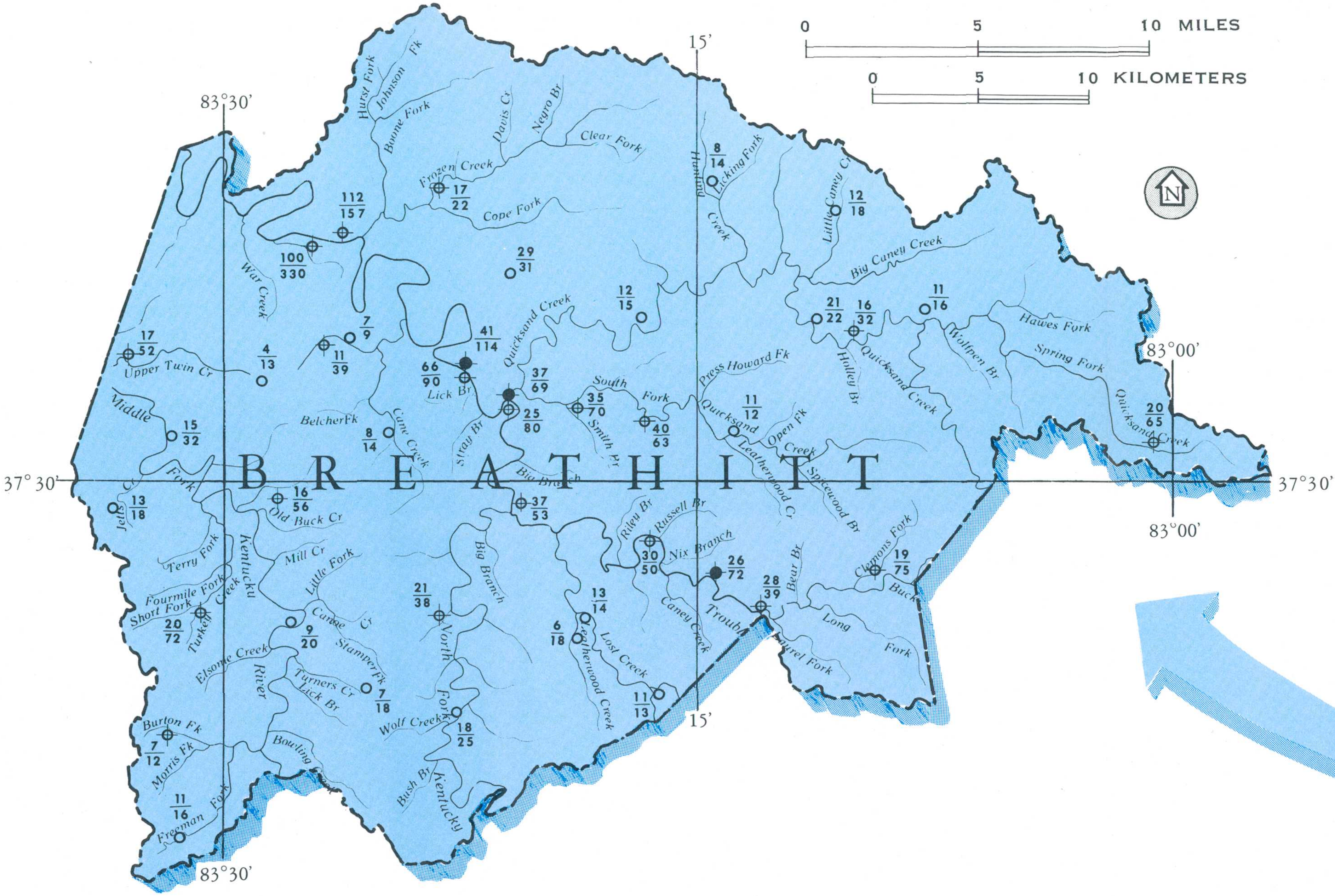


Figure 4.2-1 Miscellaneous ground-water network in Breathitt County.

EXPLANATION

- ⊕ Drilled well
- ○ Dug well
- ◆ Drilled well yielding salty water

15/50 — Depth to water, in feet, below land surface; Depth of well, in feet, below land surface

(Adapted from Hydrologic Atlas 36)

EXPLANATION

R	Observation well, recording
	Observation well, non-recording and ground water quality sampling site
146	Depth of well, in feet, below land surface
374501083043401	Well number (latitude - longitude identifer)

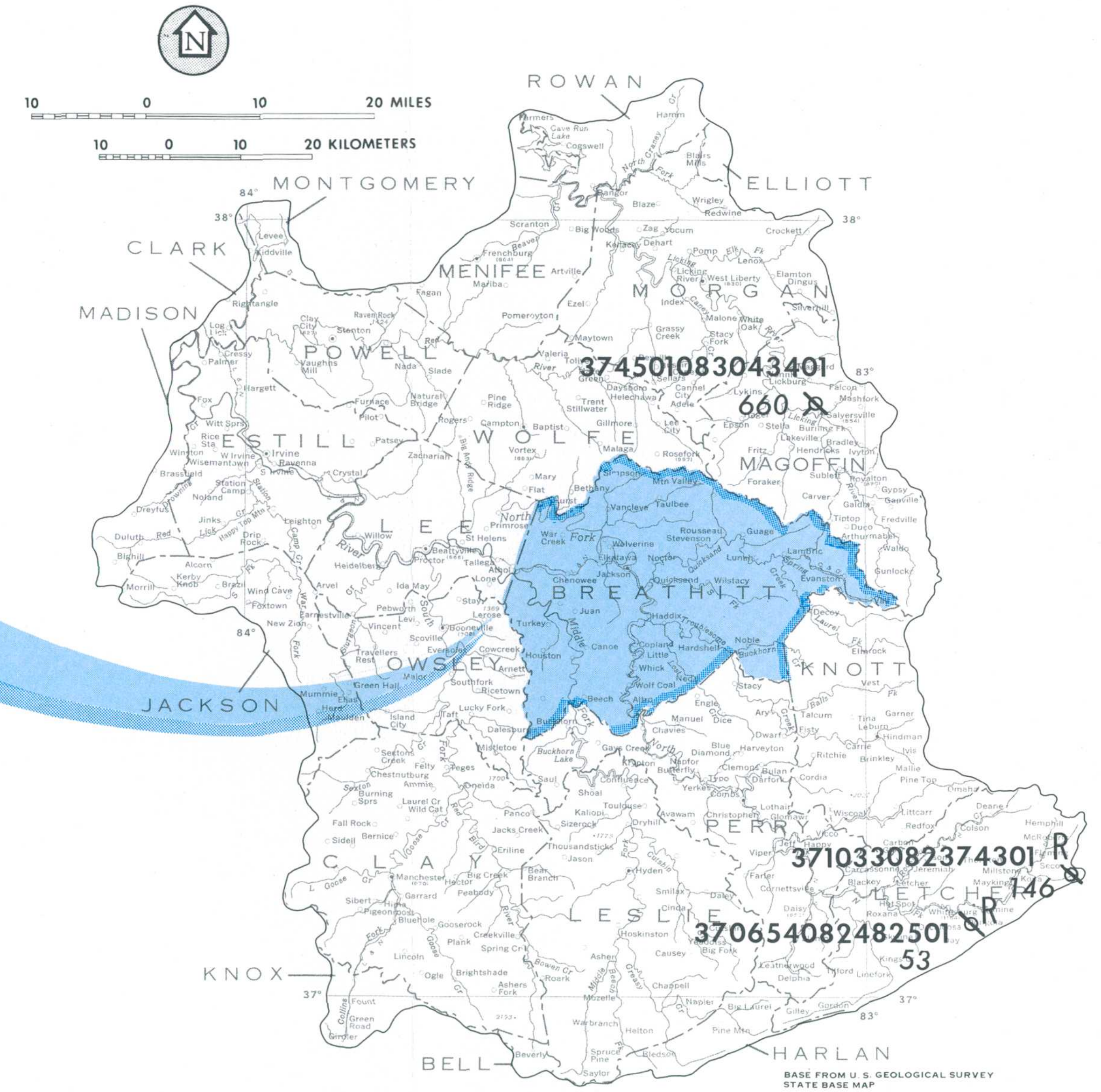


Figure 4.2-2 Long-term ground-water stations.

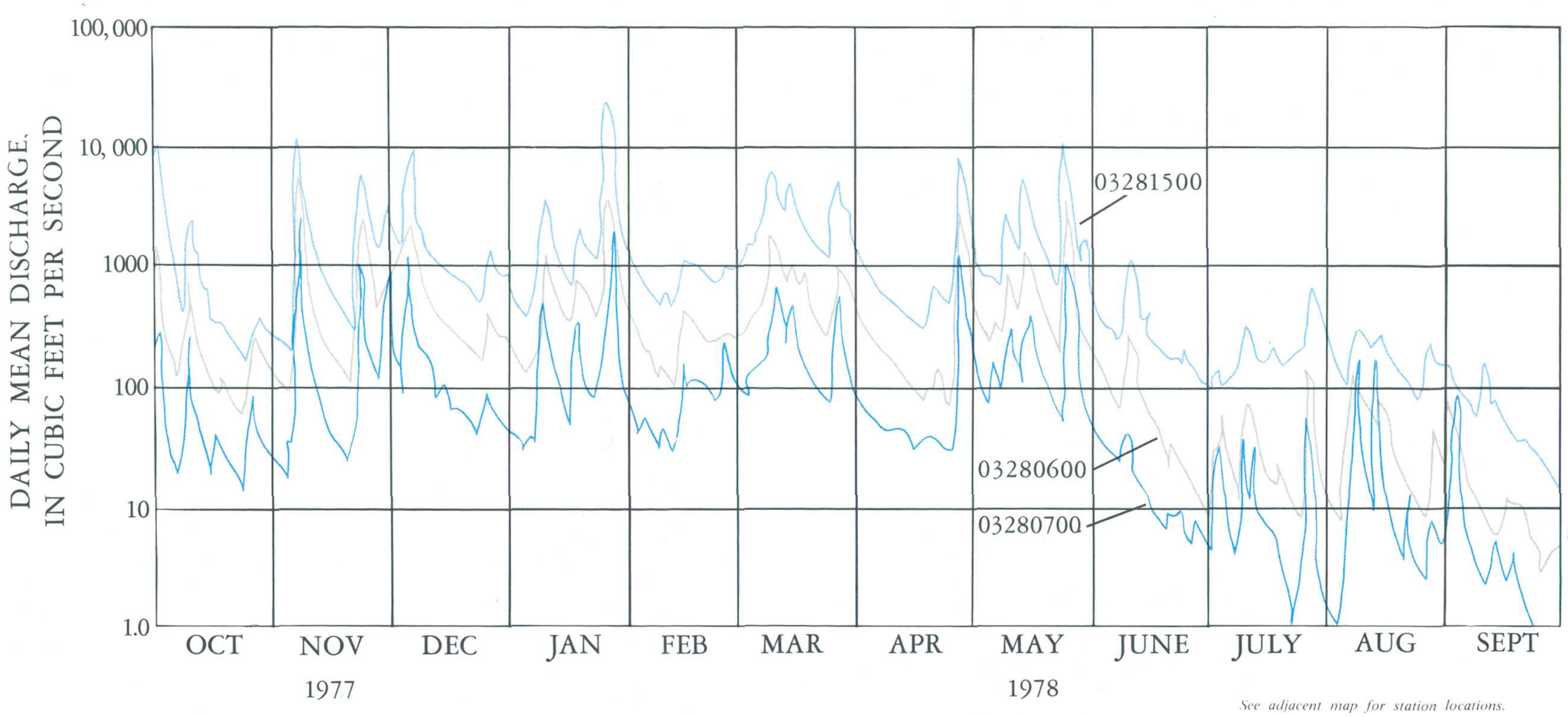
5.0 SURFACE WATER

5.1 Mean Daily Streamflow

STREAMFLOW VARIES SEASONALLY

Mean daily streamflow fluctuates seasonally with precipitation and evapotranspiration.

Streamflow throughout Area 14 varies seasonally with precipitation and evapotranspiration. Typical streamflow hydrographs from three stations in the area are shown in figure 5.1-1. These hydrographs represent small to large gaged basins and show a seasonal increase in flow from November through January in response to increasing precipitation and decreasing evapotranspiration. An increase in precipitation normally occurs during the winter months. Runoff increases during the spring months with increasing precipitation and some snow melt. Spring thunderstorms help to maintain a relatively high runoff through May, although increasing evapotranspiration tends to decrease streamflows. The low-flow season, resulting from a combination of decreasing precipitation and increasing evapotranspiration, extends from about June to about October.



See adjacent map for station locations.

Figure 5.1-1 Typical daily mean discharge hydrographs.

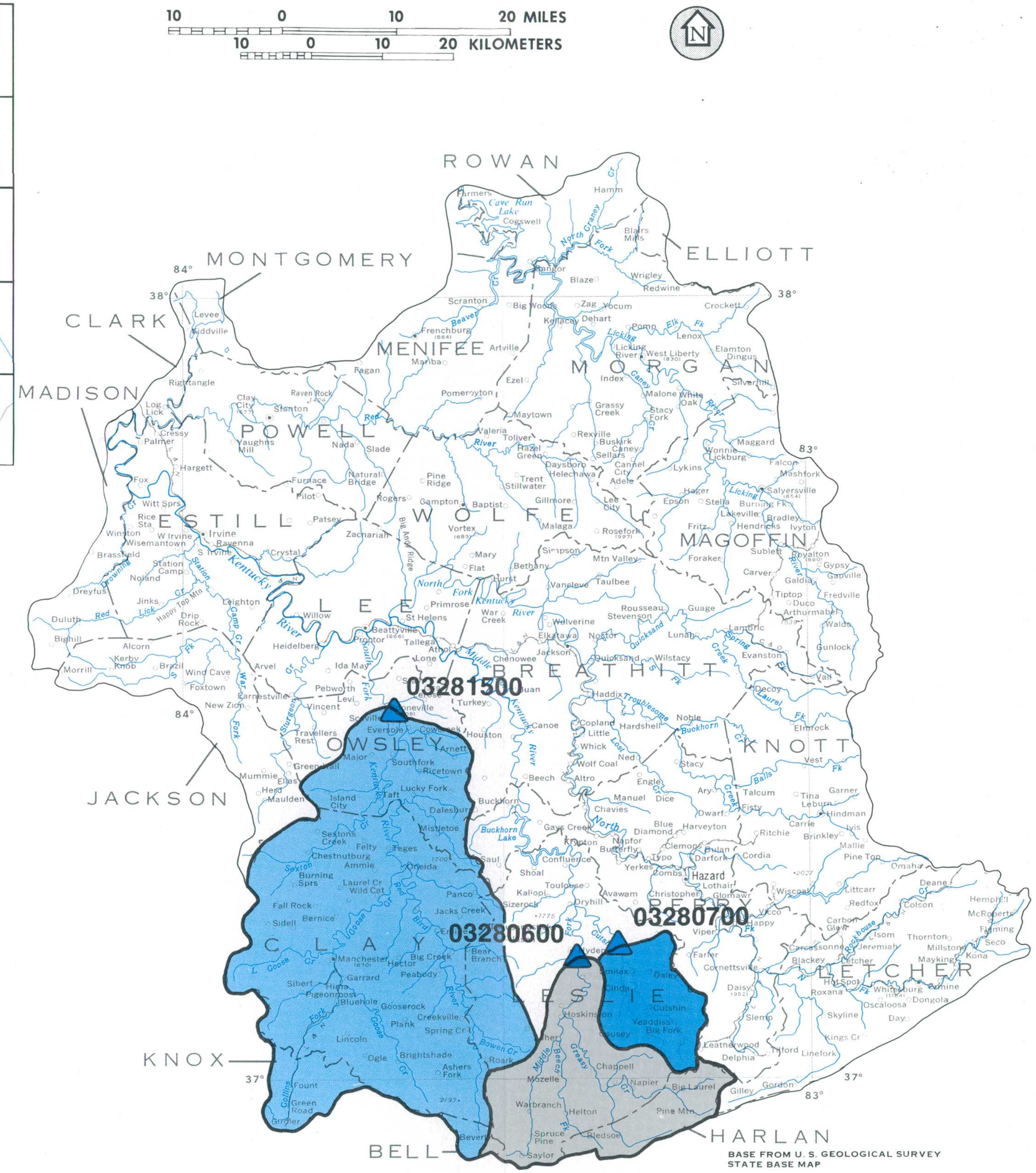
EXPLANATION

Drainage basin of indicated station:

- South Fork Kentucky River at Booneville (03281500) Drainage Area - 722 square miles.
- Middle Fork Kentucky River near Hyden (03280600) Drainage Area - 202 square miles.
- Cutshin Creek at Wooton - (03280700) Drainage Area - 61.3 square miles.

▲ 03280700 - Streamflow gaging station and station number

Basin boundary

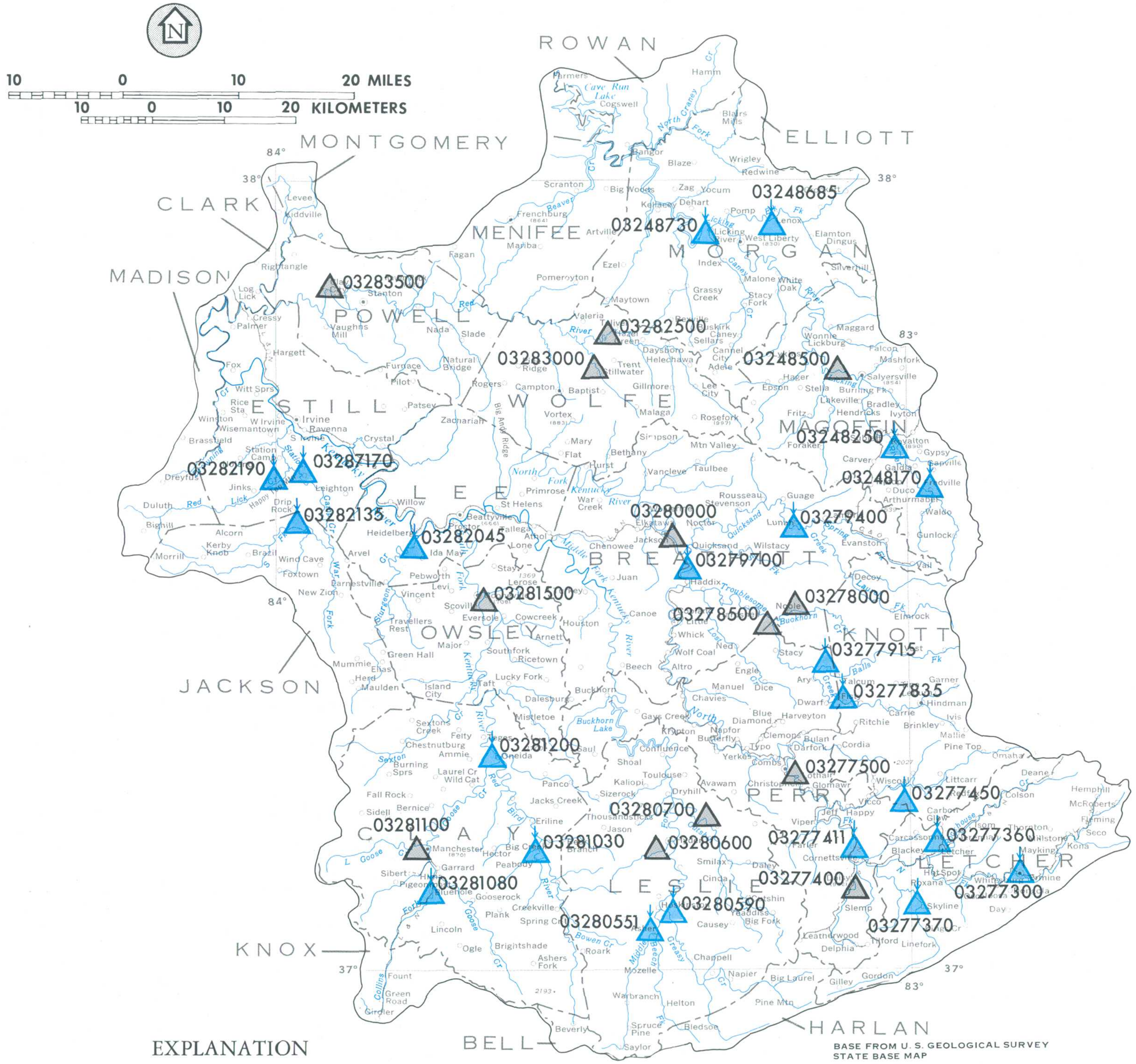


MOST STREAMS DRAINING LESS THAN 100 SQUARE MILES GO DRY OCCASIONALLY

Low flows of streams in Area 14, draining less than 100 mi^2, have a 7-day 10-year discharge of zero.

Topography and geology in Area 14 are the most important factors affecting low flows. Steep slopes in the area cause rapid surface runoff. In some areas the low permeability of the soils reduces infiltration, minimizing ground-water recharge and subsequent base streamflows. Most of the streams draining less than 100 mi^2 approach zero flow during the low-flow season, which normally occurs from June through October (Table 5.2-1).

A network of low-flow sites has been operated throughout the area for many years (fig. 5.2-1). Partial results of the frequency analyses at gaged and ungaged sites were published (Swisshelm, 1974). An update of the published data, including 7-day 10-year low flows and other low-flow frequencies can be obtained from the U.S. Geological Survey District Office in Louisville (Sullavan, 1980).



EXPLANATION

03281100
Index station and number

03281030
Low-flow station and number

Figure 5.2-1 Low-flow network.

TABLE 5.2-1 7-DAY 2-YEAR AND 7-DAY 10-YEAR LOW FLOWS AT STATIONS IN AREA 14

STATION NUMBER	DRAINAGE AREA (SQUARE MILES)	7-DAY 2-YEAR DISCHARGE (CUBIC FEET PER SECOND)	7-DAY 10-YEAR DISCHARGE (CUBIC FEET PER SECOND)
03248170	40.3	0.1	0.0
03248250	76.7	.6	0
03248500	140	1.3	0
03248685	59.4	.6	0
03248730	41.4	.1	0
03277300	66.4	4.4	2.0
03277360	51.5	.9	.3
03277370	40.8	.9	.3
03277400	40.9	1.3	.7
03277411	322	9.4	3.5
*03277450	60.6	.7	0
03277500	466	8.8	2.1
03277835	59.6	.3	0
03277915	45.4	.2	0
03278000	2.21	0	0
03278500	177	1.4	.1
03279400	101	.3	0
03279700	203	1.6	.1
03280000	1,110	24	3.1
03280551	70.6	.4	0
03280590	95.0	.7	.1
03280600	202	2.1	.4
03280700	61.3	.9	.1
03281030	125	.9	.1
03281080	67.4	.1	0
03281100	163	2.7	1.1
03281200	486	2.3	.1
03281500	722	9.0	.7
03282045	96.4	.3	0
03282135	41.4	.2	0
03282170	115	.4	0
03282190	69.5	.2	0
03283500	362	11	3.4

* Prior to Regulation

FLOODING SEVERE IN AREA 14

Severe flooding throughout Area 14 is produced by intense precipitation. Peak discharges and precipitation data have been recorded over a period of 50 years.

Maximum known instantaneous peak discharges at stations in Area 14 range from 9,000 to 120,000 ft^3/s (Appendix 4). The intensity of these floods may be compared among streams if expressed on a yield per square mile of drainage area. Extreme recorded yields in the area range from 45 to 297 $[(ft^3/s)/mi^2]$. The December 1978 flood yields ranged from 31 to 121 $[(ft^3/s)/mi^2]$.

Runoff increases rapidly during floods at sites throughout Area 14. During the December 1978 flood, at sites in the headwaters of the area, flood flows increased tenfold within 12-15 hours (fig. 5.3-1). At a downstream site, Kentucky River at Lock 14 at Heidelberg, the flood flows increased from 5,000 to 82,000 ft^3/s within a period of about 40 hours. The steep valley slopes of the upper basin promote rapid runoff and flash flooding, while the flatter slopes of the lower basin promote slower runoff and the flooding covers larger areas for longer periods of time.

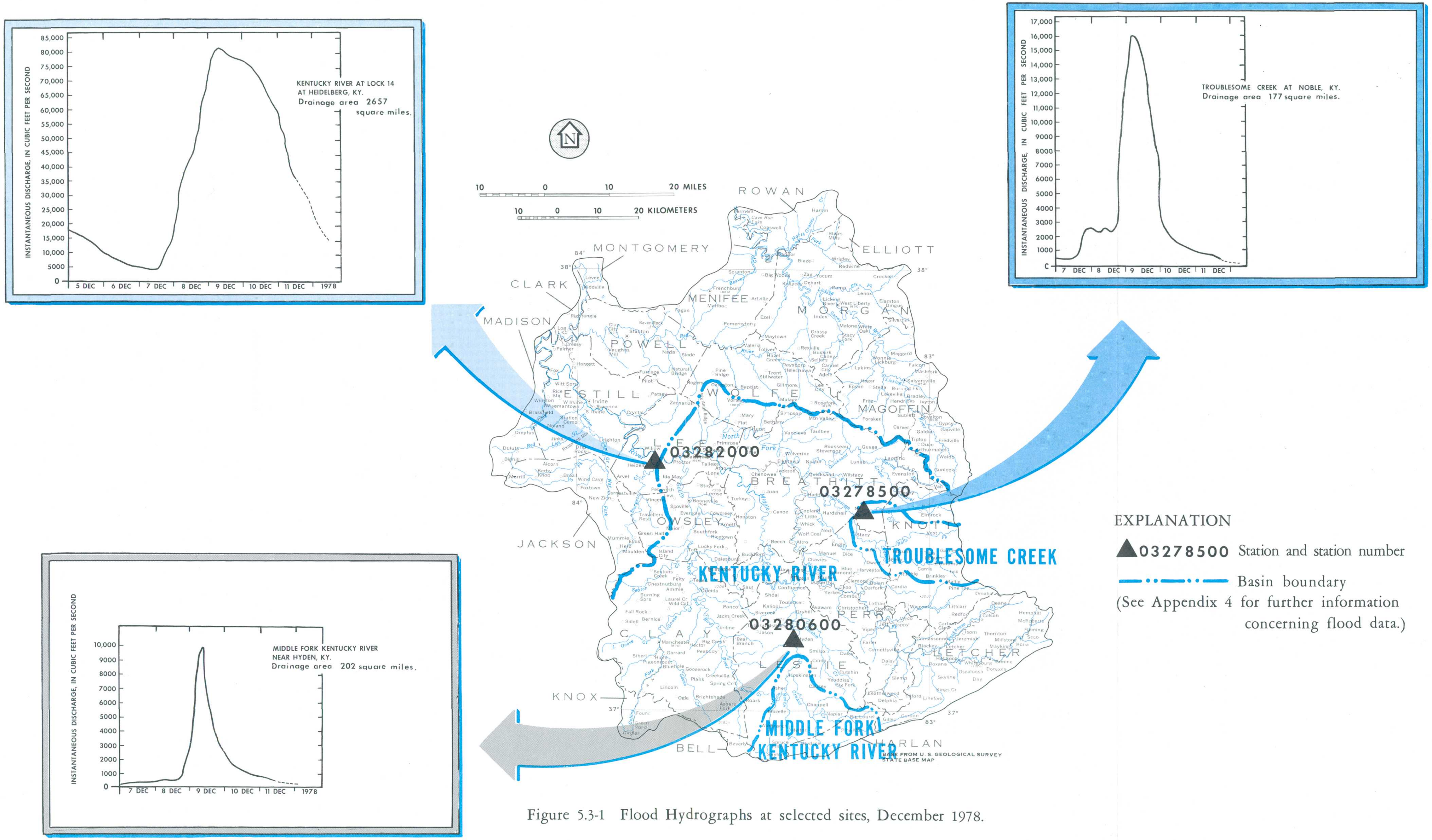


Figure 5.3-1 Flood Hydrographs at selected sites, December 1978.

