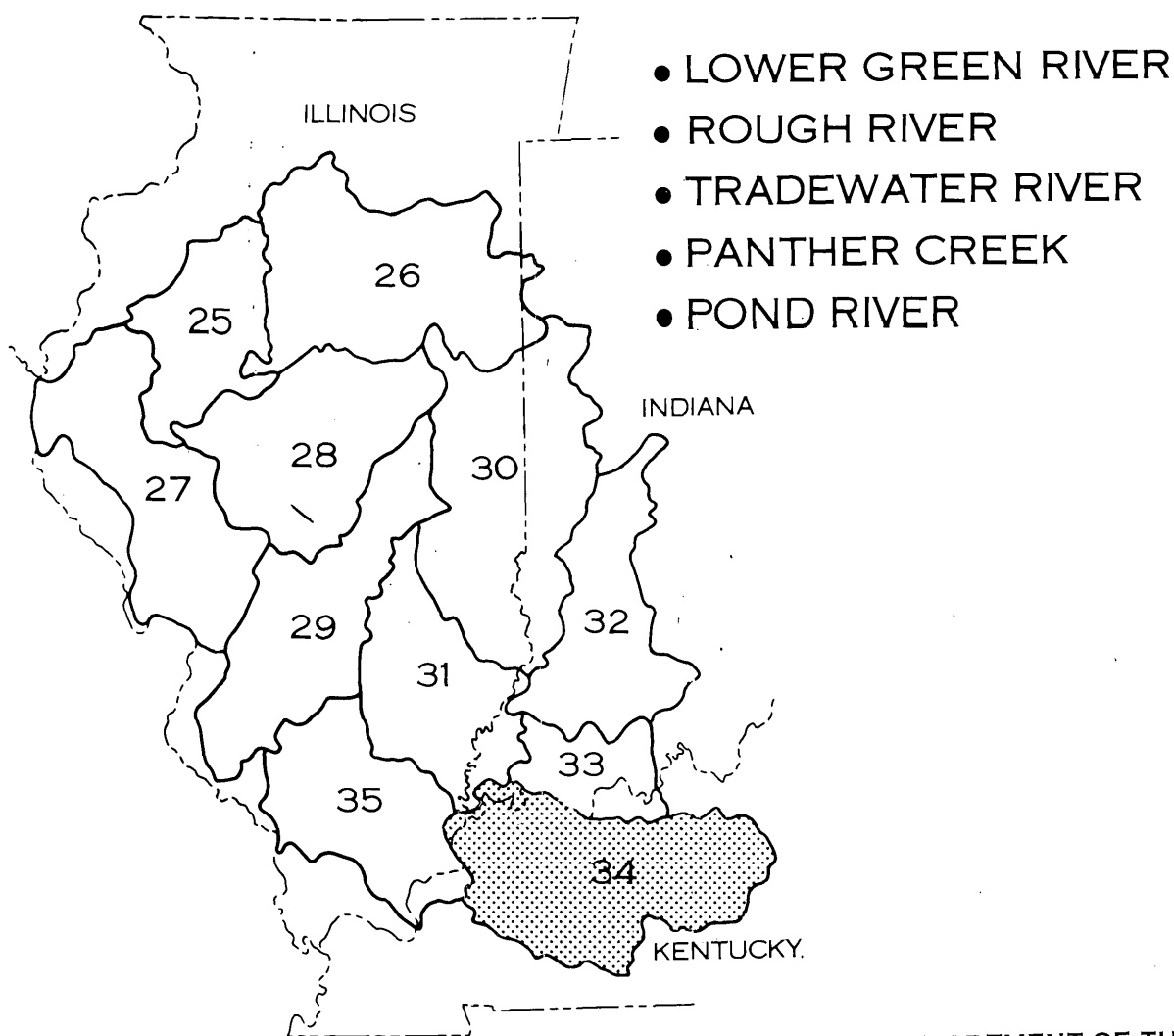


HYDROLOGY OF AREA 34, EASTERN REGION, INTERIOR COAL PROVINCE, KENTUCKY, INDIANA AND ILLINOIS



UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER RESOURCES INVESTIGATIONS
OPEN FILE REPORT 82-638

HYDROLOGY OF AREA 34, EASTERN REGION, INTERIOR COAL PROVINCE, KENTUCKY, INDIANA AND ILLINOIS

BY
FERDINAND QUINONES, KAREN L. YORK, AND
RAYMOND O. PLEBUCH

U.S. GEOLOGICAL SURVEY

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LOUISVILLE, KENTUCKY
MAY, 1983

UNITED STATES DEPARTMENT OF THE INTERIOR

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

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

Multiply	By	To obtain
inches (in)	25.40	millimeters (mm)
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 (lb)	453.6	grams (g)
tons (tons)	0.9072	metric tons (t)
tons per square mile per year [(tons/mi ²)/yr]	0.3503	metric tons per square kilometer per year [(t/km ²)/a]

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

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Abstract