FLOODS VARY WITH DRAINAGE AREA, TOPOGRAPHY AND GEOLOGY

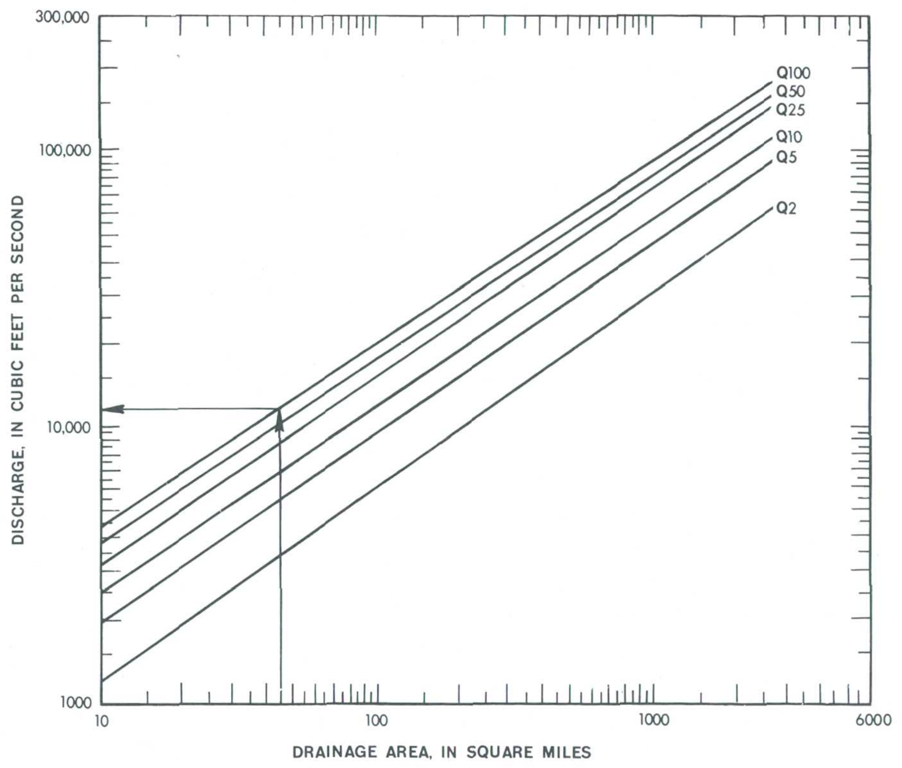
Differences in geography contribute to the magnitude and frequency of flood events in Area 14. Several techniques are available to estimate the magnitude and frequency of floods.

Flood frequency analysis is important for the design of structures. Flood frequencies are expressed as a probability of exceedance, or as recurrence interval. There is a 0.02 (two percent) probability that the discharge of the 50-year flood will be equalled or exceeded in any year.

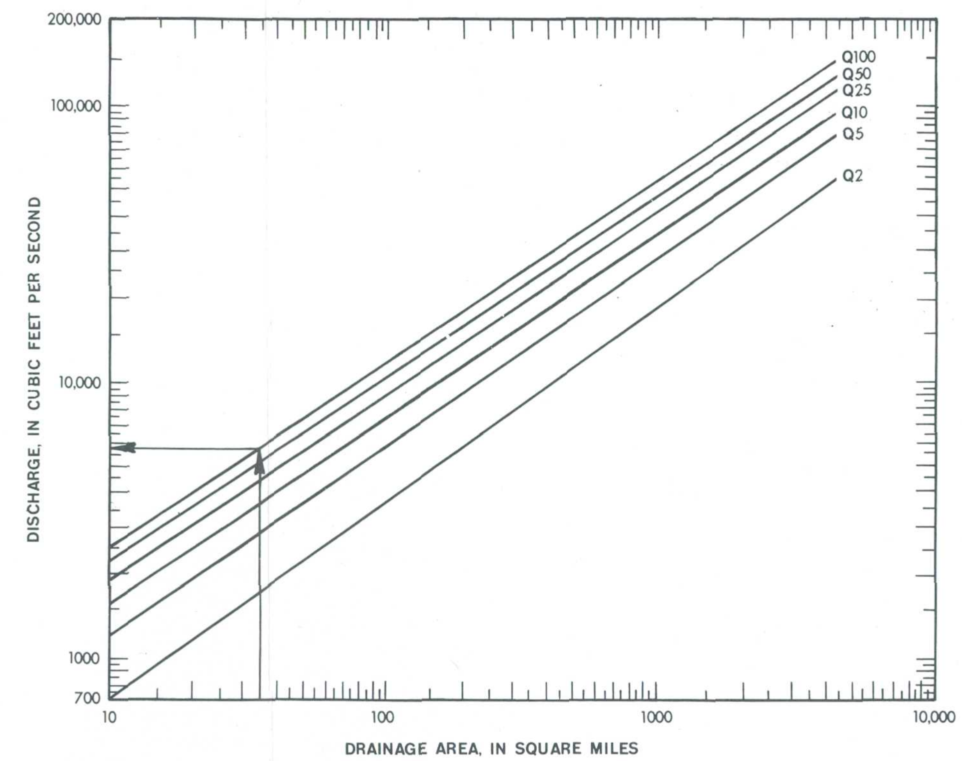
Techniques for estimating magnitude and frequency of floods at gaged and ungaged sites throughout Kentucky have been developed by McCabe (1962) and Hannum (1976). Hannum developed generalized regression equations from which estimates at any site can be made. For the 50-year flood, the following equation applies:

$$Q_{50} = 638A^{0.663}R^{1.040},$$

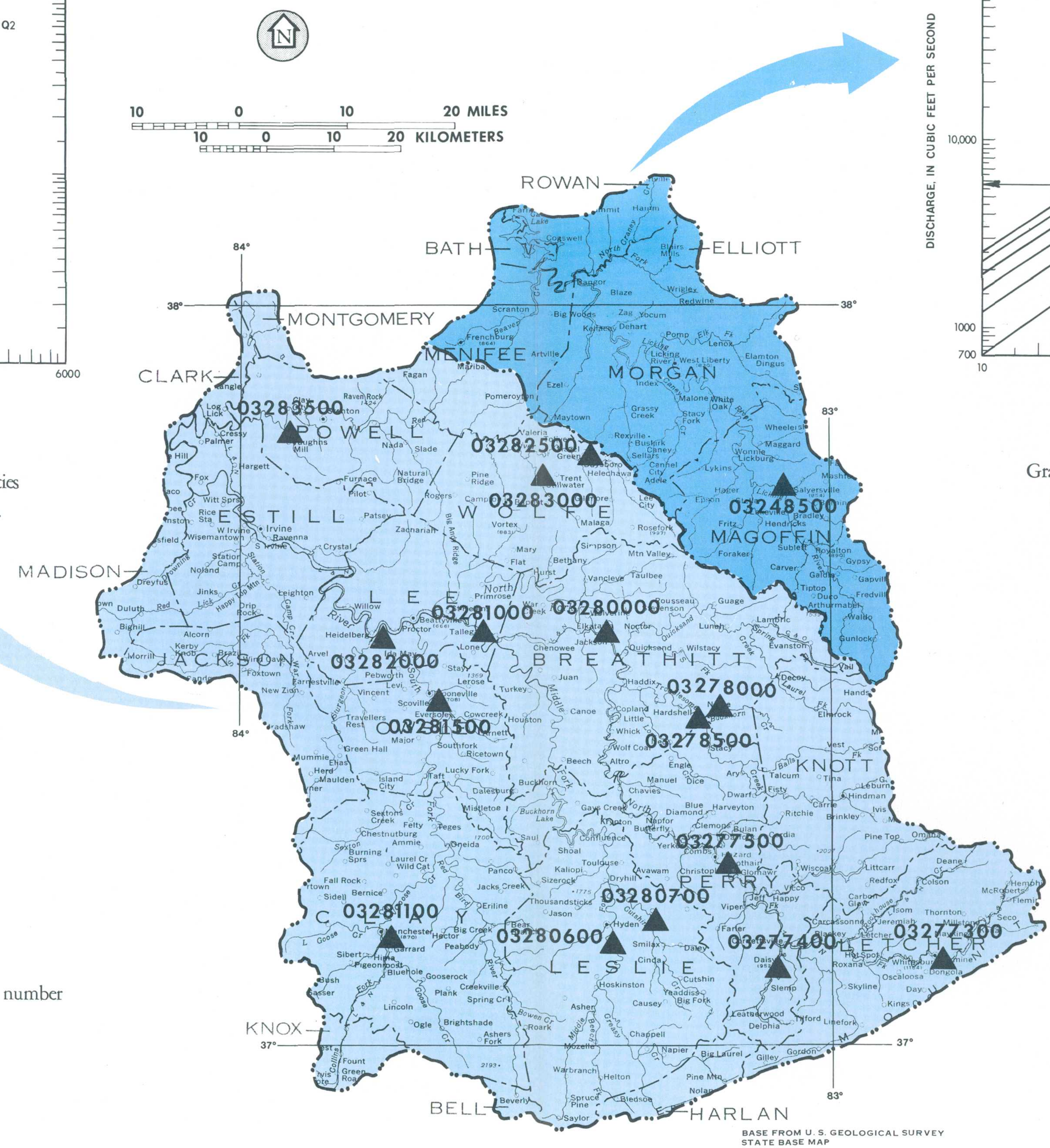
where Q_{50} = discharge of 50-year flood in cubic feet per second, A = drainage area, in mi^2, and R is a geographical factor related to the geology and topography. A difference of nearly 40 percent in the R factors occurs between the Kentucky and Licking River basins. Graphical solutions to the above and other regression equations (simplifying the estimation of selected flood frequencies) in Area 14 are shown in figure 5.4-1. Flood flows at long-term stations in Area 14 are shown in Appendix 4.



Graphical solution for estimating flood frequencies in the upper Kentucky and Red River basins. (Hannum, 1976)



Graphical solution for estimating flood frequencies in the Licking River basin. (Hannum, 1976)



EXPLANATION

Licking River basin

Kentucky and Red River basins

Basin boundary

▲ **03283000** Long-term streamflow gaging station and number

See Appendix 4

Figure 5.4-1 Flood flows in area 14.

MAPS DEFINING FLOOD-PRONE AREAS AVAILABLE

The limits of inundation by the 100-year recurrence interval flood or the maximum known flood are shown on 35 maps for part of Area 14.

The National Flood Insurance Act of 1968, and the Flood Disaster Protection Act of 1973, established programs for investigating the severity and extent of flooding in urban areas and rural communities. In 1968, the U.S. Geological Survey began a program to delineate flood-prone areas and maximum known floods for selected areas in Kentucky. The objective of the program was to define the 100-year flood in areas identified as subject to flooding. Areas were selected where enough information was available to estimate the depth of the 100-year flood. A map delineating the maximum known flood regardless of the recurrence interval was prepared for areas where information was not available to define the 100-year flood.

Maps for 35 flood-prone areas within Area 14 are available (fig. 5.5-1). These include 29 maps where the 100-year flood has been defined and 6 maps where the maximum known flood has been delineated. Areas that may be subject to flooding are outlined on 7½ minute quadrangle topographic bases at a scale of 1:24,000 (1 in = 2000 ft). Maps are available from:

Kentucky Geological Survey
311 Breckinridge Hall
University of Kentucky
Lexington, KY 40506

or

Kentucky Department of Commerce
Map Sales Office
133 Holmes Street
Frankfort, KY 40601

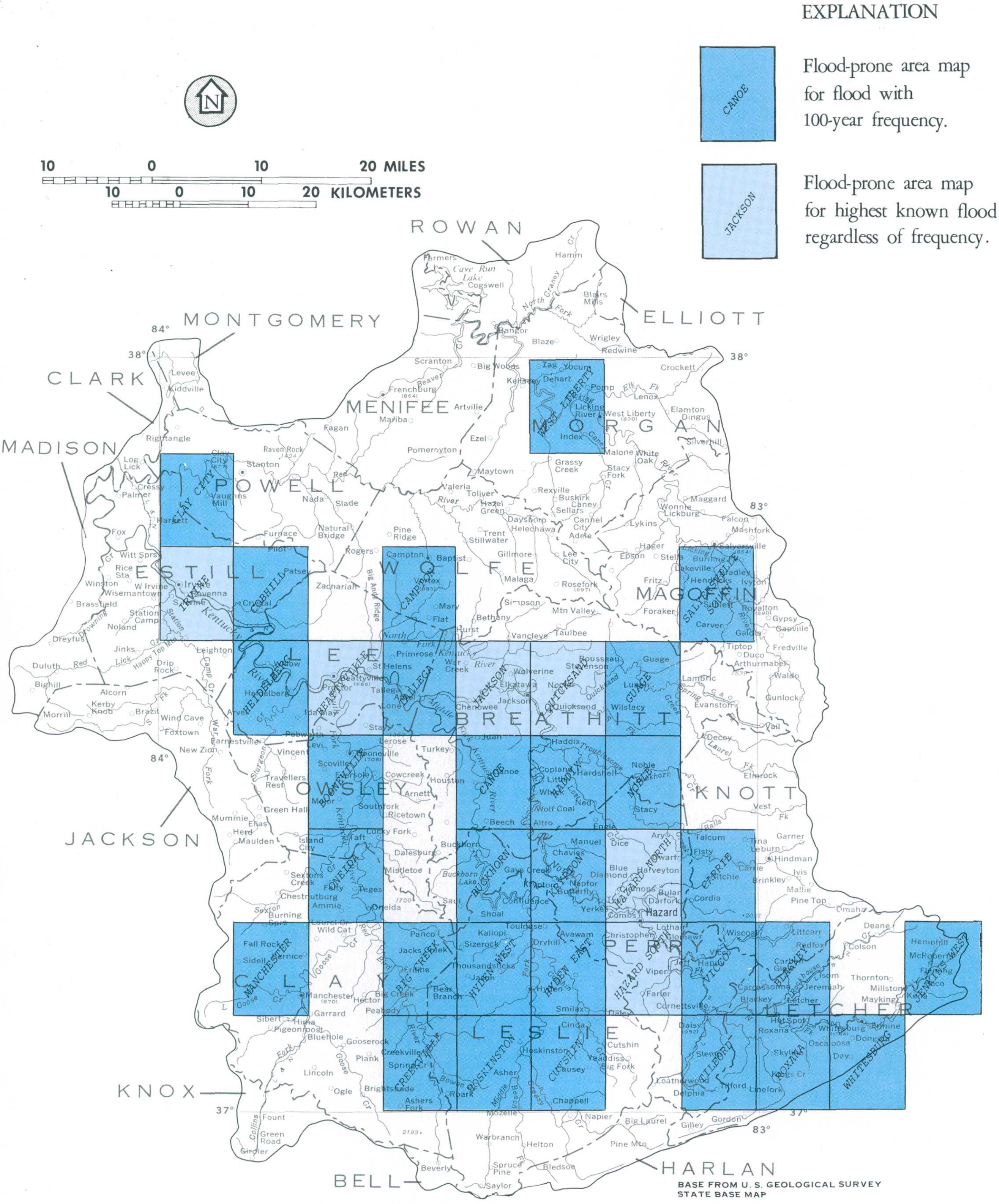


Figure 5.5-1 Availability of flood-prone area maps.

FLOW OF STREAMS IS POORLY SUSTAINED

Flow-duration data are available for 11 stations. Streamflow in Area 14 is highly variable and low flows decrease rapidly during the dry season.

The streamflow at a given point is an integration of the partial effects of climate, topography, and geology, providing a distribution of runoff in time and magnitude. The flow duration curve is a cumulative frequency curve that shows the percent of time that a discharge was equalled or exceeded. Mean daily discharges are particularly suitable for flow-duration analysis because they are available from continuous recording stations. Flow-duration data provide a convenient method of comparing flow characteristics of streams and estimating the percent of time that a given amount of flow was exceeded. Searcy (1959) describes how flow-duration data at ungaged sites may be estimated if several streamflow measurements made during low flow are available.

The slope of the flow-duration curve for a stream is a measure of the variability of flow. A steep slope indicates highly variable flow whereas a flat slope indicates more uniform flow which can be caused by surface or ground-water storage contributions.

Flow-duration data are available for 11 stations in Area 14 (fig. 5.6-1 and Appendix 5), with length of records ranging from 6 to 52 years.

The flow-duration curves from sites in Area 14 are typical of basins with steep slopes, short time-of-travel between the headwaters and lower basin, and minor contributions to streamflow from ground water (fig. 5.6-1). Low-flows at most of the sites diminish rapidly, except where regulation is significant such as at the Kentucky River at Heidelberg. Low-flow augmentation occurs as a result of controlled releases from the reservoirs in the area.

Poor recharge and ground-water storage conditions result in poor yields during dry periods. In the basins where coal is mined, although flows are also poorly sustained, ground water discharges appear to be more sustained. Some of the increase in base flows could be due to increased inflitration of surface runoff in mined areas. Changes in the relief of the mined area may increase the recharge area and reduce the slope of the terrain. Similar conditions were observed by Dyer and Curtis (1977) in several small basins in Breathitt county.

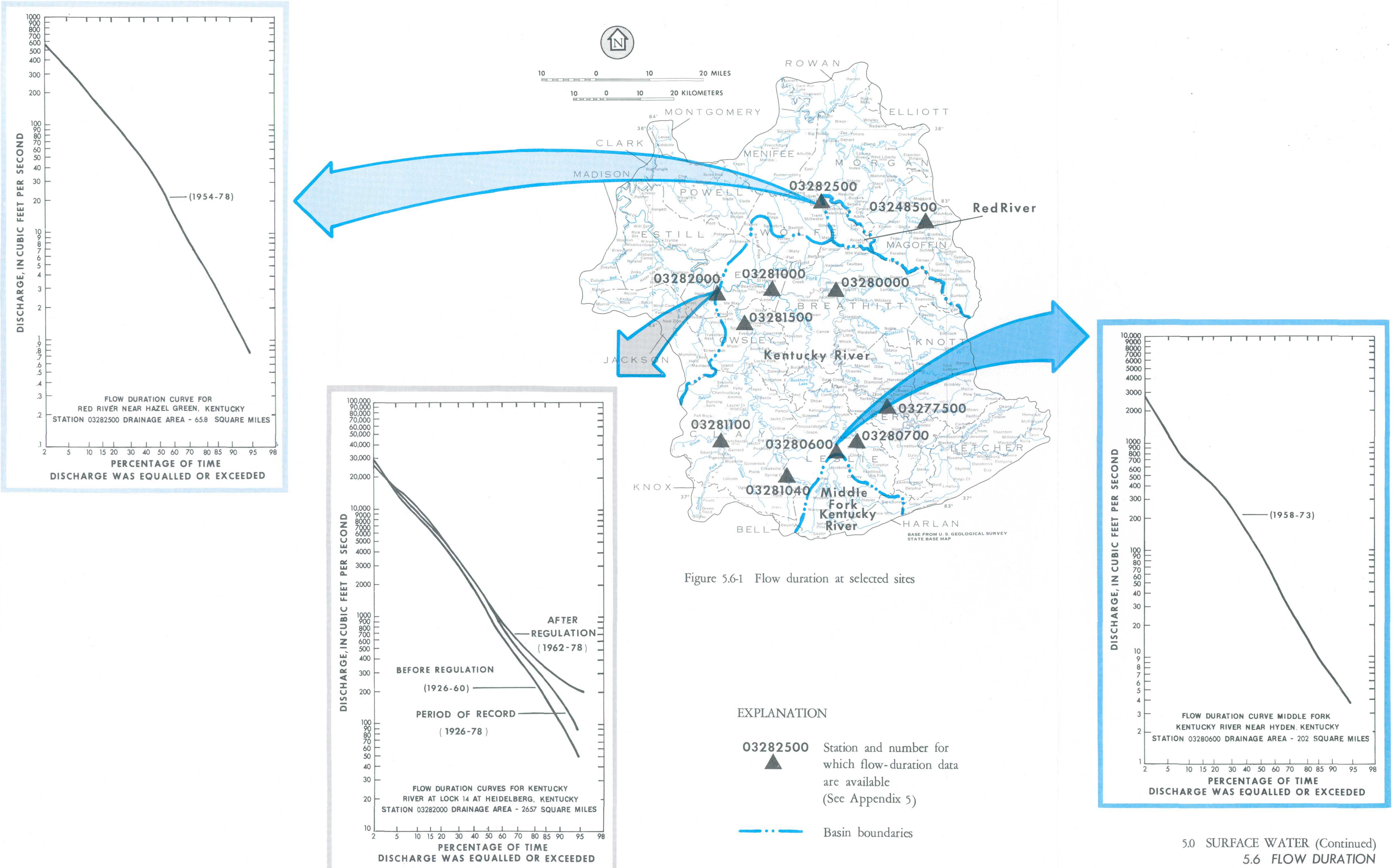


Figure 5.6-1 Flow duration at selected sites

WATER QUALITY DATA COLLECTED AT 64 SITES

Six sampling trips in 1979 and 1980 in addition to historical data provide a general view of water quality in Area 14.

Some of the effects of surface coal-mining activities on the hydrologic environment can be evaluated from water-quality data. The Surface Mining Control and Reclamation Act of 1977 established a series of maximum-permissible limits for a number of water-quality related constituents. The most important ones are:

1. pH range from 6.0 to 9.0 units.

2. Total manganese concentration of 4,000 μg/L.

3. Total iron concentration of 7,000 μg/L.

4. Total suspended-solids concentration of 70 mg/L.

Sufficient data to define seasonal water-quality changes are also required by several sections of the Act.

The water-quality sampling network in Area 14 consists of 64 active sites (fig. 6.1-1 and Appendix 2). Samples are collected at various frequencies at each site for the determination of pH, specific conductance, alkalinity, temperature, iron and manganese concentrations (total and dissolved), sulfate, dissolved solids and suspended-sediment concentrations. Additional parameters are determined from samples collected during a low-flow sampling trip to determine concentrations of most common constituents (calcium, magnesium, sodium, potassium, chloride and fluoride), selected trace constituents (barium, cadmium, chromium, copper, lead, silver, zinc, cyanide, arsenic, mercury, and selenium), and percent of coal in bottom material.

In addition to this network, numerous streams in the basin have had limited water-quality data collected in the past. Many of these historical sites are incorporated in the present network (Appendix 2). Analyses of the historical data, plus the data collected during the 1979 and 1980 sampling trips are presented in the following sections of this report.

The sampling trips made in 1979 and 1980 were conducted during the spring, summer, and fall seasons in an effort to sample during several flow regimes (low, medium, and high flow conditions). Samples collected represent water-quality conditions during extreme low, medium, and some high flows; extreme high flow conditions were not encountered. Several streams visited in July and September, 1980, were dry. The data collected provide an instantaneous or synoptic view of water quality during the time of sampling.

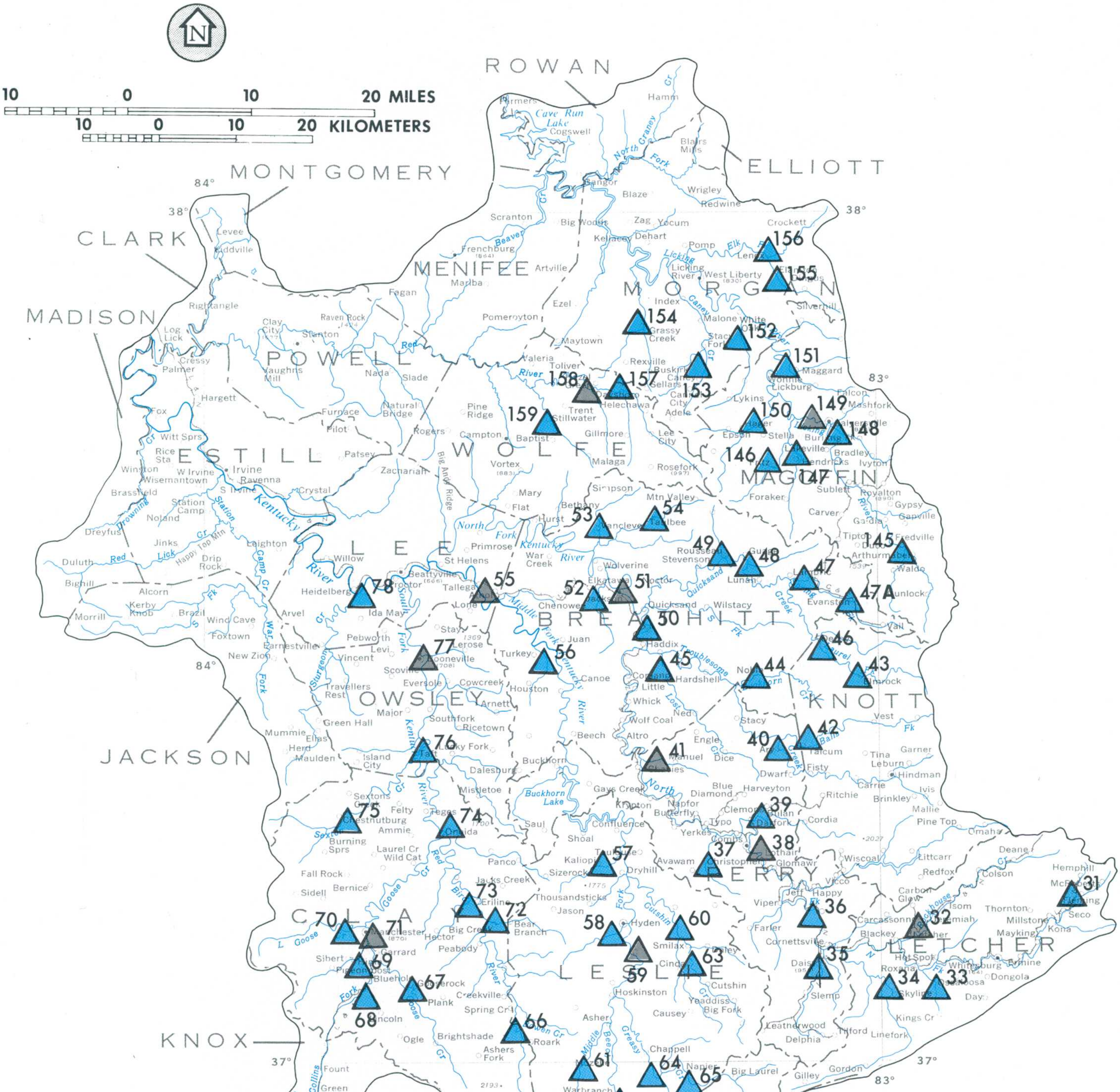


Figure 6.1-1 Surface-water network.

EXPLANATION

71 Baseline recording station and number

72 Synoptic station and number

NOTE: See Appendix 3 for more detailed explanation on each station.

SPECIFIC CONDUCTANCE CAN BE USED TO ESTIMATE WATER-QUALITY CHARACTERISTICS

Specific conductance of surface waters in Area 14 ranges from 55 to 5,350 micromhos per centimeter at 25°C. The highest values occur in areas affected by intensive surface mining. Significant correlations between specific conductance, streamflow, and sulfate concentrations have been defined at long-term sites.

The specific conductance of water, expressed as micromhos per centimeter at 25°C (μmhos/cm), is a general indicator of the amount of dissolved solids, (Hem, 1970). The simple and inexpensive procedure for the field determination of specific conductance makes it one of the most valuable tools for general estimation of dissolved constituents. Many of the ions dissolved in water correlate with the specific conductance. At a particular site, a correlation may be developed with the concentration of sulfate or the discharge. For these reasons, specific conductance is routinely determined at all sites where streamflow measurements are made or water samples are collected (fig.6.2-1 and 6.2-2).

Conductance values throughout Area 14 vary with stream location and flow (table. 6.2-1). Minimum instantaneous values range from 52 to 630 μmhos/cm, while maximum instantaneous values range from 55 to 5,350 μmhos/cm. Correlation analyses between specific conductance and sulfate concentrations were highly significant at the 95 percent confidence level for those stations in the headwaters of the North Fork Kentucky River (Appendix 6). A significant correlation also exists at most sites in the basins between the specific conductance and instantaneous streamflow showing that the specific conductance decreases with increases in streamflow.

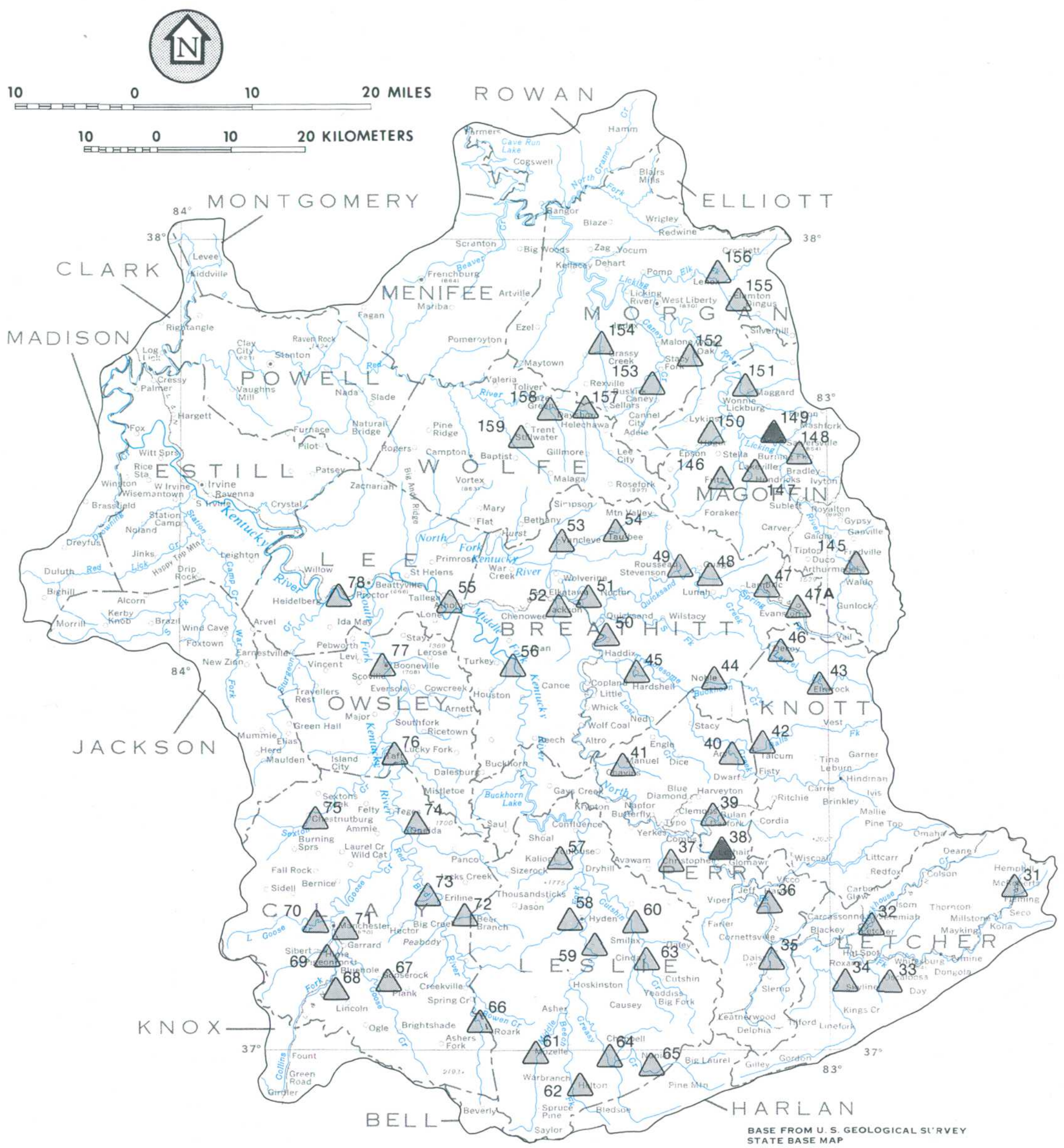


Figure 6.2-1 Specific conductance measuring sites.

EXPLANATION

▲38 Station and number

(See Appendix 3)

EXPLANATION

○ 1979-80 Values determined at station 149 (unmined)

△ 1979-80 Values determined at station 38 (mined)

r correlation coefficient

Se Standard error of estimate

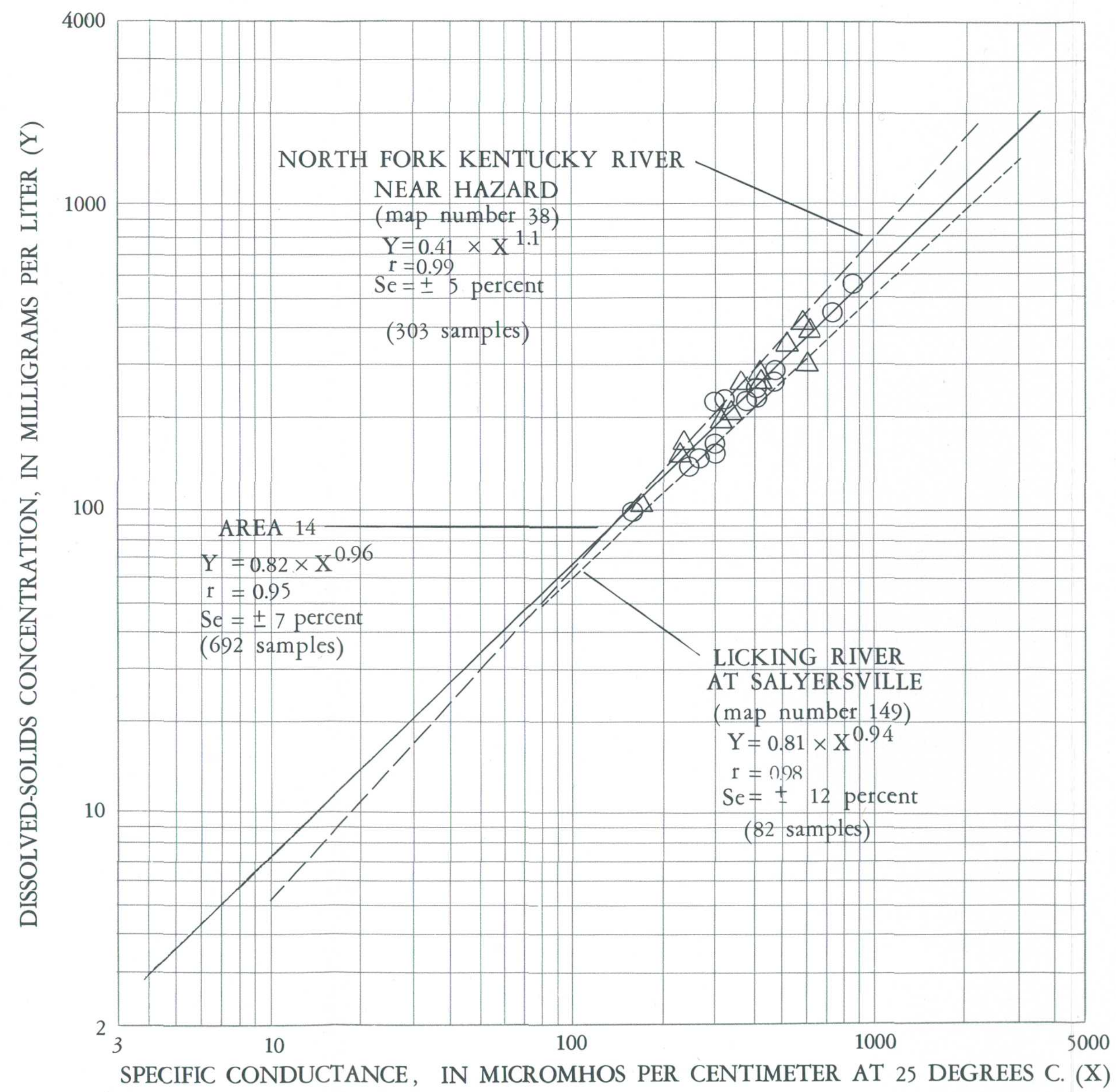


Figure 6.2-2 Relation between dissolved-solids concentration and specific conductance values at selected sites.

Table 6.2-1 Specific conductance, in micromhos per centimeter at 25 degrees C.

SITE NUMBER	NUMBER OF SAMPLES	MINIMUM	MAXIMUM	MEAN	STANDARD DEVIATION
31	6	370	740	581	--
32	6	235	560	415	--
33	6	130	275	195	--
34	6	115	290	185	--
35	9	170	468	325	--
36	6	180	800	485	--
37	6	540	1045	805	--
38	330	100	1720	423	224
39	6	630	1250	947	--
40	6	270	720	433	--
41	6	295	735	518	--
42	6	105	373	223	--
43	6	54	170	112	--
44	6	115	690	361	--
45	6	360	850	628	--
46	6	61	120	81	--
47	6	120	260	183	--
47A	4	108	170	152	--
48	7	110	249	193	--
49	3	68	195	116	--
50	7	245	600	429	--
51	28	130	585	357	129
52	7	78	365	236	--
53	4	80	245	166	--
54	6	86	350	170	--
55	35	100	400	177	70
56	6	70	255	138	--
57	7	68	179	121	--
58	6	120	430	275	--
59	41	75	305	161	71
60	35	105	620	284	131
61	6	155	370	263	--
62	6	162	460	304	--
63	6	120	530	284	--
64	6	65	235	152	--
65	6	53	275	158	--
66	33	90	400	230	79
67	7	59	195	121	--
68	6	75	200	126	--
69	6	160	585	324	--
70	6	210	560	407	--
71	40	68	670	199	116
72	6	198	425	321	--
73	4	106	180	142	--
74	6	84	215	154	--
75	7	110	588	292	--
76	6	95	200	156	--
77	33	76	375	195	73
78	6	145	455	285	--
145	6	110	363	225	--
146	6	85	263	180	--
147	6	90	258	178	--
148	6	240	5350	1743	--
149	99	52	1169	254	164
150	6	75	175	129	--
151	6	125	260	192	--
152	6	100	235	169	--
153	6	120	282	210	--
154	6	85	270	189	--
155	6	110	280	183	--
156	6	100	232	161	--
157	6	70	173	115	--
158	36	53	160	101	30
159	5	85	283	168	--

pH OF STREAMFLOW USUALLY NEAR NEUTRAL RANGE

Long term and recent data show that pH values in Area 14 usually range from 6.2 to 8.3 units. Most acid waters are neutralized close to their source.

The acidity or alkalinity of water is expressed in pH units. A pH value of 7.0 is neutral, while acidic waters are represented by values less than 7.0 units. Alkaline waters have pH values greater than 7.0.

The pH of waters draining areas affected by surface coal-mining may be altered by chemical reactions with minerals in spoils. The oxidation of pyrite, marcasite, and other minerals containing sulfur results in the production of sulfuric acid. If the acid production is significant, mine drainage may have pH values ranging from 2.0 to 5.0 pH units. Unless the acid is neutralized, the pH of the waters receiving the acid-mine drainage may be lowered.

The range of pH values observed at long term and synoptic sites in Area 14 usually varies from 6.2 to 8.3 units (fig. 6.3-1 and table 6.3-1). Individual samples with pH values as low as 3.8 units have been collected in the upper North Fork Kentucky River, Perry and Letcher Counties, where surface coal mining is more intense. However, the majority of the samples collected at sites downstream from mining activities indicate that acid-mine drainage is partly neutralized by the streams. Similar observations were recorded by Dyer and Curtis (1977), in a study of six streams in Breathitt County that were unmined until 1967. Although the data collected after mining began showed tenfold increases in the concentration of dissolved constituents such as sulfate, no significant decrease in pH was detected. Dyer and Curtis concluded that the buffering capacity of the water neutralized the acid discharges from the mines.

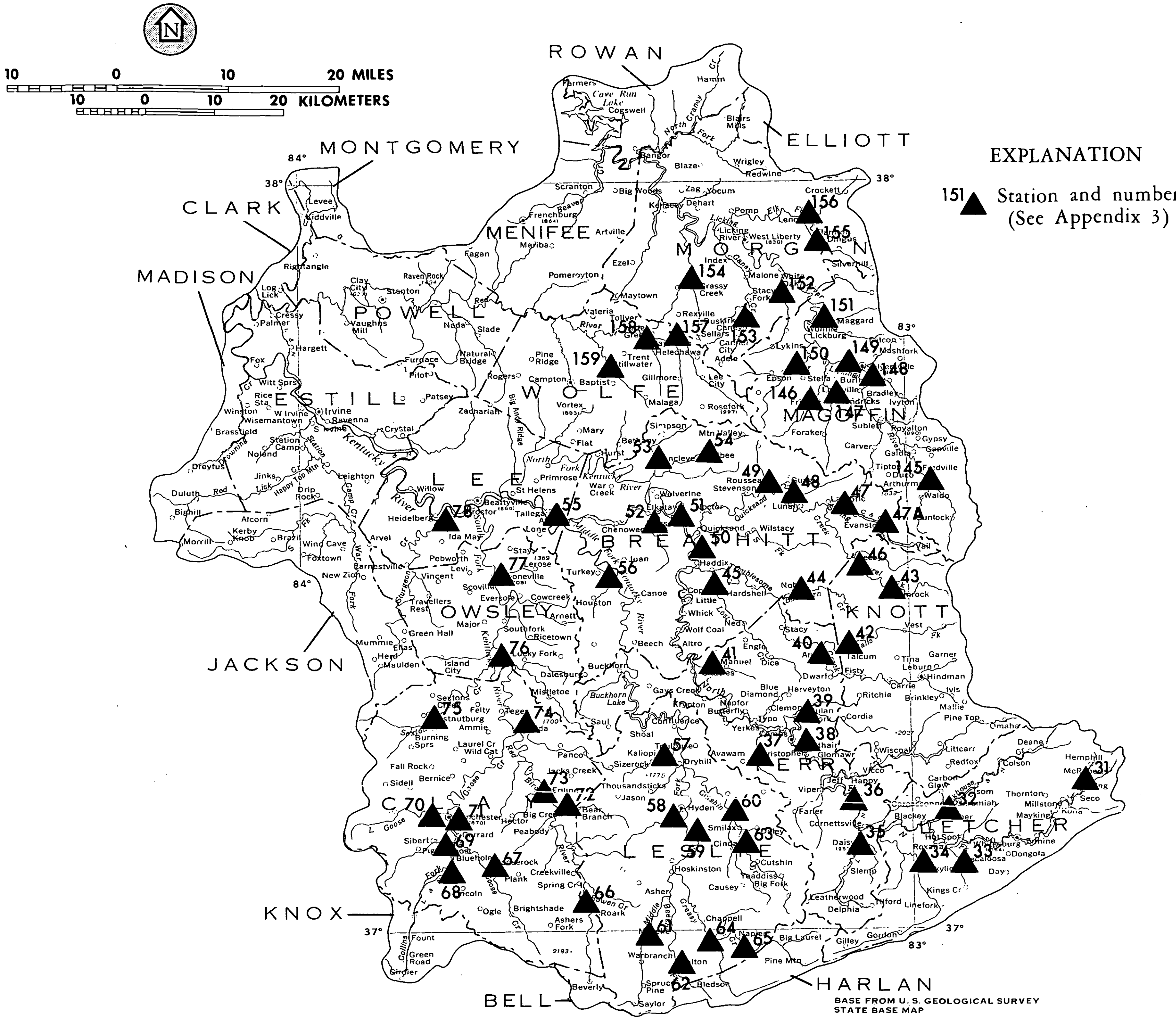


Figure 6.3-1 pH sampling sites

Table 6.3-1 pH concentrations (in pH units).

SITE NUMBER	NUMBER OF SAMPLES	MINIMUM	MAXIMUM	MEDIAN
31	6	7.7	8.0	7.9
32	6	7.5	8.3	7.9
33	6	7.5	8.7	8.0
34	6	7.6	8.6	8.1
35	7	7.5	8.6	8.0
36	6	7.3	8.0	7.5
37	6	7.3	8.5	8.0
38	227	3.8	8.2	7.2
39	6	7.1	8.0	7.6
40	6	7.6	8.4	7.9
41	6	7.6	8.2	7.7
42	6	7.5	9.0	7.8
43	7	7.1	8.0	7.3
44	6	7.2	7.9	7.7
45	6	7.4	7.9	7.7
46	6	7.0	7.7	7.3
47	6	7.2	8.2	7.4
47A	3	7.2	7.5	7.5
48	7	7.3	7.7	7.5
49	3	7.2	7.5	7.3
50	7	7.8	8.2	8.1
51	7	7.0	8.3	7.7
52	7	7.3	8.3	7.8
53	4	7.2	7.9	7.7
54	7	7.1	7.5	7.4
55	16	6.2	7.7	7.4
56	6	6.4	8.0	7.7
57	7	7.2	8.2	7.4
58	7	7.0	8.1	7.7
59	16	7.1	8.4	7.5
60	9	7.0	8.0	7.5
61	7	7.3	8.2	7.7
62	6	7.3	8.4	7.8
63	7	7.1	8.1	7.6
64	7	7.3	8.4	7.9
65	7	7.4	8.2	7.9
66	8	7.2	7.8	7.5
67	7	6.8	7.6	7.3
68	6	7.1	7.6	7.3
69	6	7.0	7.7	7.3
70	6	7.1	7.7	7.4
71	16	6.1	7.8	7.2
72	6	7.2	8.4	8.1
73	4	7.5	7.8	7.6
74	7	7.2	8.9	7.8
75	7	6.5	7.9	7.0
76	6	7.2	7.9	7.6
77	14	6.5	7.8	7.3
78	2	6.2	6.5	--
145	6	6.5	7.9	7.5
146	6	6.4	7.5	7.3
147	6	7.1	7.8	7.6
148	6	6.4	7.5	7.2
149	61	6.4	7.8	6.9
150	5	6.5	7.6	7.4
151	6	6.6	7.6	7.2
152	6	6.4	7.5	7.3
153	5	6.7	7.8	7.7
154	6	6.6	7.7	7.3
155	6	6.5	7.4	7.0
156	6	6.5	7.4	7.1
157	6	6.2	7.6	7.2
158	15	6.4	8.5	7.5
159	5	6.2	7.8	7.3

SURFACE MINING INCREASES SULFATE CONCENTRATIONS IN STREAMS

The concentration of sulfate in streams affected by mining in Area 14 ranges from 98 to 997 mg/L, several times higher than background concentrations at unaffected streams. Sulfate concentrations at mined sites can be estimated from specific conductance values.

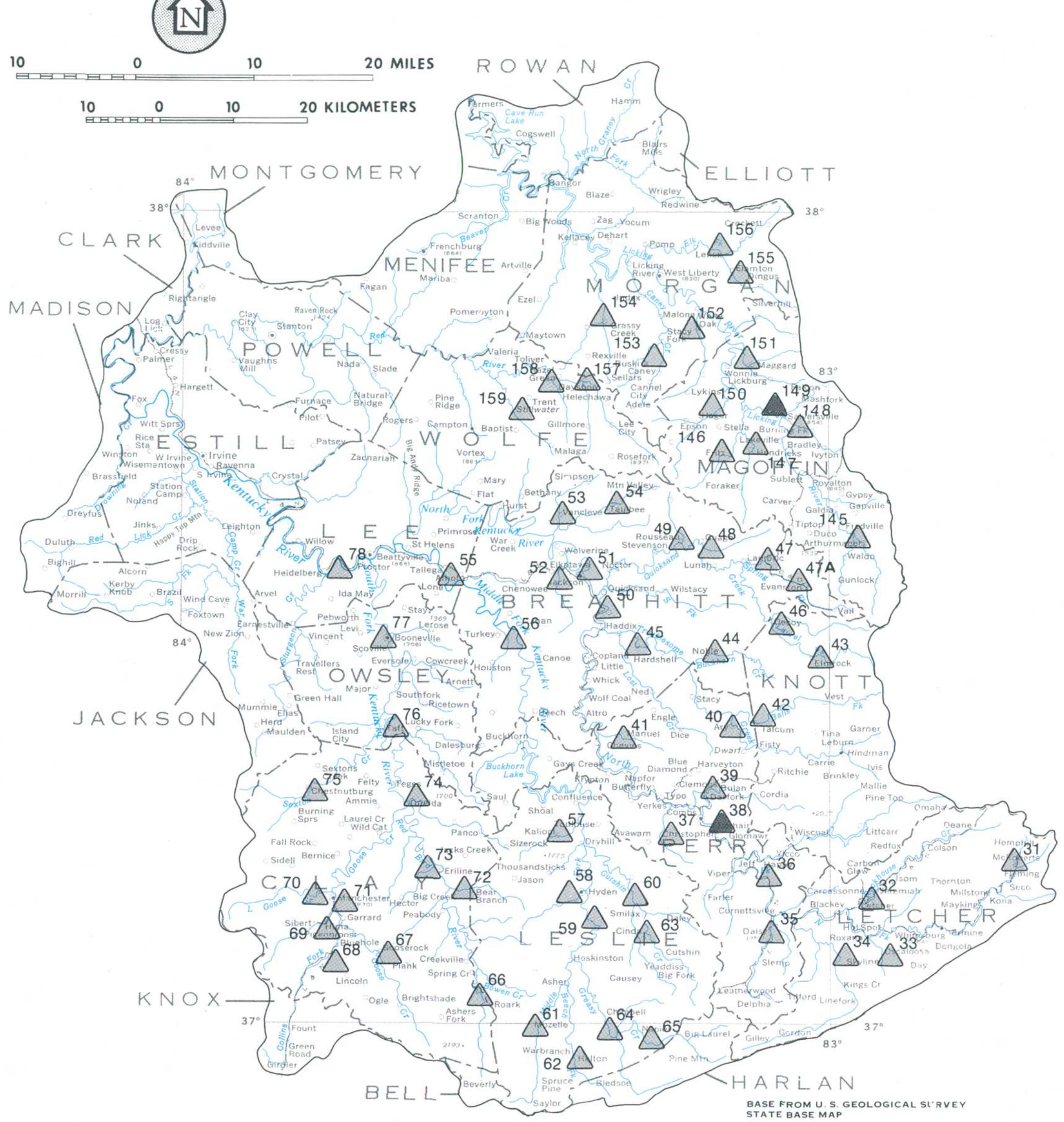
Surface-mining exposes soils and rocks to weathering and oxidation. Sulfuric acid is produced when minerals containing sulfur are oxidized. Sulfuric acid and large amounts of dissolved solids are typical in effluents from coal-mining operations. The neutralization of acid-mine drainage by alkaline or buffered waters in streams leaves significant amounts of sulfates in solution. Sulfate is very soluble in water. Its presence in streams is used as an indicator of surface mine drainage.

Sulfate concentrations from samples collected at long-term and synoptic sites in Area 14 are highest in streams draining the headwaters of Middle and North Forks Kentucky River. The long-term samples, ranging in concentration from 120 to 997 mg/L of sulfate, were collected at stream sites in the headwaters of the two forks in Perry and Knott Counties (fig. 6.4-1 and table 6.4-1). Sulfate concentrations in streams draining undisturbed basins in Area 14 seldom exceed 20-40 mg/L.

Land disturbances in a basin may cause the chemical quality of water in a stream to change. The greater concentration of sulfate in the Licking River at Salyersville during 1979-80, compared with prior concentrations, is probably caused by an increasing amount of land disturbance in the basin (fig. 6.4-2).

Both the long-term and synoptic data show that background concentrations of sulfate in Area 14 are exceeded by more than an order of magnitude at sites draining mined areas. Similar conclusions were reached by Dyer and Curtis (1967) from a study of six stream sites in Breathitt County. Their study showed that tenfold increases in sulfate occurred after mining began, increasing from about 15 to 150 mg/L.

The concentration of sulfate correlates significantly with the specific conductance (see section 6.1). Regression equations to estimate sulfate from field specific conductance measurements are given in Appendix 6.



EXPLANATION

▲38 Station and number
(See Appendix 3)

Figure 6.4-1 Sulfate sampling sites.

EXPLANATION

r = Correlation coefficient

Se = Standard error of estimate

○ Prior to 1979 } Values at site 149 (partially mined)

● 1979-80

□ 1979-80 values at site 38 (mined)

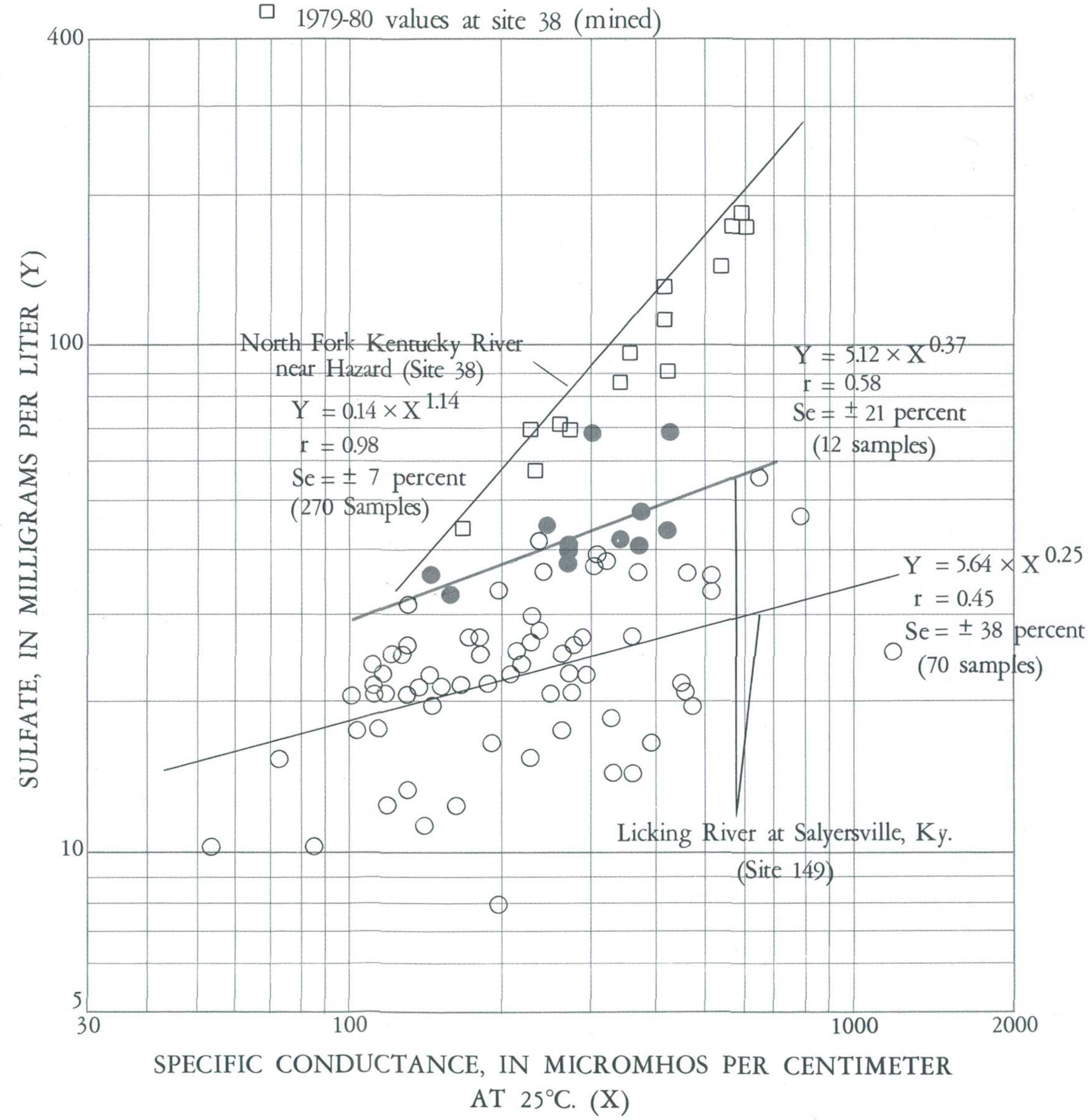


Figure 6.4-2 Relation between sulfate concentrations and specific conductance values.

Table 6.4-1 Dissolved sulfate concentrations in milligrams per liter.

SITE NUMBER	NUMBER OF SAMPLES	MINIMUM	MAXIMUM	MEAN	STANDARD DEVIATION
31	6	94	150	129	--
32	6	71	180	130	--
33	6	31	52	40	--
34	6	21	40	31	--
35	9	38	120	77	--
36	6	63	340	198	--
37	6	230	490	367	--
38	270	13	997	148	106
39	6	290	610	466	--
40	6	71	270	145	--
41	6	100	260	183	--
42	6	35	120	62	--
43	6	13	32	20	--
44	6	39	220	118	--
45	6	140	370	263	--
46	5	13	16	15	--
47	5	33	49	41	--
47A	2	30	43	--	--
48	6	29	51	40	--
49	3	14	26	--	--
50	6	55	170	121	--
51	15	37	200	116	47
52	6	18	51	32	--
53	4	18	27	23	--
54	6	8	17	13	--
55	16	17	97	37	18
56	6	16	20	17	--
57	5	18	40	26	--
58	5	31	96	59	--
59	19	15	72	36	16
60	13	37	160	71	33
61	6	51	120	81	--
62	6	49	190	106	--
63	6	34	97	60	--
64	6	10	24	16	--
65	6	11	37	19	--
66	9	36	75	58	--
67	6	12	28	17	--
68	6	18	28	23	--
69	6	45	200	96	--
70	6	72	200	132	--
71	16	17	130	54	33
72	6	43	96	74	--
73	4	20	26	23	--
74	6	19	35	27	--
75	6	38	180	90	--
76	5	22	41	32	--
77	13	26	82	44	15
78	--	--	--	--	--
145	6	27	120	60	--
146	6	21	40	32	--
147	6	22	44	32	--
148	6	22	28	24	--
149	83	8	68	27	12
150	6	15	23	19	--
151	6	24	35	29	--
152	6	29	56	39	--
153	6	32	60	47	--
154	6	20	52	37	--
155	6	34	93	54	--
156	6	29	48	36	--
157	6	13	16	15	--
158	15	13	35	16	6
159	5	14	37	21	--

IRON CONCENTRATIONS VARY WITH LOCATION AND DISCHARGE

The total recoverable iron concentration at streams in Area 14 increases with flow and is generally higher at sites draining mined areas. The dissolved fraction near mined areas is relatively minor, decreasing with increasing flow.

Iron is common in rocks and in soils rich in organic material. Surface mining exposes rocks and soils to weathering, accelerating the oxidation and dissolution of iron compounds. In addition to dissolved iron, larger amounts of its compounds are transported in waters in particulate form (Hem, 1970).

Both the dissolved and total recoverable iron (suspended plus dissolved) are important water-quality parameters that can be related to water suitability for domestic and industrial uses. Dissolved-iron concentrations in excess of 300 μg/L cause staining, impart an undesirable taste to water, and require treatment for most uses (U.S. Environmental Protection Agency, 1976). In streams, dissolved iron may precipitate, producing "yellow boy" (ferrous hydroxide, ochre-yellow precipitate), which flocculates and settles on river beds adversedly affecting bottom aquatic life. Limits have also been established for the maximum permissible concentration of total recoverable iron. The Act has established a limit of 7,000 μg/L for effluents from mining operations.

Determinations of iron concentrations are available from 65 sites in Area 14 (fig.6.5-1). Most of the sites were implemented in 1979 in response to the Surface Mining Control and Reclamation Act of 1977.

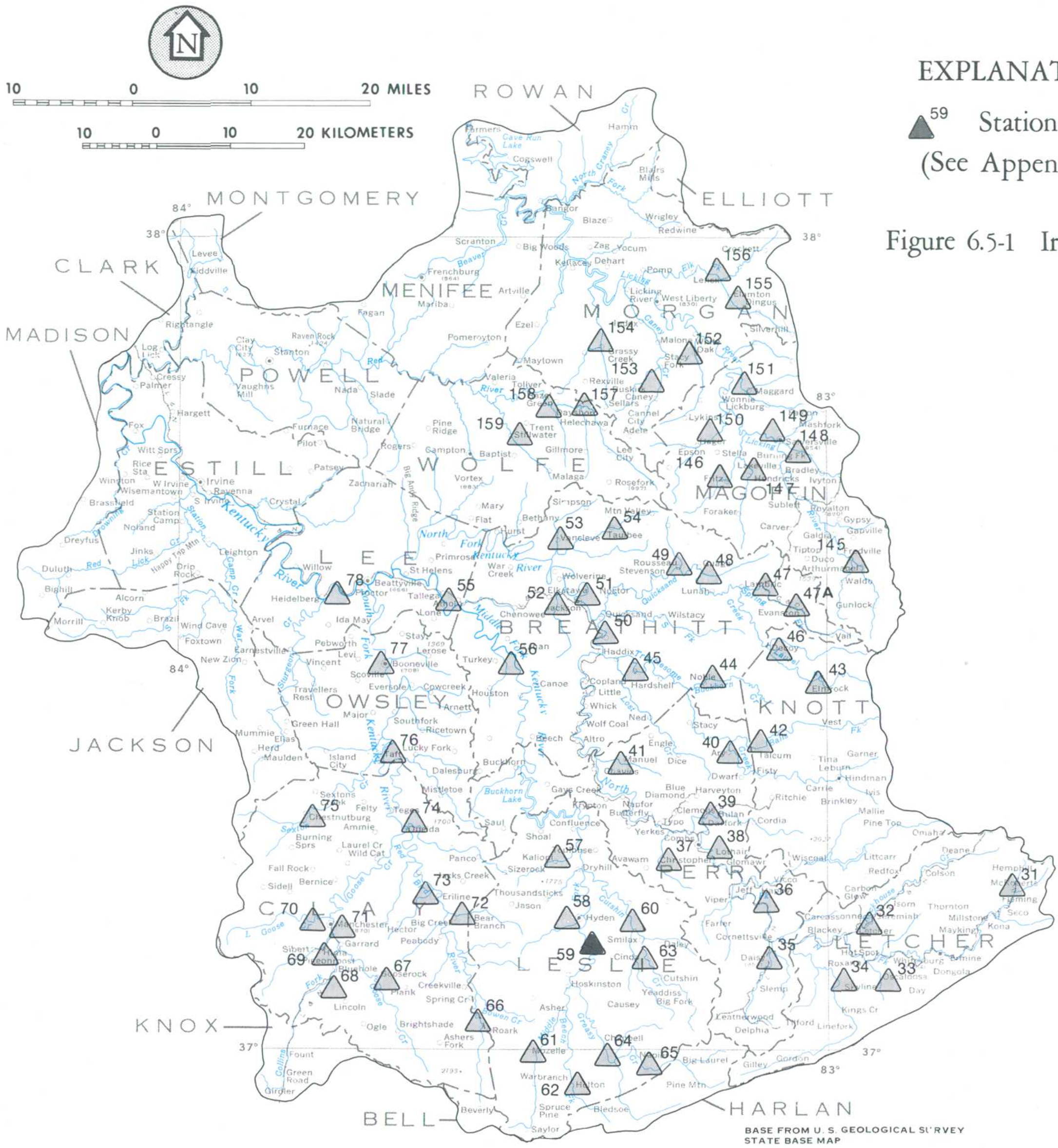
The data represent instantaneous samples collected mostly during periods of low-flow and occasionally during storms.

Total recoverable iron concentrations are available at sites in Area 14 range from 10 to 80,000 μg/L (table 6.5-1). However, at most of the sites, mean concentrations exceed 1,000 μg/L. Federal and State maximum permissible concentrations for aquatic life and water supply are frequently exceeded at many of the sites. This occurs at sites in both mined and unmined basins.

High total recoverable iron concentrations occur at sites in the headwaters of the North Fork Kentucky River basin, where coal mining is most intense. The lowest concentrations usually occur at sites in the reportedly slightly mined headwaters of Middle Fork Kentucky River basin.

Most of the iron in streamflow is Area 14 is suspended, with only a small fraction dissolved (table 6.5-2). At sites in both mined and slightly mined basins, the dissolved iron is usually less than 10 percent of the total recoverable iron. Dissolved iron does not decrease or increase significantly with the amount of streamflow. Increases in flow of more than 100-fold do not result in a significant change in the dissolved-iron concentration. A general increase in the suspended fraction with increasing streamflow occurs at most of the sites.

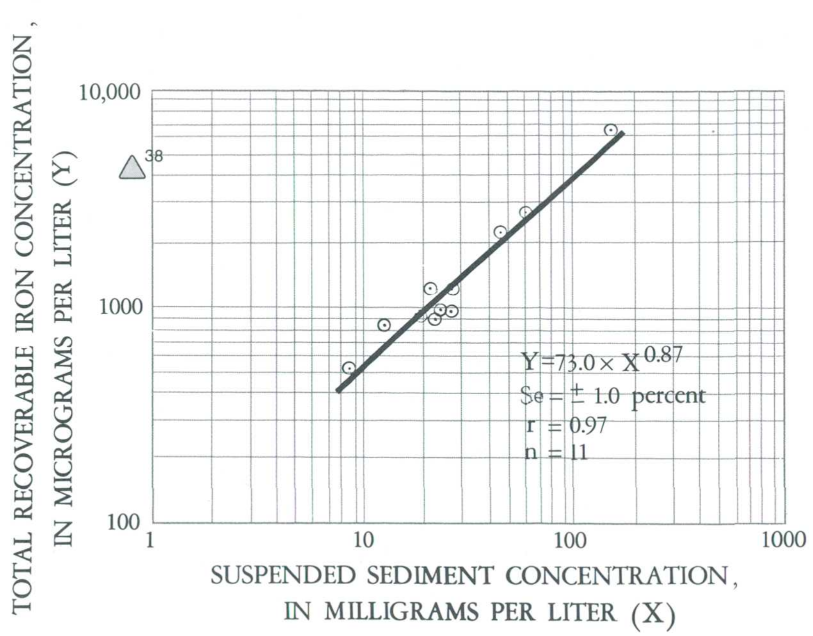
The transport of iron at selected sites in Area 14 correlates significantly with suspended-sediment concentrations (fig. 6.5-2). An increase in the iron load occurs with increasing suspended-sediment concentrations. Definition of the suspended-sediment transport characteristics at a site are essential to estimate iron yields from both mined and unmined basins. Since one storm may transport most of the annual sediment load at a site (see section 6.8), sediment and iron transport processes cannot be defined from random spot sampling. Continous monitoring is necessary to determine iron yields from a basin.



EXPLANATION

▲59 Station and number
(See Appendix 3)

Figure 6.5-1 Iron sampling sites.



EXPLANATION
Se = Standard error of estimate
r = correlation coefficient

Figure 6.5-2 Relation between total iron concentrations and suspended sediment values at Middle Fork Kentucky River near Hyden, Kentucky. (site number 59).

Table 6.5-2 Dissolved and total recoverable iron concentrations during varied flows.

STATION NAME	SITE NUMBER	STREAMFLOW (FT^3/S)	DISSOLVED IRON (UG/L)	TOTAL IRON (UG/L)
TROUBLESOME CREEK NEAR ARY	40	4.7	10	1400
		41	100	830
		136	20	1500
NORTH FORK NEAR JACKSON	51	158	10	2600
		478	70	1200
		1490	10	1600
		6410	40	12000
MIDDLE FORK KENTUCKY RIVER NEAR HYDEN	59	5.6	0	1300
		18	30	6600
		57	30	1000
		280	10	850
		438	40	920
KENTUCKY RIVER AT HEIDELBERG	78	97	30	540
		630	40	1400
		1390	90	1000
RED RIVER NEAR HAZEL GREEN	158	3.3	210	4100
		34	150	630
		119	110	500
		269	710	2200

Table 6.5-1 Total recoverable iron concentrations at synoptic sites, in micrograms per liter.

SITE NUMBER	NUMBER OF SAMPLES	MINIMUM	MAXIMUM	MEAN	STANDARD DEVIATION
31	6	640	3500	1608	--
32	6	1000	80000	15483	--
33	6	510	4000	1497	--
34	6	570	5000	2053	--
35	6	160	1800	747	--
36	6	530	3600	2188	--
37	6	280	3100	1213	--
38	12	320	13000	4105	4260
39	6	730	9100	2895	--
40	5	830	2300	1446	--
41	6	280	960	643	--
42	6	640	26000	5757	--
43	6	640	5500	1543	--
44	6	470	3200	1602	--
45	6	320	1800	752	--
46	5	660	2200	1228	--
47	5	350	1700	1050	--
47A	2	1100	1200	1150	--
48	6	380	8300	2448	--
49	3	680	2500	1560	--
50	6	380	4800	1785	--
51	12	610	61000	7547	17145
52	6	390	6100	1780	--
53	6	390	2400	1072	--
54	4	160	1600	668	--
55	12	380	7900	2222	1900
56	6	310	2200	873	--
57	6	140	13000	3020	--
58	6	800	9000	2782	--
59	15	480	6600	1798	1742
60	9	640	13000	2999	--
61	6	220	780	497	--
62	6	44	1990	106	--
63	6	600	4700	1850	--
64	6	10	24	16	--
65	6	11	37	19	--
66	6	420	2200	1063	--
67	5	600	4900	2360	--
68	6	590	2400	1215	--
69	6	930	1800	1372	--
70	6	510	1800	1218	--
71	13	500	2400	1273	499
72	6	350	4100	1272	--
73	4	440	930	618	--
74	6	400	1600	893	--
75	6	240	890	548	--
76	5	220	800	446	--
77	9	150	9500	1757	--
78	0	--	--	--	--
145	6	1100	4000	2183	--
146	6	1200	2900	1900	--
147	6	830	3000	1788	--
148	6	820	3100	1487	--
149	79	20	48000	2359	6041
150	6	1100	11000	3233	--
151	5	1000	5100	2133	--
152	6	620	3700	1780	--
153	6	340	17000	3332	--
154	6	720	2800	1317	--
155	6	650	2400	1475	--
156	6	860	3200	1743	--
157	6	620	2500	1435	--
158	12	260	4100	1529	--
159	5	560	2000	1062	--

MANGANESE CONCENTRATIONS INCREASE IN STREAMS DRAINING MINED AREAS

The concentration of total recoverable and dissolved manganese at sites draining mined areas in Area 14 is about ten times higher than at sites not affected by mining. Manganese concentrations do not increase significantly with increasing streamflow.

Manganese is one of the most common elements in soils and rocks. Soils rich in organic matter are one of the main sources of manganese to natural waters. Although dissolved manganese is an essential element for plant and animal metabolism, concentrations in excess of 150 μg/L produce objectionable taste to water and staining of fabrics (U.S. Environmental Protection Agency, 1976).

The transport and dissolution of manganese in natural waters are very similar to those of iron, with significant amounts of manganese suspended in particulate forms (Hem, 1970). The total recoverable manganese (suspended plus dissolved) normally exceeds the dissolved fraction. Most water-supply criteria (U.S. Environmental Protection Agency, 1976) contain maximum limits for dissolved manganese (50 μg/L) and the Act specifies a maximum of 4,000 μg/L as the maximum permissible concentration of total manganese in effluents from mining activities.

The concentrations of recoverable manganese (both dissolved and suspended) at sites in Area 14 are shown in figure 6.6-1 and table 6.6-1. The data show that the highest mean and maximum concentrations of the recoverable fraction tend to occur at sites in the headwaters of the North Fork Kentucky and Licking Rivers. Both sites are in actively mined areas.

Manganese concentrations in streams do not appear to change consistently or greatly with change in streamflow. Most of the manganese in streamflow in Area 14 is dissolved. Like iron, the concentration of dissolved manganese is not greatly affected by increasing streamflow. However, unlike iron, the suspended fraction does not generally change significantly with changes of streamflow. The ranges of dissolved and recoverable manganese concentrations at selected streamflows are shown in table 6.6-2.

EXPLANATION

△38 Station and number

(See Appendix 3)

Figure 6.6-1 Manganese sampling sites.

Table 6.6-2 Dissolved and total recoverable manganese concentrations at varied flows.

STATION NAME	SITE NUMBER	STREAMFLOW (FT^3/S)	DISSOLVED MANGANESE (UG/L)	TOTAL MANGANESE (UG/L)
TROUBLESOME CREEK NEAR ARY	40	4.7	160	230
		41.5	50	80
		136	210	220
NORTH FORK NEAR JACKSON	51	37	90	100
		166	200	200
		483	10	80
		1490	70	150
		6410	70	490
MIDDLE FORK KENTUCKY RIVER	59	1.6	100	130
NEAR HYDEN, KENTUCKY	18	70	110	
		57	70	90
		280	60	80
		406	80	80
KENTUCKY RIVER AT HEIDELBERG	78	97	160	260
		630	90	160
		1390	110	140
		4760	30	220
RED RIVER NEAR HAZEL GREEN	158	3.3	360	660
		34	90	100
		119	70	70
		269	50	90

Table 6.6-1 Total recoverable manganese concentration at synoptic sites, in micrograms per liter.

SITE NUMBER	NUMBER OF SAMPLES	MINIMUM	MAXIMUM	MEAN	STANDARD DEVIATION
31	6	140	210	173	--
32	6	80	1900	502	--
33	6	30	120	60	--
34	6	30	90	57	--
35	5	30	90	52	--
36	6	160	480	280	--
37	5	150	2700	1306	--
38	12	30	500	189	121
39	6	910	1300	1093	--
40	5	80	230	160	--
41	6	110	390	212	--
42	6	60	450	193	--
43	6	40	160	68	--
44	6	90	210	167	--
45	6	140	450	268	--
46	5	60	100	74	--
47	5	40	90	70	--
47A	2	50	130	90	--
48	6	40	190	112	--
49	3	60	180	103	--
50	6	40	200	98	--
51	12	50	1200	243	323
52	6	30	160	997	--
53	4	30	400	148	--
54	6	20	740	203	--
55	12	50	330	154	88
56	6	10	210	77	--
57	6	10	280	83	--
58	6	90	210	133	--
59	15	50	180	93	33
60	9	70	380	179	--
61	6	30	330	128	--
62	6	20	210	78	--
63	6	60	180	107	--
64	6	20	900	167	--
65	5	10	800	220	--
66	6	50	190	93	--
67	5	30	390	198	--
68	5	80	590	230	--
69	6	250	820	523	--
70	6	510	1000	742	--
71	13	110	910	406	229
72	6	30	120	65	--
73	4	20	40	35	--
74	6	30	140	60	--
75	6	120	2400	1067	--
76	5	20	70	36	--
77	10	40	200	116	--
78	0	--	--	--	--
145	6	240	520	397	--
146	6	150	690	307	--
147	6	150	770	322	--
148	6	130	1900	688	--
149	71	39	1100	317	285
150	6	130	570	355	--
151	6	220	670	412	--
152	6	180	12500	492	--
153	6	110	630	208	--
154	6	100	1100	463	--
155	6	530	1500	800	--
156	6	270	570	363	--
157	6	90	340	185	--
158	12	60	660	216	186
159	5	100	410	178	--

MERCURY CONCENTRATIONS CAN EXCEED RECOMMENDED LIMITS

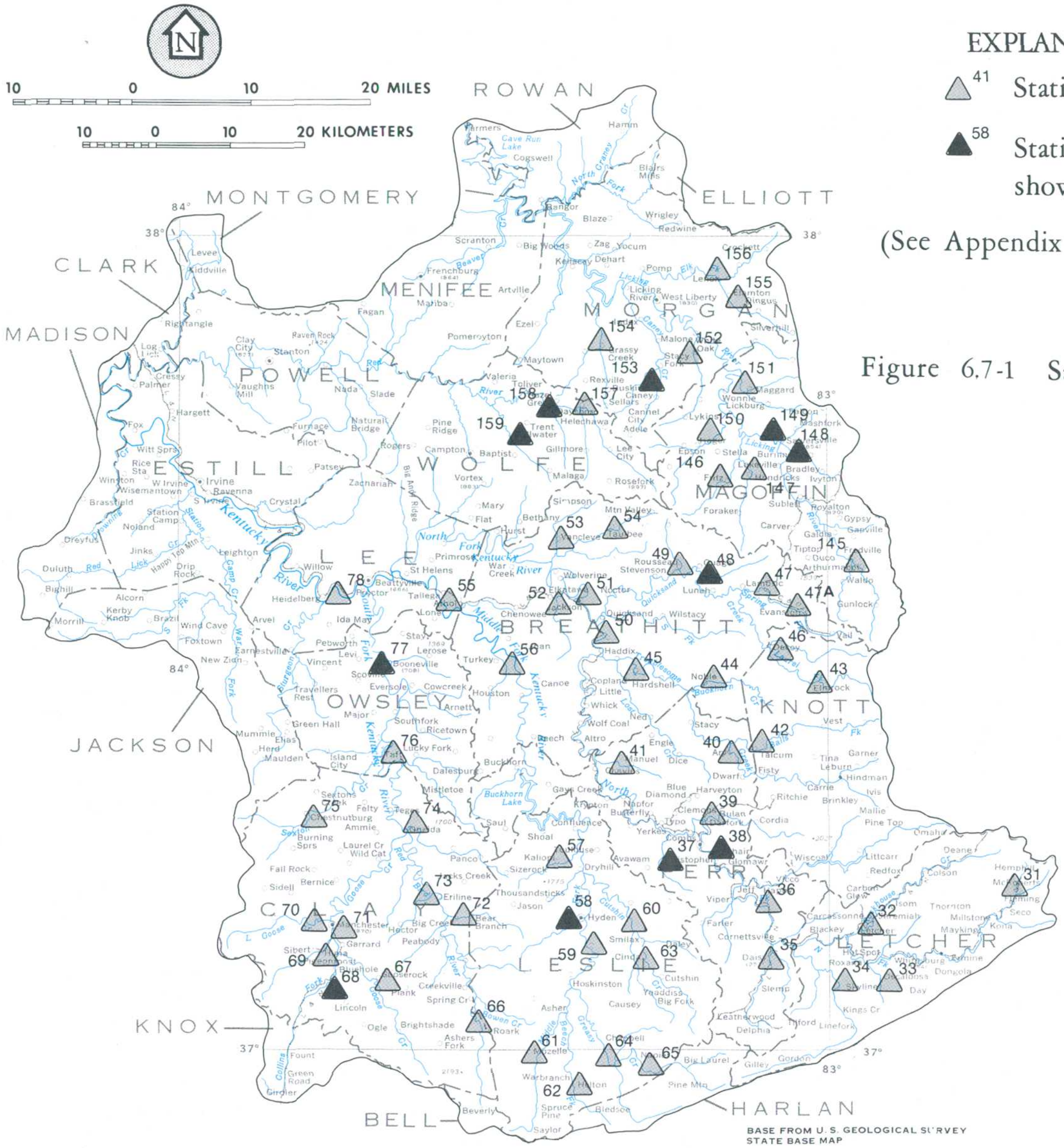
Concentration of dissolved mercury at selected sites in Area 14 at times exceeds maximum recommended State and Federal limits for water for aquatic life.

Trace elements are predominantly metals of low solubility that occur in natural water. In low concentrations most of the metals are essential to life; however, in high concentrations some of them are toxic to plants and animals. Trace metals are present in soils and under normal weathering conditions they leach slowly into natural waters. High concentrations of trace metals are usually associated with industrial-waste discharges and acid-mine drainage.

The weathering of exposed minerals in mining spoils containing sulfur produces sulfuric acid. The acid accelerates the leaching of minerals and dissolution of salts increasing the dissolved-solids concentration in water. Trace metals are common in coal and associated rocks. Mine drainage, particularly when acid, usually contain concentrations of trace metals that exceed background levels. When the mine-drainage is neutralized, the trace metals are precipitated and concentrated in bottom deposits (such as "yellow boy"). Analyses of trace elements in bottom sediments at 11 sites show that iron and manganese are the most common elements in the bottom sediments (table 6.6-1).

Concentrations of trace metals at selected sites in Area 14 (fig. 6.6-1) are shown in table 6.6-2. Mean dissolved-mercury concentrations at all sites exceeds the maximum recommended limit of 0.05 $\mu g/L$ for aquatic life, but not the maximum recommended limit of 2.0 $\mu g/L$ for domestic water supply (U. S. Environmental Protection Agency, 1976); however, one sample of 3.2 $\mu g/L$ did exceed the recommended domestic water supply limit. The highest concentrations occur at sites downstream from mined areas. Dissolved concentrations of other trace metals do not exceed normal background values.

Concentrations of trace metals from water at individual sites are listed in Appendix 7.



EXPLANATION

△ 41 Station and number

▲ 58 Stations for which data are shown in tables 6.7-1 and 6.7-2.

(See Appendix 7 for further information).

Figure 6.7-1 Sampling sites for trace elements.

Table 6.7-2 Concentration of selected trace elements in water, in micrograms per liter.

ARSENIC

MAP NUMBER	TOTAL RECOVERABLE NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX	DISSOLVED NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX
38	8	11	0	76	13	.1	0	1
77	9	.4	0	3	9	.4	0	3
78	8	.5	0	3	1	10	--	--
149	8	6	0	39	7	1	0	8
158	9	2	0	5	9	.2	0	2

LEAD

MAP NUMBER	TOTAL RECOVERABLE NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX	DISSOLVED NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX
38	1	9	--	--	12	1	0	6
77	9	10	0	23	8	6	1	20
78	8	37	10	100	1	6	--	--
149	8	9	4	30	7	7	0	17
158	9	6	0	25	9	5	0	9

CADMIUM

MAP NUMBER	TOTAL RECOVERABLE NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX	DISSOLVED NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX
38	8	3	0	8	13	.5	0	4
77	9	2	0	11	8	3	0	12
78	8	3.5	0	12	1	1	--	--
149	8	3	0	12	7	3	0	18
158	9	1	0	3	9	.9	0	6

MERCURY

MAP NUMBER	TOTAL RECOVERABLE NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX	DISSOLVED NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX
38	9	.3	0	.9	8	.3	0	1.1
77	9	.1	0	.3	8	.1	0	.3
78	8	.4	0	.8	1	.5	--	--
149	9	.4	0	2.3	6	.1	0	.3
158	9	.8	0	2.8	9	1	0	3.2

COBALT

MAP NUMBER	TOTAL RECOVERABLE NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX	DISSOLVED NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX
38	--	--	--	--	12	.3	0	2
77	8	2	2	6	8	3	0	16
78	8	3	0	10	1	12	--	--
149	8	3	0	7	7	2	0	4
158	8	1	0	5	9	0	0	0

SELENIUM

MAP NUMBER	TOTAL RECOVERABLE NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX	DISSOLVED NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX
38	1	3	--	--	7	10	0	40
77	1	4	--	--	2	2	0	3
78	1	2	--	--	--	--	--	--
149	8	6.2	0	20	1	0	--	--
158	1	4	--	--	--	--	--	--

COPPER

MAP NUMBER	TOTAL RECOVERABLE NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX	DISSOLVED NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX
38	1	3	--	--	7	3	2	4
77	9	32	6	160	8	3	10	30
78	8	26	3	93	--	--	--	--
149	8	15	0	35	7	3	1	6
158	9	14	6	33	9	5	0	9

ZINC

MAP NUMBER	TOTAL RECOVERABLE NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX	DISSOLVED NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX
38	8	59	8	150	1	3	--	--
77	9	38	0	110	8	33	4	130
78	8	62	7	130	1	10	--	--
149	9	29	6	60	7	9	0	20
158	9	46	10	140	9	17	0	50

Table 6.7-1 Selected trace elements in bottom sediments, in micrograms per gram.

SITE NUMBER	ARSENIC NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX	CADMIUM NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX	CHROMIUM NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX
37	1	0	--	--	1	10	--	--	1	20	--	--
38	7	15	1	68	7	10	10	10	7	9	3	10
48	1	0	--	--	1	10	--	--	1	10	--	--
58	1	10	--	--	1	10	--	--	1	10	--	--
68	1	10	--	--	1	10	--	--	1	10	--	--
77	8	16	0	94	8	11	10	20	8	10	8	10
148	1	0	--	--	1	10	--	--	1	10	--	--
149	8	11	0	35	8	9	3	10	8	9	2	10
153	1	0	--	--	1	10	--	--	1	10	--	--
158	7	4	2	6	7	10	10	10	7	10	10	10
159	1	0	--	--	1	10	--	--	1	10	--	--

SITE NUMBER	LEAD NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX	MANGANESE NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX	MERCURY NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX
37	1	40	--	--	1	810	--	--	1	0	--	--
38	7	60	10	220	--	--	--	--	7	2	0	11
48	1	10	--	--	1	230	--	--	1	0	--	--
58	1	20	--	--	1	420	--	--	1	0	--	--
68	1	10	--	--	1	920	--	--	1	0	--	--
77	8	34	10	1000	--	--	--	--	8	.2	0	1.1
148	1	10	--	--	1	130	--	--	1	0	--	--
149	8	32	10	1000	--	--	--	--	8	.8	0	2.6
153	1	20	--	--	1	670	--	--	1	0	--	--
158	8	10	10	10	--	--	--	--	7	.1	0	.5
159	1	10	--	--	1	840	--	--	1	0	--	--

SITE NUMBER	COBALT NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX	COPPER NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX	IRON NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX
37	1	20	--	--	1	20	--	--	1	0	--	--
38	7	16	10	50	7	10	5	15	--	--	--	--
48	1	10	--	--	1	10	--	--	1	8800	--	--
58	1	10	--	--	1	10	--	--	1	6600	--	--
68	1	10	--	--	1	10	--	--	1	15000	--	--
77	8	19	0	50	8	10	10	10	--	--	--	--
148	1	10	--	--	1	10	--	--	1	15000	--	--
149	8	19	5	50	8	12	8	30	--	--	--	--
153	1	20	--	--	1	10	--	--	1	38000	--	--
158	8	19	10	80	8	11	10	20	--	--	--	--
159	1	20	--	--	1	20	--	--	1	58000	--	--

SITE NUMBER	SELENIUM NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX	ZINC NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX
37	1	0	--	--	1	110	--	--
38	--	--	--	--	7	35	20	70
48	1	0	--	--	1	30	--	--
58	1	0	--	--	1	30	--	--
68	1	0	--	--	1	40	--	--
77	--	--	--	--	8	32	20	50
148	1	0	--	--	1	30	--	--
149	--	--	--	--	8	20	10	30
153	1	0	--	--	1	0	--	--
158	--	--	--	--	8	16	10	20
159	1	0	--	--	1	80	--	--

SEDIMENT DATA ARE INADEQUATE FOR CORRELATION WITH LAND USE

Suspended-sediment data are available from one daily and three partial-record sites in Area 14. The data suggest that sediment yields are higher from areas where surface mining predominates.

Surface mining drastically alters the land surface and the drainage and erosion patterns. The removal of vegetative cover and exposure of unconsolidated material to weathering, results in increasing erosion, transport, and deposition of large amounts of sediment. In areas where erosion is not controlled, river channels and lakes are often clogged with the deposited sediment.

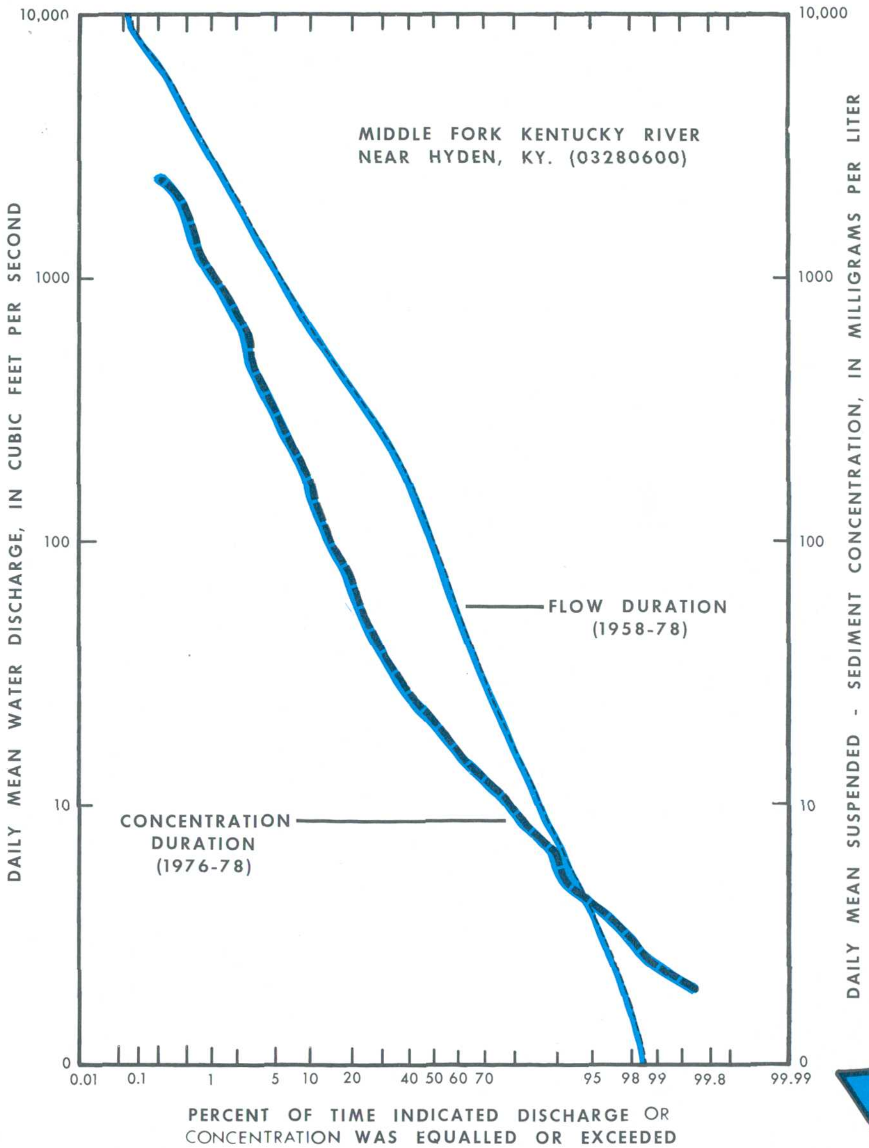
The collection of sediment data in Area 14 has been limited. A daily suspended-sediment sampling station has been in operation since early 1977 at the Middle Fork Kentucky River near Hyden (fig. 6.8-1). Partial-record stations have been in operation since 1978 at three other sites in the basin.

Annual suspended-sediment yields at the Middle Fork Kentucky River station range from 654 to 899 tons/mi^2. Other studies conducted in eastern Kentucky show that in areas where surface mining was not extensive, suspended sediment yields ranged from about 700 to 3,500 tons/mi^2 (Curtis and others, 1978). In heavily mined areas annual yields ranged from about 3,000 to 21,000 tons/mi^2. The size of the basins in the study by Curtis was generally smaller than the basin of the Middle Fork Kentucky River near Hyden. In the study by Curtis, the only basin of comparable size to the Middle Fork Kentucky River had an annual suspended-sediment yield of 1,360 tons/mi^2.

Data from the Middle Fork Kentucky River station near Hyden also show that one storm can contribute as much as 70 percent of the annual suspended-sediment load. For example, during the April 4, 1977 flood about 126,000 tons of suspended sediment were discharged. A graph of typical relations between suspended-sediment load and water discharge for a flood at a later date is shown in figure 6.8-1. The increase in suspended sediment load on December 4 is apparently the result of a cleansing or flushing of the basin by base flow in the river and low rainfall in the area. The flood of December 8-10 (3.6 inches of rain measured at Haydin) also caused an increase in the sediment load. However, the relations of suspended-sediment load to discharge during the two rises is susstantianlly different. This indicates the need to monitor sediment yields on a continuous basis rather than synoptically or from miscellaneous observations.

The frequency of daily suspended-sediment concentrations and daily mean stream flows (as a duration curve) can be used to estimate sediment yields for periods of no record (fig. 6.7-1). The assumption must be made that the distribution of the sediment-concentration curve does not change with time. Estimates may not be accurate in areas affected by surface mining, where soils exposed to erosion could result in changes to the natural distribution of the concentrations.

Suspended-sediment loads at three other sites in Area 14 can be estimated from regression equations relating load to streamflow that were developed from samples collected during both low and high flows (fig. 6.8-1). Compared to Red River and Goose Creek, significantly more sediment is produced in the intensively-mined Troublesome Creek basin during any condition other than high flows. During high flows the regressions converge, indicating that the mining effects may not be as obvious as other effects under these flow conditions.



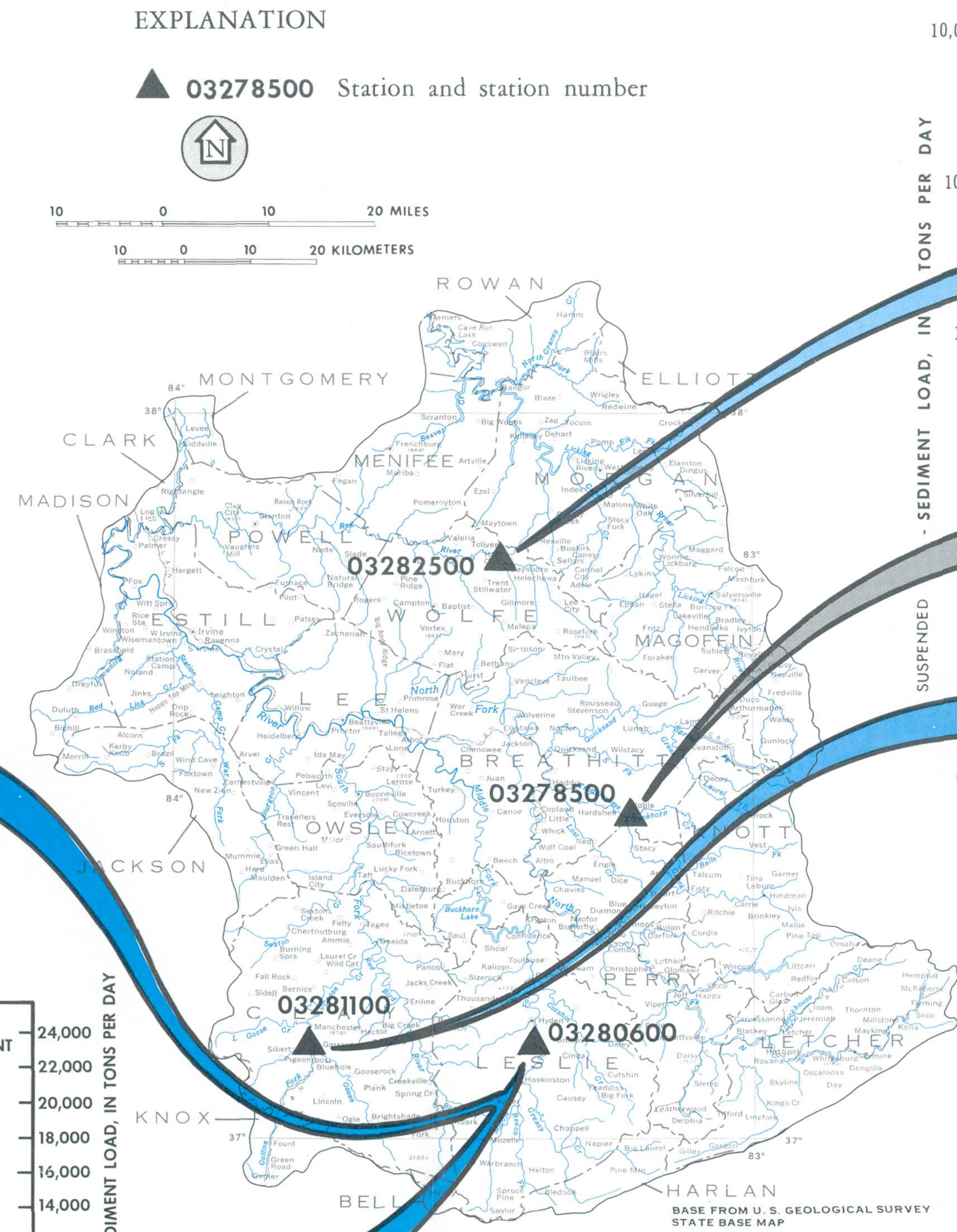
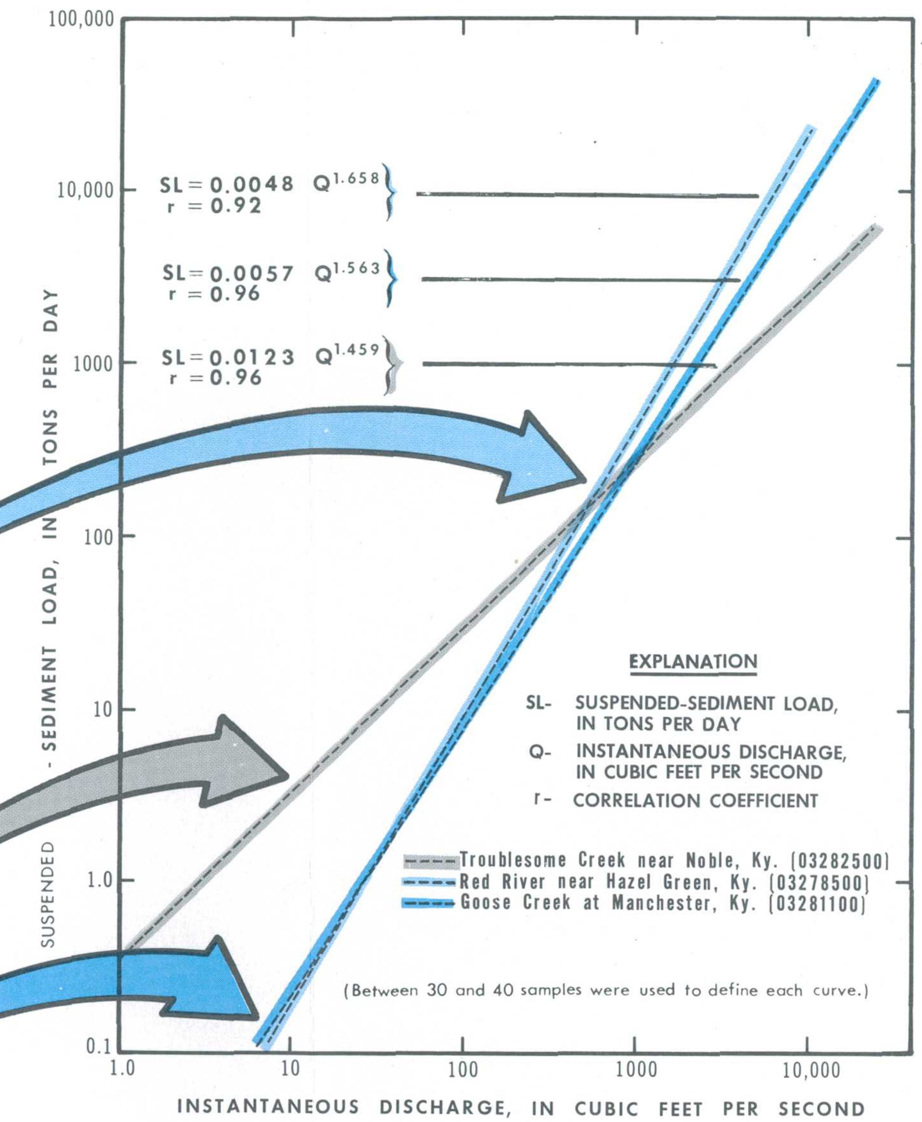
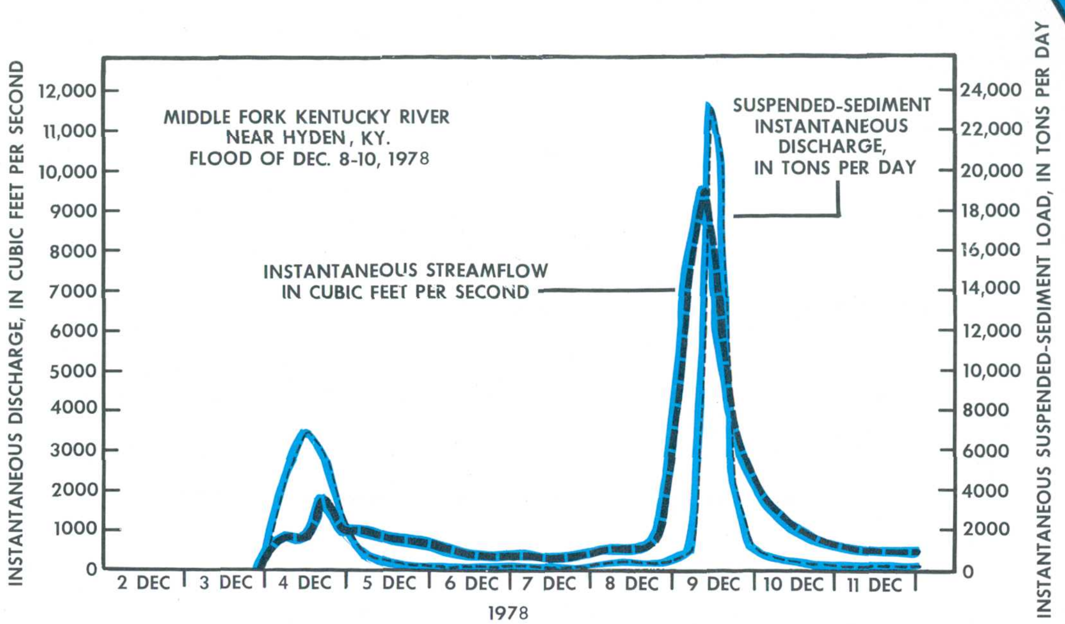


Figure 6.8-1 Suspended-sediment





AQUIFERS RECHARGED DIRECTLY BY PRECIPITATION

Multiple sandstone aquifers are present in the Breathitt and Lee Formations in Area 14. They discharge to springs and streams maintaining base flow.

Almost all ground water in Area 14 originates as precipitation that percolates downward until it enters a zone of saturation, the upper surface of which is called the water table. The water table generally follows the shape of the land surface but is not as deep under valleys as under hilltops. Multiple ground-water reservoirs can underlie the same area and each reservoir can have its own water table or artesian head. A confined (artesian) aquifer occurs between less permeable beds and the water in a well tapping this aquifer rises above the level where the water is first found in the well. The water in a well tapping an unconfined (water table) aquifer stands at the top of the zone of saturation and is the same elevation as the water table. Perched reservoirs, located above the main ground-water reservoir are common in Area 14 where hilly terrain is underlain by alternating beds of permeable (sandstone) and less permeable (clay and shale) rocks (figs. 7.1-1).

Ground water is stored in and moves through intergrannular (primary) and fracture (secondary) openings in rocks. In Area 14 more water moves through secondary openings because they are larger than primary openings. Thus most of the water from aquifers in the area comes from secondary openings that are best developed in sandstones in the Breathitt and Lee Formations. In the northwest part of Area 14, solutionally enlarged secondary openings in limestones of pre-Pennsylvanian age permits relatively free movement of large quantities of ground water to wells and springs.

Little is known about the direction of water movement in regional aquifers in Area 14. Movement is generally downdip along bedding planes or toward the southeast. Locally water may move in different directions because of influences of topography and the orientation of fracture systems. The rate of movement depends on the size and interconnection of water bearing openings and the hydraulic gradient.

Direct infiltration of precipitation is the major source of recharge to upper aquifers (fig. 7.1-1). Lower aquifers are recharged by leakage from overlying aquifers and to a lesser extent by direct infiltration of precipitation. Some water is contributed by streams that flow over the outcrop of the aquifer provided the water table is below stream level. Recharge from streams can be high where the streams cross an aquifer that has been extensively fractured.

All ground water is in motion from areas of recharge to areas of discharge. Water discharges downward from upper aquifers and laterally to the outcrop of the aquifer. Lateral discharge from an aquifer is seen as seeps or springs on hillsides (fig. 7.1-1). The quantity of water discharged to lower aquifers is controlled by the nature of underlying rocks and the hydraulic gradient. Discharge from lower aquifers moves downward and laterally thence upward to become streamflow. Pumpage from wells can alter the natural hydraulic gradient system so that water levels in nearby wells or streams may be lowered.

The depth to water is generally less than 50 feet under valleys and more than 100 feet under ridges. However, the depth to water may be considerably less where perched water zones occur under ridges. Water flows naturally from some wells.

Continuous water-level records for observation wells in Area 14 may be obtained from the U.S. Geological Survey at Louisville or from the series of annual reports "Water Resources Data for Kentucky," published by the U.S. Geological Survey.

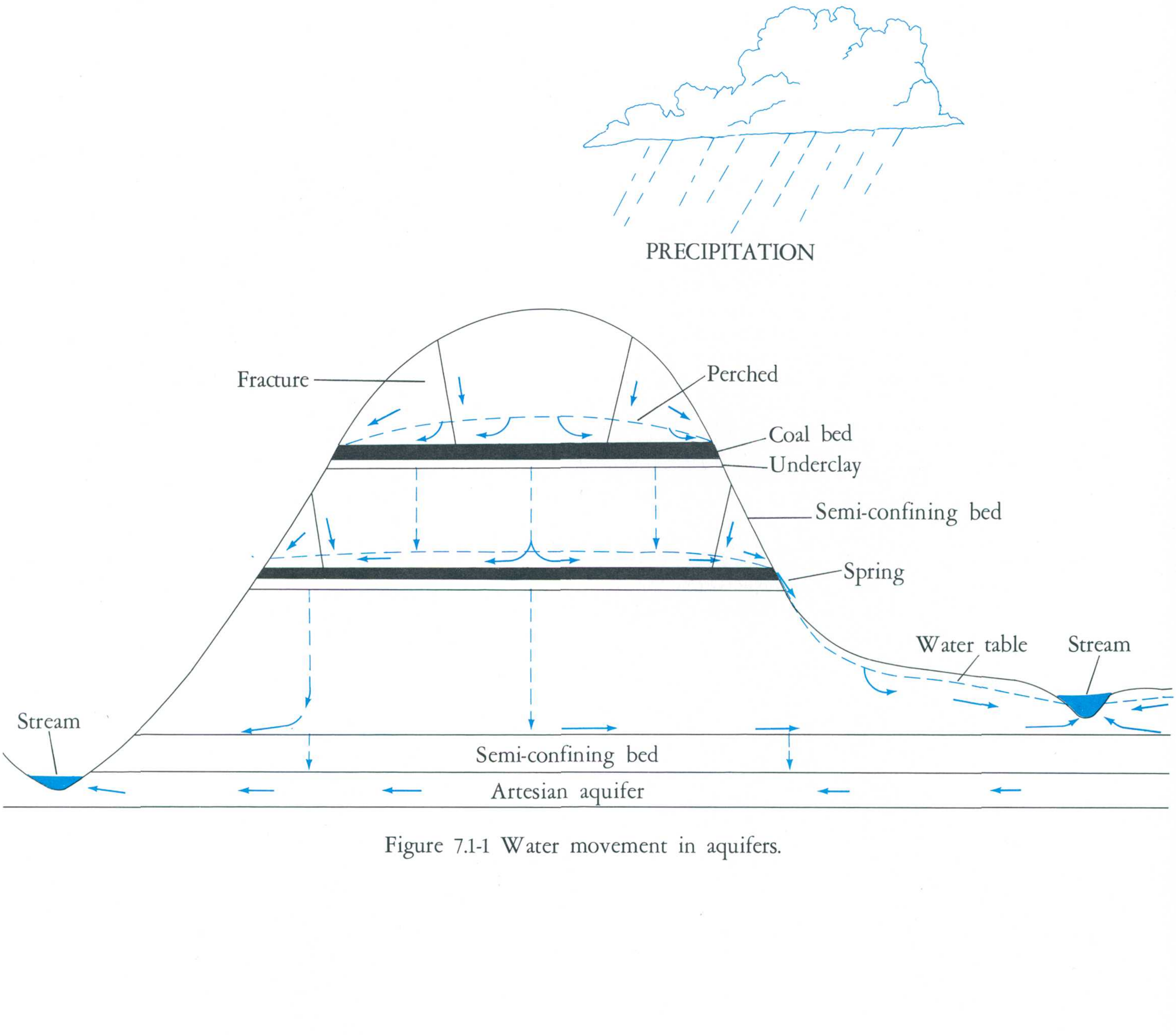


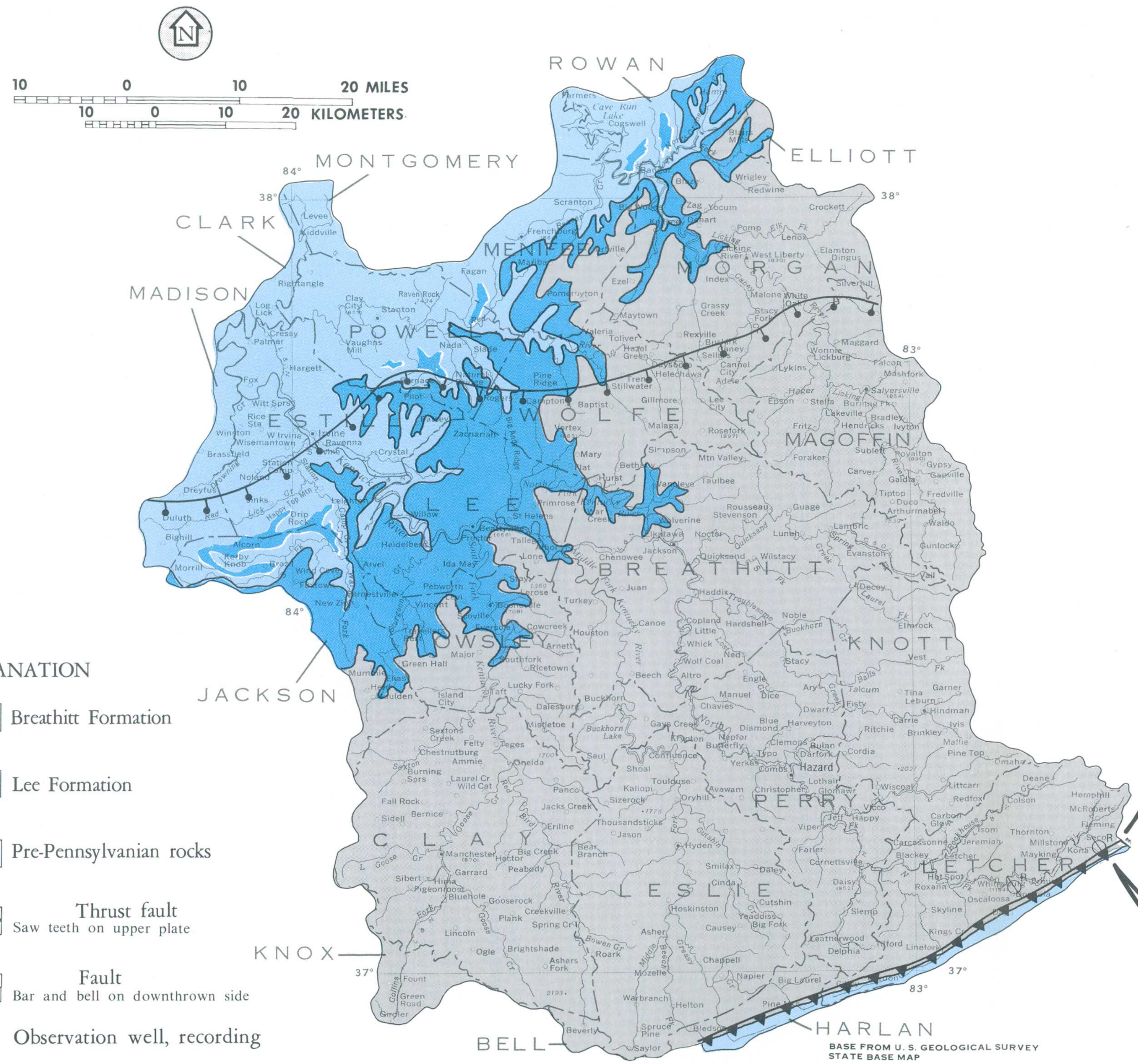
Figure 7.1-1 Water movement in aquifers.

WATER LEVELS IN AREA 14 FLUCTUATE SEASONALLY

Water-level fluctuations reflect seasonal variations in the rate of recharge to, and discharge from, aquifers in Area 14.

Water levels in Area 14 fluctuate in response to recharge and discharge of ground water. The principal factors affecting water levels are precipitation, evapotranspiration, natural discharge, and pumpage from wells. During the growing season plants intercept water before it can enter the zone of saturation. The use of water by plants, coupled with evaporation causes a decline in water levels during the growing season as discharge continues to be greater than recharge. The lowest water levels occur in the fall prior to the first killing frost. During the winter months, the water normally used by plants recharges the aquifers and water levels rise as recharge exceeds discharge. Thus the highest water levels usually occur in the spring prior to the onset of the growing season.

Long-term ground-water level data are available from two wells in Area 14. Water levels for a 5-year period for one of the wells are shown in the hydrograph, figure 7.2-1. There are no long-term rising or falling water level trends. The hydrograph for the 1978 water year (fig. 7.2-1) shows the typical water-level response to seasonal variations in recharge from precipitation except in August, 1978 when locally heavy rainfall was not reflected in ground-water levels. The peaks in the ground-water record occur when recharge from precipitation exceeds discharge from the aquifers. Individual peaks may be caused by an isolated period of precipitation or reflect the cumulative effects of several periods of moderate precipitation. The range in water-level changes is about 4 feet. The fluctuation can vary from place to place and may be considerably different in other parts of the area. Larger variations in water levels are typical in the limestone rocks of pre-Pennsylvanian age in Area 14. Water levels are more variable in these rocks due to faster recharge and discharge through solution openings.



EXPLANATION

- Breathitt Formation
- Lee Formation
- Pre-Pennsylvanian rocks
- Thrust fault — Saw teeth on upper plate
- Fault — Bar and bell on downthrown side
- Observation well, recording
- Geologic contact

Adapted from the following Hydrologic Atlases:
HA-17, 18, 19, 36, 37, and 38.

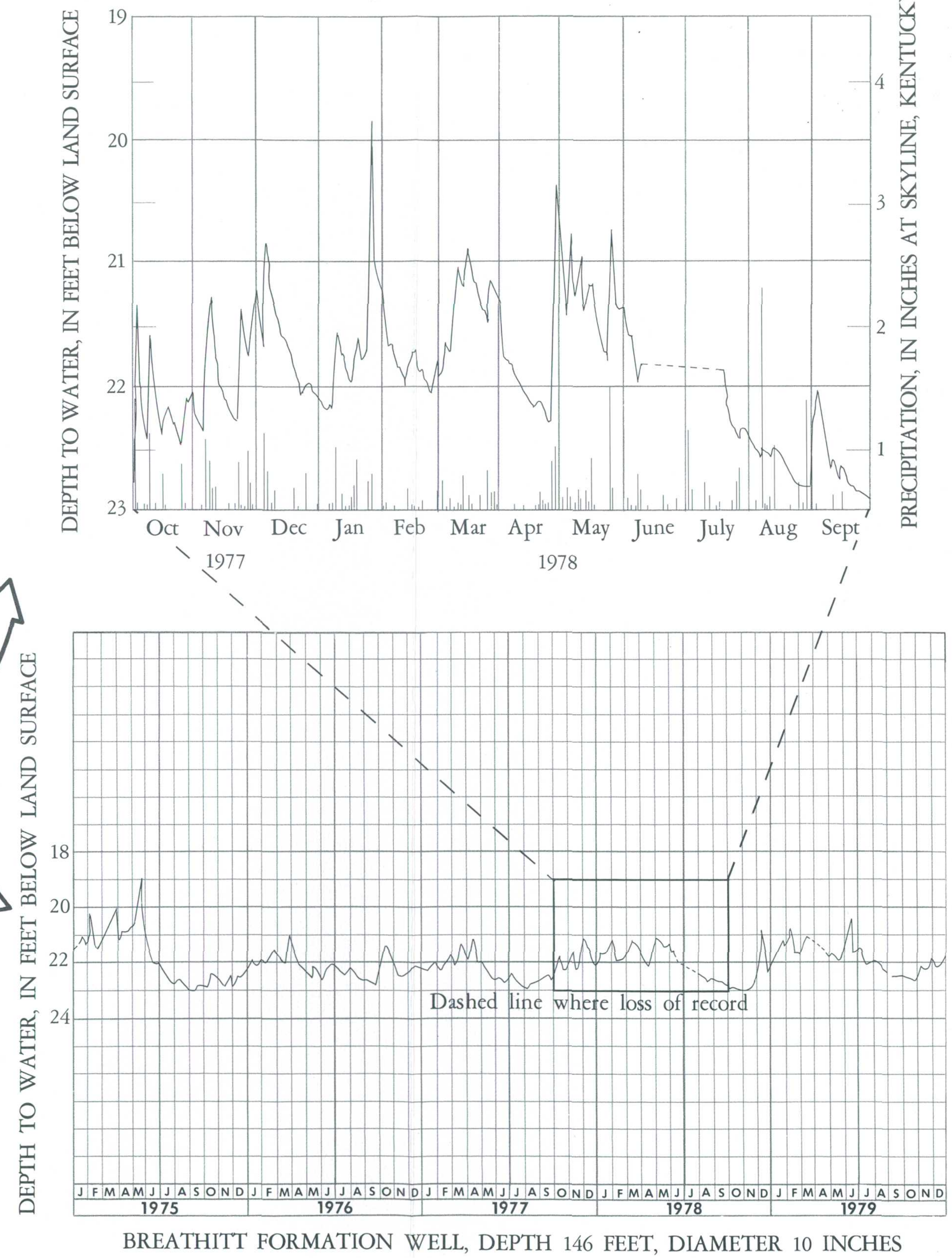


Figure 7.2-1 Water-level fluctuations and regional geology.

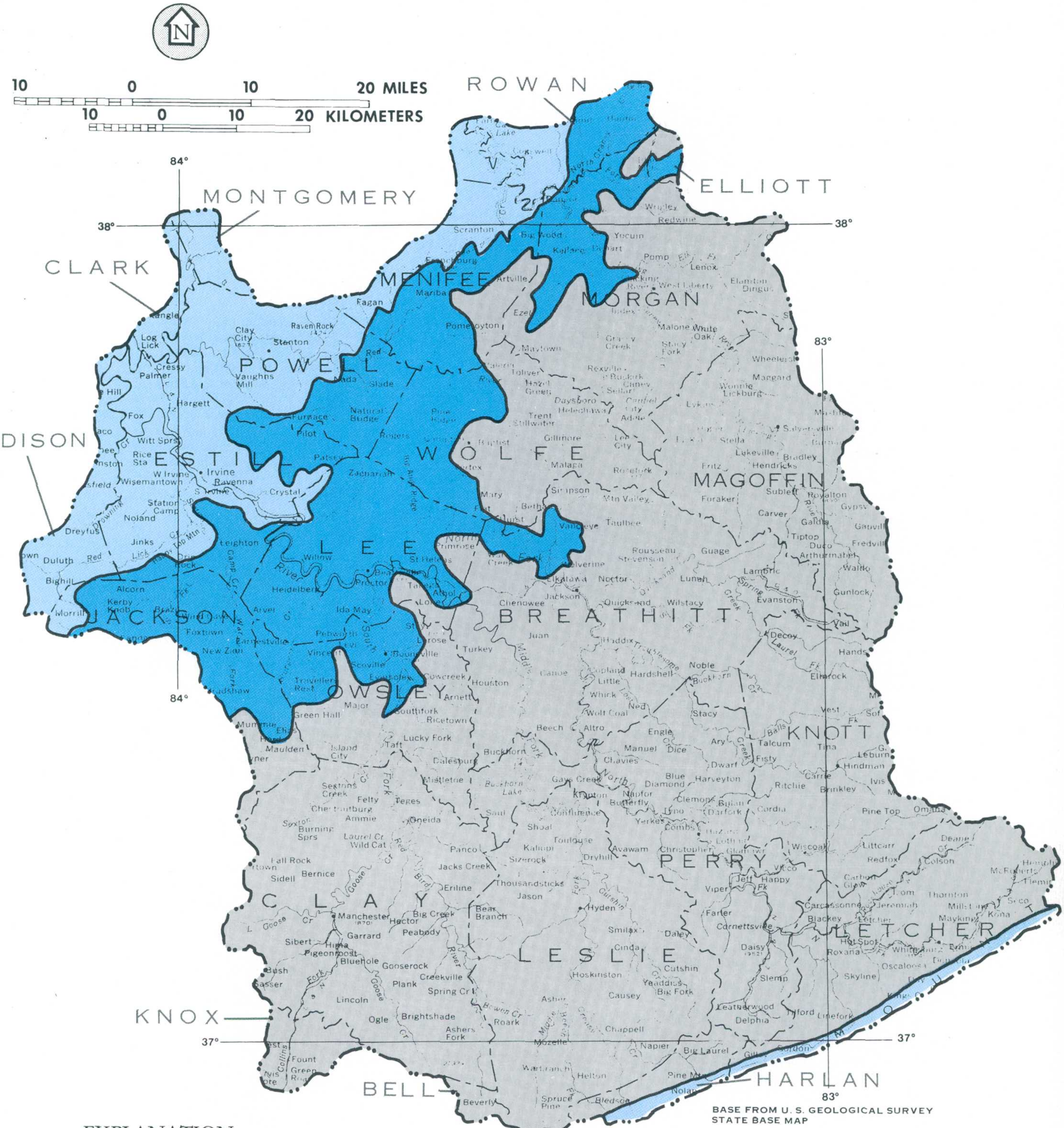
MEASURED YIELDS FROM WELLS RANGE FROM 1 TO 325 GALLONS PER MINUTE

Recorded wells in the Breathitt and Lee Formations yield from 1 to 325 gal/min depending on location and well depth. Yields from wells in the pre-Pennsylvanian rocks are generally less than 50 gal/min.

The main sources of ground water in Area 14 are the Breathitt and Lee Formations (fig. 7.3-1). Sandstone is the principal aquifer but shale and coal also yield water to some wells. Yields usually range from less than 1 to 25 gal/min. Fractures tend to be larger and more numerous near fault zones. Thus yields up to 325 gal/min are known from fractured sandstones of the Breathitt Formation near the Pine Mountain fault in Letcher County. Similar yields may be obtained in the vicinity of other major faults in Area 14.

The principal factors governing well yields are well depth, location, and the lithology of the rocks tapped. In general, deeper wells have greater yields, however, fractures are generally fewer in number and smaller at greater depths. Hence, greater depths may not necessarily produce a corresponding increase in yield. Yields up to 140 gal/min are known from wells tapping sandstone of the Lee Formation below the valleys of perennial streams. The yields from depths greater than 300 feet are probably from intergranular pore spaces where sandstone particles are poorly cemented.

The availability of ground water pre-Pennsylvanian rocks is related to well depth, topography, rock type, and the character of the overlying Pennsylvanian rocks. The major aquifers are limestone rocks that may yield more than 50 gal/min from interconnected, solution openings. Springs can yield more than 20 gal/min from similar openings. Yields generally range from less than 1 to more than 50 gal/min, but typically are less than 1 gal/min where limestone above stream level is overlain by shale or siltstone of Pennsylvanian age.



Adapted from the following Hydrologic Atlases: HA-17, 18, 19, 36, 37, and 38.

EXPLANATION
YIELDS TO WELLS
(In gallons per minute)

- Breathitt Formation: From less than 1 to about 325
- Lee Formation: From less than 1 to more than 140
- Pre-Pennsylvanian rocks: From less than 1 to more than 50

Figure 7.3-1 Yields to wells

CHEMICAL QUALITY OF GROUND WATER IS HIGHLY VARIABLE

Ground water in Area 14 is generally suitable for most uses. High iron concentrations are common. Water ranges from soft to very hard.

The quality of ground water in Area 14 is highly variable from place to place but is generally acceptable for most uses with proper treatment. Most water analyses from the Breathitt Formation are from Letcher County. In addition, a few analyses are available from rocks of pre-Pennsylvanian age in the area. Not enough chemical analyses are available to adequately define the characteristics of ground water throughout Area 14.

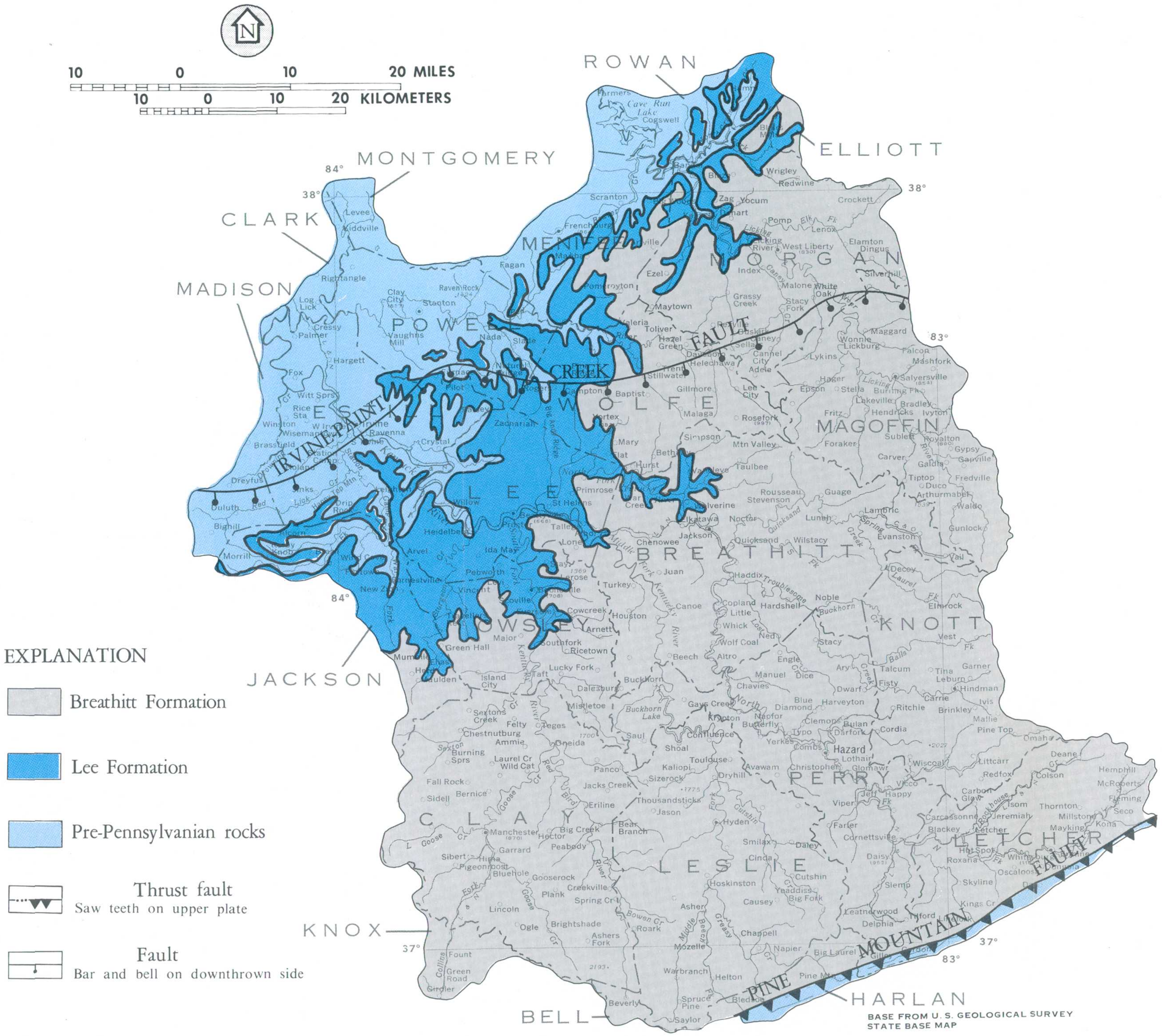
Minimum, median, and maximum values for major chemical constituents in each geologic unit are shown in figure 8.0-1. Median values are shown because they are more representative than average or extreme values, especially in the Lee Formation where brines or brackish water occurs. Ground-water quality data for Kentucky has been compiled by Faust and others (1980).

Salty water (water having more than 1,000 mg/L dissolved solids) in Area 14 is found at depths less than 300 feet except in southeastern Letcher County. Salty water occurs at depths less than 100 feet below the level of the deeper valleys in Breathitt, Clay, Leslie, and Owsley Counties. It is common in the vicinity of oil and gas fields because it can migrate upward through improperly plugged or abandoned oil, gas, or test wells. In general, the concentration of dissolved solids increases with depth, and water classified as brines (more than 35,000 mg/L dissolved solids) can be reached by deep wells in any part of the area.

Generally the most common constituent found in ground water which may limit its use in Area 14 is iron which ranges from 0.01 to 800 mg/L. Water from coal mines or water that has drained through beds of black shale is most likely to have high iron concentrations. Locally, water from all formations in the area may contain iron concentrations in excess of the 0.3 mg/L recommended limit for water for domestic use (U.S. Environmental Protection Agency, 1977).

Hardness is frequently troublesome in ground water from Area 14. Water from rocks of Pennsylvanian age contains both the greatest and the least hardness, as calcium carbonate ($CaCO_3$) concentration, of any water sampled from this area; hardness ranges from 4 to 866 mg/L. Hardness shows little relation to depth or location of wells.

Most waters from rocks of Pennsylvanian age in Area 14 can be classified as calcium-magnesium-bicarbonate, sodium-bicarbonate or sodium-sulfate types. None of these types is unique to either the Breathitt or Lee Formation. All types occur in each formation. The principal factors that govern the chemical quality of ground water are geology, source of the water, and the amount of time it has been in contact with the rocks. Water from deep wells tends to be more highly mineralized than water from shallow wells or springs. Water from wells located on hilltops is usually less mineralized than water from wells in valleys. In places where coal and black shale are relatively close to the surface, water in these rocks tends to have pH values less than 7.0 units.



Adapted from the following Hydrologic Atlases:
HA-17, 18, 19, 36, 37, and 38.

(Concentrations in milligrams per liter; specific conductance values in micromhos per centimeter at 25. C; pH values in units)

	CONSTITUENT	RANGE	MEDIAN	NUMBER OF SAMPLES
Breathitt Formation	Iron (Fe)	0.01 - 890	0.73	188
	Calcium (Ca)	1.4 - 124	32	29
	Magnesium (Mg)	.9 - 41	10	29
	Sodium (Na)	.6 - 318	83	26
	Potassium (K)	1.0 - 9.4	3	25
	Bicarbonate (HCO3)	0.0 - 620	138	189
	Sulfate (SO4)	0.0 - 1100	22	189
	Chloride (Cl)	.8 - 1200	10	240
	Specific Conductance	22 - 4530	388	189
	Hardness as Calcium Carbonate (CaCO3)	4 - 886	96	189
	pH	3.5 - 9.7	6.9	183
Lee Formation	Iron (Fe)	0.01 - 6.4	0.23	40
	Calcium (Ca)	3.6 - 52	5.5	28
	Magnesium (Mg)	.2 - 24	1.4	28
	Sodium (Na)	2.3 - 317	247	27
	Potassium (K)	1.1 - 28	2.2	27
	Bicarbonate (HCO3)	14 - 512	267	50
	Sulfate (SO4)	0.0 - 65	4.0	51
	Chloride (Cl)	.5 - 2050	44	74
	Specific Conductance	40 - 1620	809	50
	Hardness as Calcium Carbonate (CaCO3)	7 - 256	27	51
	pH	6.0 - 8.9	7.5	46
Pre-Pennsylvanian rocks	Iron (Fe)	0.01 - 14	0.4	10
	Calcium (Ca)	13 - 14	-	2
	Magnesium (Mg)	1.0 - 1.2	-	2
	Sodium (Na)	.8 - 1.0	-	2
	Potassium (K)	.07- 1.2	-	2
	Bicarbonate (HCO3)	9 - 442	122	10
	Sulfate (SO4)	1.4 - 260	7.0	11
	Chloride (Cl)	1.0 - 134	5	11
	Specific Conductance	52 - 55	-	2
	Hardness as Calcium Carbonate (CaCO3)	32 - 272	82	9
	pH	6.0 - 7.5	7.1	6

Figure 8.0-1 Chemical composition of ground water .

NAWDEX, WATSTORE, AND OWDC 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. These activities are:

(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 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 are given in sections 9.2, 9.3, and 9.4.

NAWDEX SIMPLIFIES ACCESS TO WATER DATA

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

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

Services are available through a Program Office located at the U.S. Geological Survey's National Center in Reston, Virginia, and a nationwide network of Assistance Centers located in 45 states and Puerto Rico, which provide local and convenient access to NAWDEX facilities (fig. 9.2-1). A directory is available on request that provides names of organizations and persons to contact, addresses, telephone numbers, and office hours for each of these locations [Directory of Assistance Centers of the National Water Data Exchange (NAWDEX), U.S. Geological Survey Open-File Report 79-423 (revised)].

NAWDEX can assist any organization or individual in identifying and locating needed water data and referring the requester to the organization that retains the data required. To accomplish this service, NAWDEX maintains a computerized Master Water Data Index (fig. 9.2-2), which identifies sites for which water data are available, the type of data available for each site, and the organization retaining the data. A water Data Sources Directory (fig. 9.2-3) also is maintained that identifies organizations that are sources of water data and the locations within these organizations from which data may be obtained. In addition NAWDEX has direct access to some large water-data bases of its members and has reciprocal agreements for the exchange of services with others.

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

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

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

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

Hours: 7:45 - 4:15 Eastern Time

or

NAWDEX ASSISTANCE CENTER
KENTUCKY
U.S. Geological Survey
Water Resources Division
Room 572 - Federal Building
600 Federal Place
Louisville, KY 40202

Telephone: (502) 582-5241
FTS 352-5241

Hours: 8:00 - 4:45 Eastern Time

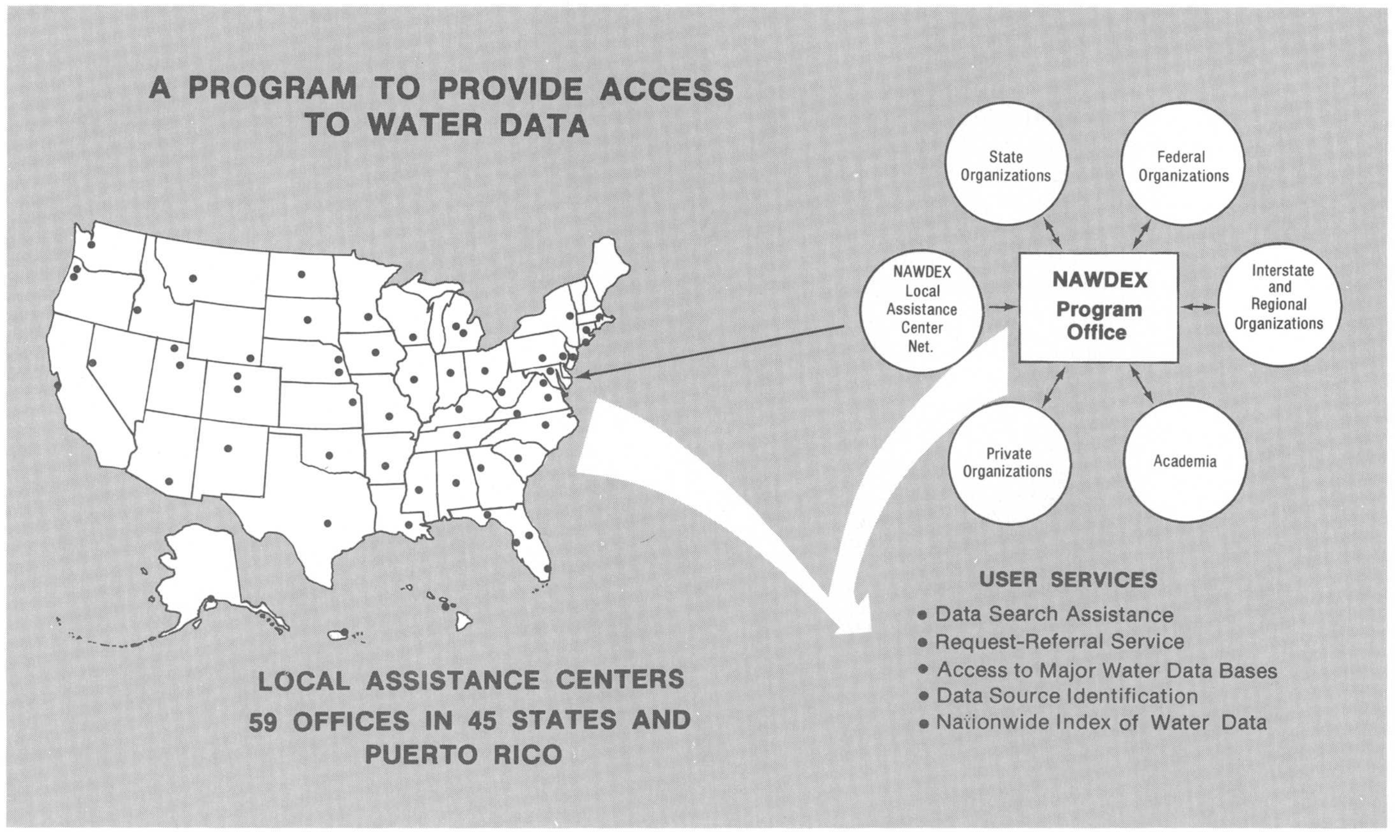


Figure 9.2-1 Access to water data

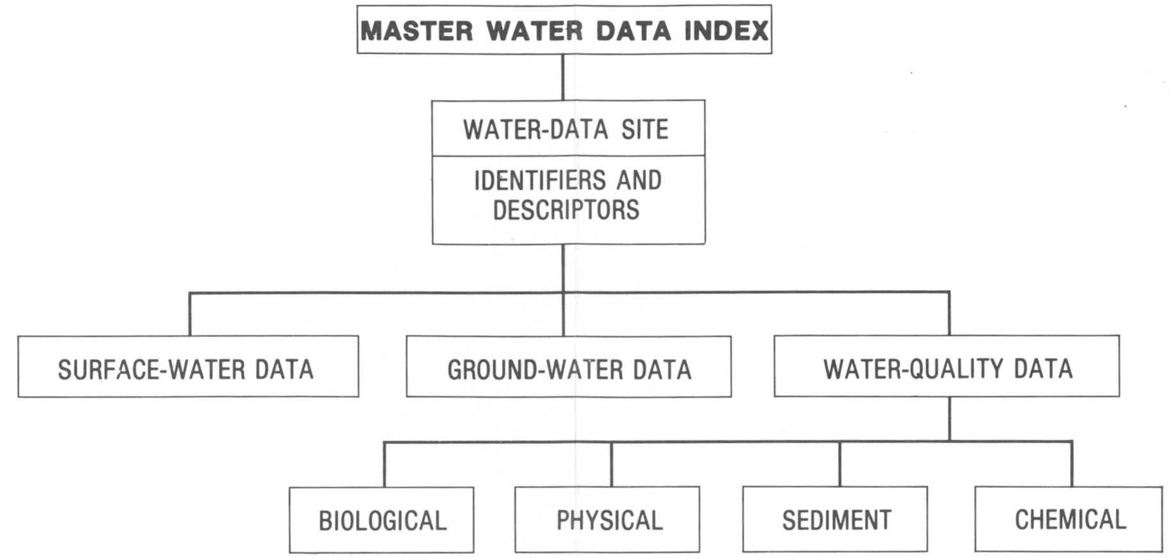


Figure 9.2-2 Master water-data index

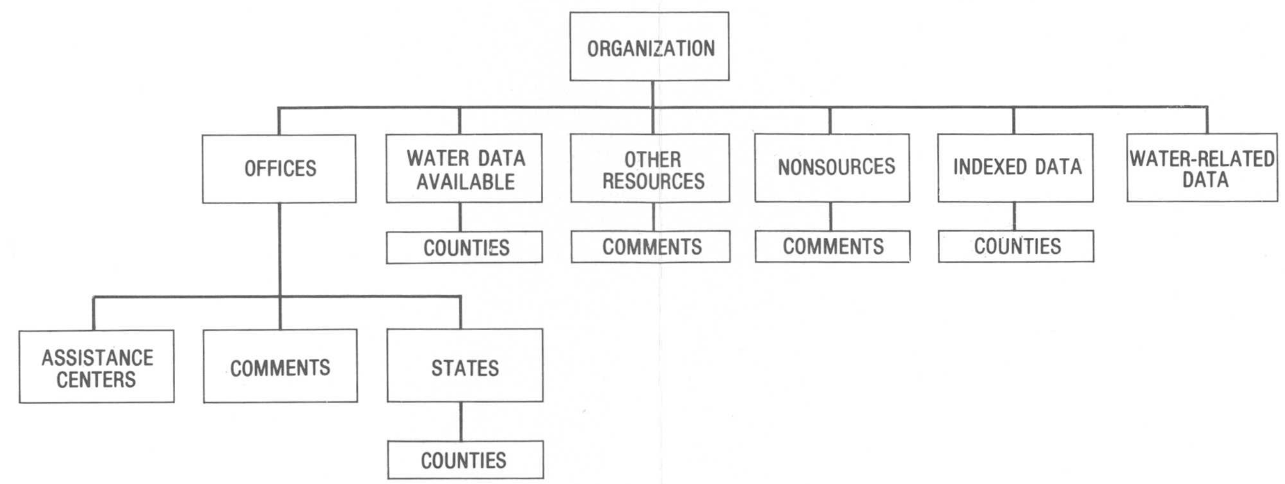


Figure 9.2-3 Water-data sources directory

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, VA 22092

or

U.S. Geological Survey
Water Resources Division
Room 572 - Federal Building
600 Federal Place
Louisville, KY 40202

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 is also 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. 9.3-1). A brief description of each file is as follows:

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

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

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

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

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

Ground-Water Site-Inventory File: This file is 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 70,000 sites.

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

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

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

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

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

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

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

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

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

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

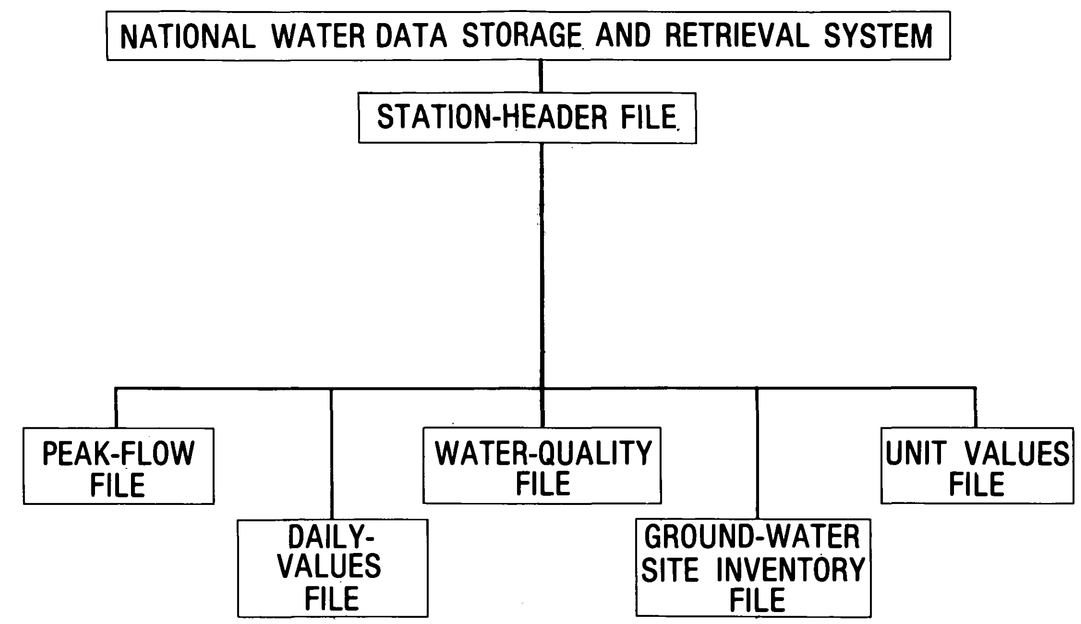


Figure 9.3-1 Index file stored data

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. 9.4-1): volume I, Eastern Coal province; volume II, Interior Coal province; volume III, Northern Great Plains and Rocky Mountain Coal provinces; volume IV, Gulf Coast Coal province; and volume V, Pacific Coast and Alaska Coal provinces. The information presented will aid the user in obtaining data for evaluating the effects of coal mining on water resources and in developing plans for meeting additional water-data needs. The report does not contain the actual data; rather, it provides information that will enable the user to determine if needed data are available.

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

Those who need additional information from the Catalog file or who need assistance in obtaining water data should contact the National Water Data Exchange (NAWDEX) (see section 9.2).

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

U.S. Geological Survey
Water Resources Division
Room 572 - Federal Building
600 Federal Place
Louisville, KY 40202

Telephone: (502) 582-5241
FTS 352-5241

or

Office of Surface Mining
U.S. Department of the Interior
530 Gay St., Suite 500
Knoxville, TN 37902

Telephone: (615) 637-8060
FTS 852-0060

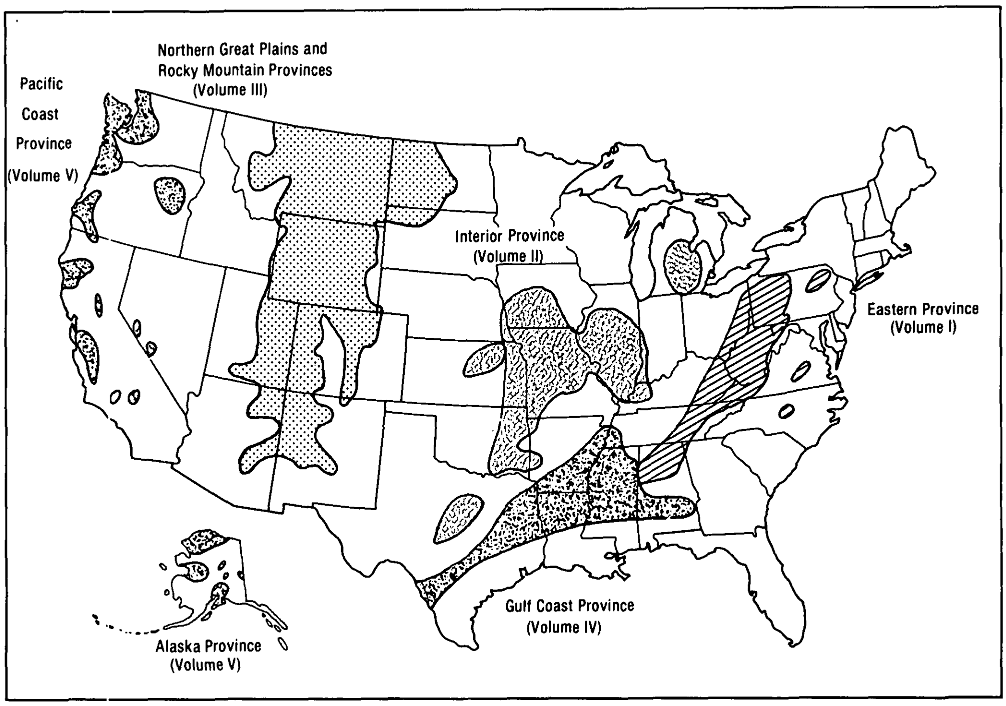


Figure 9.4-1 Index volumes and related provinces

10.0 LIST OF REFERENCES

Currens, J. C., and Smith, G. E., 1977, Coal production in Kentucky, 1790-1975: Kentucky Geological Survey Information Circular 23, 66 p.

Curtis, W. F., Flint, R. F., and George, F. H., 1978, Fluvial sediment study of Fishtrap and Dewey lakes drainage basins, Kentucky-Virginia: U.S. Geological Survey Water Resources Investigation 77-123, 92 p.

Division of Water Resources, 1979, Rainfall frequency values for Kentucky: Commonwealth of Kentucky, Department of National Resources and Environmental Protection, Engineering Memorandum No. 2, 37 p.

Dyer, K.L., and Curtis, W. R., 1977, Effect of strip mining on water quality in small streams in Eastern Kentucky, 1967-75: USDA Forest Service Research Paper NE-372, 13 p.

Faust, R.J., Banfield, G.R., and Willinger, G.A., 1980, A compilation of ground water quality for Kentucky: U.S. Geological Survey Open -File Report 80-685, 963p.

Hannum, C. H., 1976, Technique for estimating magnitude and frequency of floods in Kentucky: U.S. Geological Survey WRI 76-62, 70 p., 1 plate.

Harvey, C. E., 1977, The economics of Kentucky coal: The University Press of Kentucky, Lexington, 173 p.

Hem, J. D., 1970, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water-Supply Paper 1473. 363 p.

Hendrickson, G. E., 1958, Summary of occurrence of ground water in Kentucky: U.S. Geological Survey Hydrologic Investigations Atlas HA-10.

Hopkins, Herbert T., 1966, Fresh-saline water interface map of Kentucky: Kentucky Geological Survey Series 10.

------, 1970, Occurrence of fresh water in the Lee Formation in parts of Elliott, Johnson, Lawrence, Magoffin, and Morgan Counties, Eastern Coal Field Region, Kentucky: U.S. Geological Survey Water Supply Paper 1867, 44 p.

Huddle, J.W., Lyons, E.J., Smith, H.L., Ferm, J.C., and others, 1963, Coal reserves of eastern Kentucky: U.S. Geological Survey Bulletin 1120, 247 p.

Jillson, W. R., 1919, The Kendrick Shale: a new calcareous fossil horizon in the coal measures of eastern Kentucky: Kentucky Department of Geology and Forestry, series 5, vol. 1, no. 2, p. 96-104.

Karan, P.P., and Mather, Cotton, editors, 1977, Atlas of Kentucky: The University Press of Kentucky, Lexington, 182p.

Kilburn, Chabot, Price, W.E., Jr., and Mull, D.S., 1962, Availability of ground water in Bell, Clay, Jackson, Knox, Laurel, Leslie, McCreary, Owsley, Rockcastle, and Whitley Counties, Kentucky: U.S. Geological Survey Hydrologic Investigations Atlas HA-38.

Kirkpatrick, H. N., 1979, Annual report Kentucky Department of Mines and Minerals, 1978: Commonwealth of Kentucky, Department of Mines and Minerals, 218 p.

McCabe, J. A., 1962, Floods in Kentucky--magnitude and frequency: Kentucky Geological Survey, series 10, Information Circular 9, 196 p.

McFarlan, A. C., 1943, Geology of Kentucky: Lexington, Ky., University of Kentucky, 531 p. (Reprinted 1961, Kentucky Department Economic Development).

Mull, D. S., 1965, Ground-water resources of the Jenkins-Whitesburg area, Kentucky: U.S. Geological Survey Water-Supply Paper 1809-A, 36 p.

Murray, C. R., and Reeves, E. B., 1977, Estimated use of water in the United States in 1975: U.S. Geological Survey Circular 765, 39 p.

National Oceanic and Atmospheric Administration, 1973, Monthly normals of temperature, precipitation, and heating and cooling degree days 1941-70: U.S. Department of Commerce Pub. No. 81 (KY), 7 p.

Newell, W. L., and Rice, Charles L., 1977, Bedrock geologic map of the Kentucky River Area Development District and vicinity, Kentucky: U.S. Geological Survey Map MF-865A.

Price, W. E., Jr., Kilburn, Chabot, and Mull, D. S., 1962, Availability of ground water in Breathitt, Floyd, Harlan, Knott, Letcher, Martin, Magoffin, Perry, and Pike Counties, Kentucky: U.S. Geological Survey Hydrologic Investigations Atlas HA-36.

-----, 1962A, Availability of ground water in Boyd, Carter, Elliott, Greenup, Johnson, Lawrence, Lee, Menifee, Morgan, and Wolfe Counties, Kentucky: U.S. Geological Survey Hydrologic Investigations Atlas HA-37.

Price, W. E., Jr., Mull, D. S., and Kilburn, Chabot, 1962, Reconnaissance of ground-water resources in the Eastern Coal Field region of Kentucky: U.S. Geological Survey Water-Supply Paper 1607, 56 p.

Quinones, F., and Macy, J. A., 1980, Flow-duration at selected stream sites in Kentucky: U.S. Geological Survey Open-File Report 80-1221, 146 p.

Rice, Charles L., Sable, Edward G., Dever, Garland

R., Jr., and Kehn, Thomas M., 1979, The Mississippian and Pennsylvanian (Carboniferous) Systems in the United States--Kentucky: U.S. Geological Survey Professional Paper 1110-F, 32 p.

Searcy, James K., 1959, Flow-duration curves: U.S. Geological Survey Water-Supply Paper 1542-A.

State Conservation Needs Inventory Committee, 1970, Kentucky Soil and Water Conservation Needs Inventory: Commonwealth of Kentucky, Division of Soil and Water Conservation special report, 256 p.

Sullavan, J. N., 1980, Low-flow characteristics of Kentucky streams: U.S. Geological Survey Open-File Report 80-1225, 1 plate.

Sullavan, J. N., Quinones, F., and Flint, R. F., 1979, Floods of December 1978 in Kentucky: U.S. Geological Survey Open-File Report 79-977, 53 p.

Swisshelm, R. V., 1974, Low-flow characteristics of Kentucky streams: U.S. Geological Survey Open-File Report, 1 plate.

U.S. Department of Agriculture, Soil Conservation Service, 1978, Land cover survey of the Kentucky River basin: Soil Conservation Service, Report Number 02172-014-21, 19 p.

U.S. Environmental Protection Agency, 1976, Quality criteria for water: Environmental Protection Agency Report, 256 p.

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

U.S. Geological Survey, Water resources data for Kentucky annual reports: U.S. Geological Survey, Louisville, Kentucky.

Zogorski, J. S., and Kiesler, J. L., 1976, Water temperatures of Kentucky: U.S. Geological Survey Water Resources Investigations 76-86, 1 plate.

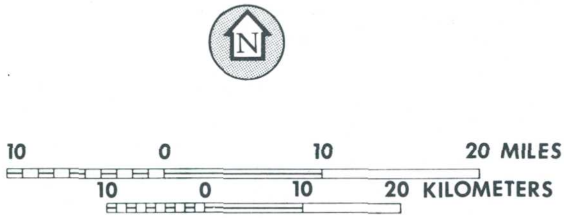
Appendix 1. Index to published geologic quadrangle maps.

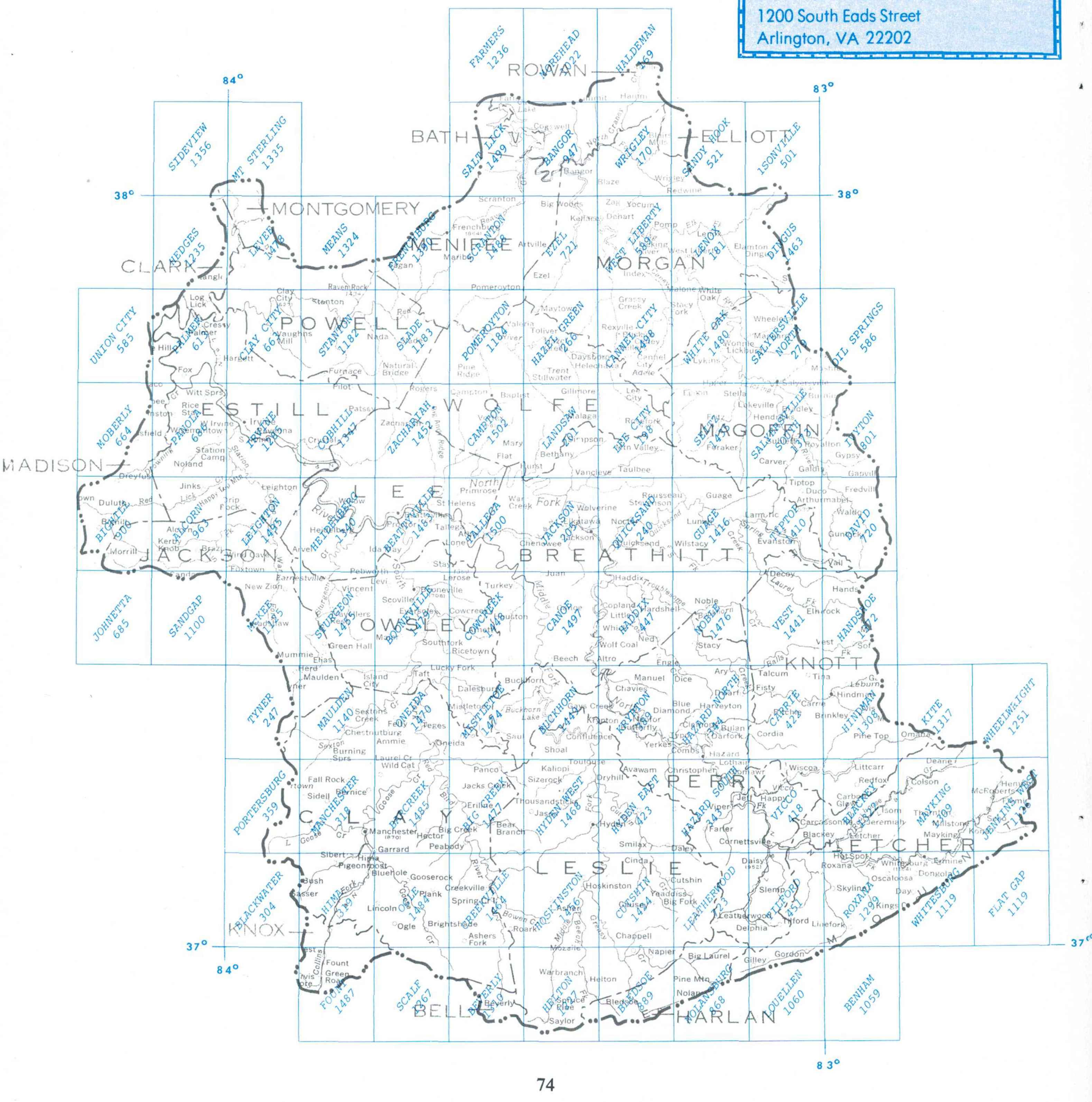
AGENTS FOR MAP SALES

Kentucky Geological Survey
311 Breckinridge Hall
University of Kentucky
Lexington, KY 40506

Kentucky Department of Commerce
Map Sales Office
133 Holmes Street
Frankfort, KY 40601

U.S. Geological Survey
Branch of Distribution
1200 South Eads Street
Arlington, VA 22202





Appendix 2. Land use in the Upper Kentucky River Basin (upstream from Kentucky River at Heidelberg.

Land Use By Types, In Acres And Percent

COUNTY	CROPLAND	GRASSLAND	HARDWOODS	CONIFERS	PARTIALLY STABILIZED STRIP MINES	STABILIZED STRIP MINES	UNSTABILIZED STRIP MINES	URBAN	WATER	UNCLASSIFIED	TOTAL
Breathitt	5,726	15,453	274,094	3,880	1,668	4,873	5,479	510	1,949	5,548	316,200
	1.8	4.9	86.8	1.2	.5	1.5	1.7	.2	.6	.8	
Clay	13,125	37,989	226,702	9,637	1,104	---	9,715	1,228	891	2,969	303,360
	4.3	12.5	74.7	3.2	.4	---	3.2	.4	.3	1.0	
Estill	6,636	34,142	117,140	4,170	---	---	---	374	2,122	1,810	166,400
	4.0	20.5	70.4	2.5	---	---	---	.2	1.3	1.1	
Knott	3,255	9,544	195,678	2,260	1,110	8,186	6,153	998	403	253	227,840
	1.4	4.2	85.9	1.0	.5	3.6	2.7	.4	.2	.1	
Lee	2,877	14,664	109,319	4,042	---	---	285	285	1,729	1,199	134,400
	2.1	10.9	81.3	3.1	---	---	.2	.2	1.3	.9	
Leslie	7,357	12,042	226,813	3,465	572	3,460	5,442	431	910	3,188	263,680
	2.8	4.6	86.0	1.3	.2	1.3	2.1	.2	.3	1.2	
Letcher	3,044	10,174	179,431	2,430	1,126	9,452	7,854	1,900	289	1,170	216,970
	1.4	4.7	82.7	1.1	.5	4.5	3.6	.9	.1	.5	
Owsley	4,718	10,750	103,469	3,717	---	426	494	289	761	1,456	126,080
	3.8	8.6	82.1	3.0	---	.3	.4	.2	.6	1.0	
Perry	3,664	12,977	166,373	3,372	3,029	14,912	12,106	1,957	309	821	219,520
	1.7	5.9	75.9	1.5	1.4	6.8	5.5	.9	.1	.3	
Powell	2,526	17,794	82,844	2,513	---	---	---	2,441	539	2,028	110,720
	2.3	16.1	74.9	2.3	---	---	---	2.2	.5	1.7	
Wolfe	4,018	13,347	119,871	4,316	153	195	1,340	281	268	1,491	145,280
	2.8	9.2	82.5	3.0	.1	.1	.9	.2	.2	1.0	
Total Acres	56,946	188,876	1,801,734	43,802	8,762	41,504	48,870	10,694	10,170	18,933	2,230,450
Percent of Total	2.6	8.5	80.9	2.0	.1	1.9	2.2	.1	.1	.1	

(Adapted from Soil Conservation Service, 1978)

Appendix 3. List of stream flow and quality of water stations in area 14.

STATION			LOCATION			PERIOD AND TYPE OF RECORD		
SITE NUMBER	NUMBER	NAME	LATITUDE [o] ' "	LONGITUDE [o] ' "	DRAINAGE AREA (mi[2])	DAILY DISCHARGE	CHEMICAL QUALITY	DAILY SEDIMENT
31	03277260	Wonts Cr nr Neon	371053	824302				
32	03277361	Rockhouse Cr nr Fletcher	370836	825743				
33	03277320	Kings Cr nr Roxana	370529	825518				
34	03277370	Line Fk at Defeated Cr	370314	825921	11.6	1958-76		
35	03277400	Leatherwood Cr at Daisy	370648	830533	40.9	1963		
36	03277415	Right Fk Macys Cr nr Farlar	371004	831037				
37	03277580	Big Cr nr Avawan	371409	831533				
38	03277500	N.F. Ky R at Hazard	371448	831055	466	1925-	1949-75, 79	1979-
39	03277515	Lotts Cr nr Darfork	371701	831115				
40	03277800	Troublesome Cr nr Ary	372201	830905				
41	03277700	Grapevine Cr nr Lamont	372111	831914				
42	03277900	Balls Fk nr Talcum	372208	830643				
43	03279250	Laurel Fk nr Elmrock	372704	830123				
44	03278100	Buckhorn Cr nr Noble	372655	831144				
45	03279150	Lost Cr nr Lost Cr	372756	831914				
46	03279300	M.F. Quicksand Cr nr Decoy	372957	830529				
47	03279370	Hawls Fk nr Tiptop	373417	830548				
48	03279430	Caney Cr nr Camp Lewis	370507	831128				
49	03279460	Hunting Cr nr Rousseau	373533	831341				
50	03279650	S.F. nr Press	373157	831948				
51	03280000	N.F. Ky R at Jackson	373305	832305	1,101	1904	1949-75, 79-	1979-
52	03280100	Cane Cr nr Jackson	373304	832457				
53	03280450	Boone Fk nr Vancleve	373734	832453				
54	03280400	Frozen Cr nr Taulbee	373830	831911				
55	03281000	M.F. Ky R at Tallega	373318	833538	537	1930	1949-75, 79-	1979-
56	03280950	Turkey Cr nr Turkey	372857	833004				
57	03280750	Hell For Certain Cr nr Kaliopi	371351	832430				
58	03280630	Rockhouse Cr nr Hyden	370918	832337				
59	03280600	M.F. Ky R nr Hyden	370813	832217	202	1957	1974-	1976-
60	03280700	Cutshin Cr at Wooton	370954	831829	61.3	1957	1974-	
61	03280520	M.F. Ky R nr Warbranch	365819	832656				
62	03280540	Beech Fk nr Helton	365727	832348				
63	03280670	Cutshin Creek near Cinda	370657	831642				
64	03280575	Laurel Fork near Lewis Creek	365843	831935				
65	03280560	Greasy Creek near Napier	365832	831706				
66	03281040	Red Bird River near Big Creek	371043	833535	155	1972-		
67	03281065	Goose Creek near Gooserock	370450	834133				
68	03281075	Collins Fork near Bluehole	370503	834605				
69	03281097	Horse Creek near Hima	370713	834646				
70	03281133	Little Goose Cr nr Manchester	370909	834713				
71	03281100	Goose Creek at Manchester	370907	834537	163	1964-	1964-	1979-
72	03281035	Big Creek near Big Creek	370942	833416				
73	03281045	Hector Bridge near Eriline	371118	833639				
74	03281175	Bullskin Creek near Brutus	371437	833506				
75	03281340	Sextons Creek near Chestnutberg	371724	834743				
76	03281360	Lower Allen Creek near Conkling	372238	834138				
77	03281500	S.F. Kentucky R at Booneville	372845	834038	722	1925-	1949-75,79-	1979-
78	03282000	Ky R at lk 14 at Heidelberg	373319	834606	2,657	1902-		
145	03248165	Licking R near Fredville	373600	825736				
146	03248530	Right Fork at Fritz	374219	830853				
147	03248520	Left Fork near Hendricks	374250	830657				
148	03248380	Burning Fork at Salyersville	374428	830322				
149	03248500	Licking R near Salyersville	374503	830504	140	1938-	1970-76,79-	1979-
150	03248560	Johnson Creek near Kernie	374524	831010				
151	03248580	Lick Creek near Bloomington	374855	830850				
152	03248610	White Oak Creek at White Oak	375132	831213				
153	03248710	Caney Creek near Caney	374914	831521				
154	03248750	Grassy Creek at Grassy Creek	375201	832045				
155	03248685	Elk Fork near Lenox	375652	831257				
156	03248670	Williams Creek near Elanton	375608	830910				
157	03282400	Red River at Daysboro	374729	832240				
158	03282500	Red River near Hazel Green	374844	832750	65.5	1954-	1970-	
159	03283000	Stillwater Creek at Stillwater	374524	832912	24	1954-		
159a	03283100	Red River near Pine Ridge	374911	833429	142	1969-76		
159b	03283500	Red River at Clay City	375152	835559	362	1930-		

Appendix 4. Flood frequency and 10-year maximum flows at selected sites in area 14.

STATION NUMBER	DRAINAGE AREA SQUARE MILES	STATION NAME	FLOOD FLOW FOR SHOWN FREQUENCY, FT^3/S YEARS						10-YEAR FREQUENCY FLOWS, FT^3/S DAYS			
			2	5	10	25	50	100	1	3	7	15
03248500	140	Licking R nr Salyersville	4,760	7,360	9,130	11,400	13,100	14,800	6,420	4,200	2,380	1,550
03277300	66.4	N.F. Ky R at Whitesburg	2,820	4,410	5,510	6,6920	7,920	9,070	--	--	--	
03277400	40.9	Leatherwood Cr at Daisy	---	---	---	---	---	---	2,280	1,250	757	
03277500	466	N.F. at Hazard	17,700	27,100	33,600	41,900	48,100	54,600	25,400	14,900	8,170	
03278000	2.21	Bear Br nr Nobl	410	695	900	1,170	1,380	1,610	129	69	40	
03278500	177	Troublesome Cr at Noble	8,960	14,000	17,400	21,900	25,300	28,900	11,880	6,300	3,410	
03280000	1,101	N.F. Ky R at Jackson	32,400	48,900	60,100	74,300	85,100	96,200	41,700	33,000	18,700	
03280600	202	M.F. Ky R nr Hyden	9,840	15,300	19,100	23,900	27,600	31,500	12,200	6,710	3,780	
03280700	61.3	Cutshin Cr nr Wooten	4,250	6,760	8,510	10,800	12,500	14,300	3,740	2,280	1,290	
03281000	537*	M.F. Ky R at Tallega	19,600	29,900	37,000	46,000	52,800	60,000	22,880	16,300	9,200	6,120
03281100	163	Goose Cr at Manchester	---	---	---	---	---	---	11,400	6,850	3,630	
03281500	722	S.F. Ky R at Booneville	24,100	36,600	45,200	56,100	64,300	72,900	41,800	27,600	15,000	
03282000	2,657*	Ky R at Lk 14 at Heidelberg	60,200	89,400	109,000	134,00	153,000	172,000	94,900	73,700	44,000	
03282500	65.8	Red R nr Hazel Green	4,470	7,100	8,930	11,300	13,100	15,000	3,070	1,970	1,110	
03283000	24.0	Stillwater Cr at Stillwater	2,200	19,300	24,000	27,500	31,100	14,000	9,770	5,910		
03283500	362	Red R at Clay City	10,300	15,700	19,300	24,000	27,500	31,100	14,000	9,770	5,910	

*Affected by regulation

Appendix 5. Flow duration at long-term stations in area 14.

STATION NUMBER	NAME	*PERIOD OF RECORD	1	5	10	25	50	70	75	90	95	REMARKS
			PERCENT OF TIME INDICATED DISCHARGE (CUBIC FEET PER SECOND) WAS EQUALLED OR EXCEEDED									
03248500	Licking R nr Salyersville	1939-78	1,900	694	420	170	56	19	14	3.1	1.5	
03277500	N.F. Ky R at Hazard	1940-78	6,100	2,120	1,300	590	200	74	58	24	12	Historical
03277500	N.F. Ky R at Hazard	1941-75	6,340	2,160	1,300	600	200	72	56	23	12	Before Reg.
03280000	N.F. Ky R at Jackson	1929-78	13,000	5,220	3,300	1,500	510	190	150	55	28	Historical
03280000	N.F. Ky R at Jackson	1929-75	14,000	5,280	3,300	1,500	490	180	140	51	26	Before Reg.
03280600	M.F. Ky R nr Hyden	1958-73	3,230	1,170	650	320	95	27	21	6.6	3.5	
03280700	Cutshin Cr at Wooten	1958-73	983	352	210	93	28	8.9	6.5	2.1	1.2	
03281000	M.F. Ky R at Tallega	1931-73	6,240	3,060	2,000	780	240	99	80	25	10	Historical
03281000	M.F. Ky R at Tallega	1931-60	7,300	2,790	1,700	730	220	70	51	14	5.7	Before Reg.
03281040	Red Bird nr Big Cr	1972-78	3,850	1,240	680	310	130	48	35	8.3	4.4	
03281100	Goose Cr at Manchester	1965-78	3,250	1,030	590	270	82	26	20	6.2	3.8	
03281500	S.F. Ky R at Booneville	1926-78	12,000	4,290	2,500	1,100	340	110	79	23	8.9	
03282000	Ky R at Lk at Heidelberg	1926-78	31,300	14,900	9,400	4,200	1,300	510	410	170	81	Historical
03282000	Ky R at Lk at Heidelberg	1926-60	32,000	14,600	9,000	3,800	1,100	420	330	100	46	Before Reg.
03282500	Red R nr Hazel Green	1954-78	1,000	348	200	84	29	7.9	5.9	1.60	.7	

*Records analyzed through 1978. Some stations still active.

Appendix 6. Regression equations between specific conductances (SC), micromhos per centimeter at 25° Celsius and several key parameters at long-term stations in area 14.

DISCHARGE (Q_i), CUBIC FEET PER SECOND, SULFATE ($SO_4^{=}$), MILLIGRAMS PER LITER, DISSOLVED IRON (Fe^{++}), AND MANGANESE (Mn^{++}), MICROGRAMS PER LITER

STATION NUMBER	NAME	PARAMETER	NUMBER OF SAMPLES	REGRESSION EQUATION	CORRELATION COEFFICIENT (r)
03248500	Licking River near Salyersville	Q_i	72	$Q_i = 10^{6.35} SC^{-1.92}$	0.67
		$SO_4^{=}$	71	$SO^{4=} = 3.98\ SC^{0.33}$	.47
		Fe^{++}	47	$Fe^{++} = 18.6\ SC^{0.32}$	.14
		Mn^{++}	47	$Mn^{++} = 0.17\ SC^{0.32}$	.64
03277450	Carr Fork near Sassafras	Q_i	71	$Q_i = 10^{12}\ SC^{-4.32}$	.79
		$SO_4^{=}$	55	$SO_4^{=} = 1.05\ SC^{0.76}$	.85
		Fe^{++}	34	$Fe^{++} = 245\ SC^{-0.24}$	.10
		Mn^{++}	42	$Mn^{++} = 3,550\ SC^{-0.47}$	.20
03277500	North Fork Kentucky River at Hazard	Q_i	19	$Q_i = 10^{10.5}\ SC\ 3.14$	.93
		$SO_4^{=}$	261	$SO_4^{++} = 0.15\ SC^{1.14}$	.98
		Fe^{++}	16	$Fe^{++} = 30.9\ SC^{0.08}$	.01
03282000	Kentucky River at Lock 14 Heidelberg	Q_i	22	$Q_i = 10^{9.88}\ SC^{-2.95}$	.65
		$SO_4^{=}$	14	$SO_4^{=} = 0.16\ SC^{1.09}$	.98
03283100	Red River near Pine Ridge	Q_i	64	$Q_i = 10^{10.2}\ SC^{-4.22}$	.82
		SO_4^{+}	70	$SO_4^{=} = 8.91\ SC^{-0.10}$	.14
		Fe^{++}	60	$Fe^{++} = 6.17\ SC^{0.65}$	.24
		Mn^{++}	55	$Mn^{++} = 7.41\ SC^{0.29}$	.10

Appendix 7. Concentration of trace elements at selected sites in area 14, trace metals-total recoverable in micrograms per liter.

	ALUMINUM				ARSENIC				CADMIUM			
SITE NUMBER	NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX	NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX	NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX
31	--	--	--	--	1	1	--	--	1	0	--	--
32	--	--	--	--	1	0	--	--	1	0	--	--
33	--	--	--	--	1	0	--	--	1	0	--	--
34	--	--	--	--	1	1	--	--	1	0	--	--
35	--	--	--	--	1	1	--	--	1	0	--	--
36	--	--	--	--	1	1	--	--	1	0	--	--
37	--	--	--	--	1	0	--	--	1	0	--	--
38	--	--	--	--	8	11	0	76	8	3	0	8
39	--	--	--	--	1	0	--	--	1	0	--	--
40	--	--	--	--	1	1	--	--	1	1	--	--
41	--	--	--	--	1	1	--	--	1	0	--	--
42	--	--	--	--	1	1	--	--	1	1	--	--
43	--	--	--	--	1	0	--	--	1	0	--	--
44	--	--	--	--	1	1	--	--	1	0	--	--
45	--	--	--	--	1	0	--	--	1	0	--	--
46	--	--	--	--	1	0	--	--	1	0	--	--
47	--	--	--	--	1	0	--	--	1	0	--	--
47A	--	--	--	--	1	0	--	--	1	0	--	--
48	--	--	--	--	1	1	--	--	1	1	--	--
50	--	--	--	--	1	0	--	--	1	0	--	--
51	--	--	--	--	1	0	--	--	1	1	--	--
52	--	--	--	--	1	1	--	--	1	1	--	--
53	--	--	--	--	1	1	--	--	1	0	--	--
54	--	--	--	--	1	1	--	--	1	0	--	--
55	--	--	--	--	1	1	--	--	1	0	--	--
56	--	--	--	--	1	1	--	--	1	0	--	--
57	--	--	--	--	1	1	--	--	1	1	--	--
58	--	--	--	--	1	1	--	--	1	1	--	--
59	--	--	--	--	1	1	--	--	1	0	--	--
60	--	--	--	--	1	0	--	--	1	0	--	--
61	--	--	--	--	1	1	--	--	1	0	--	--
62	--	--	--	--	1	0	--	--	1	0	--	--
63	--	--	--	--	1	1	--	--	1	3	--	--
64	--	--	--	--	1	1	--	--	1	2	--	--
65	--	--	--	--	1	2	--	--	1	4	--	--
66	--	--	--	--	1	1	--	--	1	0	--	--
67	--	--	--	--	1	2	--	--	1	3	--	--
68	--	--	--	--	1	1	--	--	1	1	--	--
69	--	--	--	--	1	2	--	--	1	1	--	--
70	--	--	--	--	1	2	--	--	1	2	--	--
71	1	100	--	--	1	1	--	--	1	1	--	--
72	--	--	--	--	1	0	--	--	1	0	--	--
74	--	--	--	--	1	1	--	--	1	2	--	--
75	--	--	--	--	1	1	--	--	1	1	--	--
76	--	--	--	--	1	1	--	--	1	1	--	--
77	1	100	--	--	9	.4	0	3	9	2	0	11
78	1	100	--	--	8	1.4	0	6	8	3.5	0	12
145	--	--	--	--	1	1	--	--	1	1	--	--
146	--	--	--	--	1	1	--	--	1	0	--	--
147	--	--	--	--	1	1	--	--	1	1	--	--
148	--	--	--	--	1	1	--	--	1	0	--	--
149	1	0	--	--	8	6	0	39	8	3	0	12
150	--	--	--	--	1	1	--	--	1	0	--	--
151	--	--	--	--	1	1	--	--	--	--	--	--
152	--	--	--	--	1	1	--	--	1	0	--	--
153	--	--	--	--	1	1	--	--	1	0	--	--
154	--	--	--	--	1	1	--	--	1	0	--	--
155	--	--	--	--	1	1	--	--	1	0	--	--
156	--	--	--	--	1	1	--	--	1	1	--	--
157	--	--	--	--	1	1	--	--	1	0	--	--
158	--	--	--	--	9	2	0	5	9	1	0	3
159	--	--	--	--	1	1	--	--	1	0	--	--

Appendix 7. (Cont.)

SITE NUMBER	COBALT NUMBER OF SAMPLES	COBALT MEAN OR VALUE	COBALT MIN	COBALT MAX	COPPER NUMBER OF SAMPLES	COPPER MEAN OR VALUE	COPPER MIN	COPPER MAX	LEAD NUMBER OF SAMPLES	LEAD MEAN OR VALUE	LEAD MIN	LEAD MAX
31	--	--	--	--	1	8	--	--	1	11	--	--
32	--	--	--	--	1	6	--	--	1	7	--	--
33	--	--	--	--	1	4	--	--	1	4	--	--
34	--	--	--	--	1	5	--	--	1	3	--	--
35	--	--	--	--	1	11	--	--	1	14	--	--
36	--	--	--	--	1	8	--	--	1	4	--	--
37	--	--	--	--	1	9	--	--	1	8	--	--
38	--	--	--	--	1	9	--	--	1	3	--	--
39	--	--	--	--	1	9	--	--	1	3	--	--
40	--	--	--	--	1	10	--	--	1	9	--	--
41	--	--	--	--	1	4	--	--	1	4	--	--
42	--	--	--	--	1	6	--	--	1	14	--	--
43	--	--	--	--	1	2	--	--	1	3	--	--
44	--	--	--	--	1	5	--	--	1	5	--	--
45	--	--	--	--	1	7	--	--	1	3	--	--
46	--	--	--	--	1	3	--	--	1	6	--	--
47	--	--	--	--	1	3	--	--	1	8	--	--
47A	--	--	--	--	1	4	--	--	1	4	--	--
48	--	--	--	--	1	4	--	--	1	13	--	--
50	--	--	--	--	1	6	--	--	1	5	--	--
51	--	--	--	--	1	6	--	--	1	12	--	--
52	--	--	--	--	1	8	--	--	1	10	--	--
53	--	--	--	--	1	3	--	--	1	4	--	--
54	--	--	--	--	1	4	--	--	1	5	--	--
55	--	--	--	--	1	4	--	--	1	4	--	--
56	--	--	--	--	1	4	--	--	1	4	--	--
57	--	--	--	--	1	6	--	--	1	7	--	--
58	--	--	--	--	1	1	--	--	1	11	--	--
59	--	--	--	--	1	6	--	--	1	8	--	--
60	--	--	--	--	1	4	--	--	1	14	--	--
61	--	--	--	--	1	2	--	--	1	1	--	--
62	--	--	--	--	1	2	--	--	1	5	--	--
63	--	--	--	--	1	2	--	--	1	9	--	--
64	--	--	--	--	1	2	--	--	1	12	--	--
65	--	--	--	--	1	22	--	--	1	36	--	--
66	--	--	--	--	1	1	--	--	1	10	--	--
67	--	--	--	--	1	5	--	--	1	13	--	--
68	--	--	--	--	1	3	--	--	1	14	--	--
69	--	--	--	--	1	4	--	--	1	10	--	--
70	--	--	--	--	1	3	--	--	1	12	--	--
71	--	--	--	--	1	8	--	--	1	11	--	--
72	--	--	--	--	1	3	--	--	1	5	--	--
74	--	--	--	--	1	4	--	--	1	11	--	--
75	--	--	--	--	1	3	--	--	1	17	--	--
76	--	--	--	--	1	4	--	--	1	5	--	--
77	8	2	2	6	9	10	0	23	9	32	6	160
78	8	3	0	10	8	26	3	93	8	37	10	100
145	--	--	--	--	1	5	--	--	1	7	--	--
146	--	--	--	--	1	4	--	--	1	2	--	--
147	--	--	--	--	1	3	--	--	1	6	--	--
148	--	--	--	--	1	3	--	--	1	3	--	--
149	8	3	0	7	8	9	4	30	8	15	0	35
150	--	--	--	--	1	3	--	--	1	4	--	--
151	--	--	--	--	--	--	--	--	--	--	--	--
152	--	--	--	--	1	5	--	--	1	5	--	--
153	--	--	--	--	1	3	--	--	1	0	--	--
154	--	--	--	--	1	4	--	--	1	5	--	--
155	--	--	--	--	1	5	--	--	1	6	--	--
156	--	--	--	--	1	5	--	--	1	7	--	--
157	--	--	--	--	1	3	--	--	1	3	--	--
158	8	1	0	5	9	6	0	25	9	14	6	33
159	--	--	--	--	1	4	--	--	1	0	--	--

Appendix 7. (Cont.)

	MERCURY				SELENIUM				ZINC			
SITE NUMBER	NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX	NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX	NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX
31	1	.1	--	--	1	1	--	--	1	40	--	--
32	1	.2	--	--	1	0	--	--	1	30	--	--
33	1	.1	--	--	1	0	--	--	1	30	--	--
34	1	.1	--	--	1	0	--	--	1	140	--	--
35	2	.3	.1	.5	1	0	--	--	1	140	--	--
36	1	.1	--	--	1	0	--	--	1	40	--	--
37	1	.1	--	--	1	0	--	--	1	100	--	--
38	9	.3	0	.9	2	2	1	3	8	59	8	150
39	1	.1	--	--	1	1	--	--	1	50	--	--
40	1	.2	--	--	1	1	--	--	1	40	--	--
41	1	.1	--	--	1	0	--	--	1	20	--	--
42	1	.2	--	--	1	1	--	--	1	30	--	--
43	1	.1	--	--	1	0	--	--	1	10	--	--
44	1	.2	--	--	1	1	--	--	1	20	--	--
45	1	.4	--	--	1	0	--	--	1	30	--	--
46	1	.1	--	--	1	0	--	--	1	20	--	--
47	1	.1	--	--	1	0	--	--	1	10	--	--
47A	1	.1	--	--	1	0	--	--	1	20	--	--
48	1	.1	--	--	1	0	--	--	1	30	--	--
50	1	.1	--	--	1	1	--	--	1	10	--	--
51	1	.1	--	--	1	1	--	--	1	20	--	--
52	1	.1	--	--	1	0	--	--	1	60	--	--
53	1	.1	--	--	1	0	--	--	1	10	--	--
54	1	.1	--	--	1	0	--	--	1	20	--	--
55	3	3.4	.1	6.1	1	0	--	--	1	10	--	--
56	1	.1	--	--	1	0	--	--	1	20	--	--
57	1	.1	--	--	1	0	--	--	1	20	--	--
58	1	.1	--	--	1	0	--	--	1	20	--	--
59	2	.4	.3	.5	1	1	--	--	1	20	--	--
60	1	.1	--	--	1	0	--	--	1	30	--	--
61	1	.1	--	--	1	0	--	--	1	10	--	--
62	1	.1	--	--	1	0	--	--	1	20	--	--
63	1	.1	--	--	1	0	--	--	1	20	--	--
64	1	.1	--	--	1	0	--	--	1	10	--	--
65	1	.1	--	--	1	0	--	--	1	80	--	--
66	1	.1	--	--	1	0	--	--	1	10	--	--
67	1	.1	--	--	1	0	--	--	1	20	20	20
68	1	.1	--	--	1	0	--	--	1	10	--	--
69	1	.1	--	--	1	0	--	--	1	10	--	--
70	1	.1	--	--	1	0	--	--	1	20	--	--
71	1	.1	--	--	1	0	--	--	1	20	--	--
72	1	.5	--	--	1	0	--	--	1	20	--	--
74	1	.1	--	--	1	0	--	--	1	10	--	--
75	1	.1	--	--	1	0	--	--	1	10	--	--
76	1	.1	--	--	1	0	--	--	1	10	--	--
77	9	.1	0	.3	2	2	0	4	9	38	0	110
78	8	.4	0	.8	1	2	--	--	8	62	7	130
145	1	3.5	--	--	1	0	--	--	1	50	--	--
146	1	2.9	--	--	1	1	--	--	1	10	--	--
147	1	3.3	--	--	1	0	--	--	1	10	--	--
148	1	5.3	--	--	1	0	--	--	1	20	--	--
149	9	.4	0	2.3	1	0	--	--	9	29	6	60
150	1	.8	--	--	1	0	--	--	1	20	--	--
151	1	1.3	--	--	1	0	--	--	1	50	--	--
152	1	1.3	--	--	1	0	--	--	1	10	--	--
153	1	1.3	--	--	1	0	--	--	1	20	--	--
154	1	1.5	--	--	1	0	--	--	1	20	--	--
155	1	1.4	--	--	1	1	--	--	1	40	--	--
156	1	.8	--	--	1	0	--	--	1	30	--	--
157	1	1.3	--	--	1	0	--	--	1	30	--	--
158	9	.8	0	2.8	1	0	--	--	9	46	10	140
159	1	1.4	--	--	1	0	--	--	1	20	--	--

☆U.S. GOVERNMENT PRINTING OFFICE: 1981/752-401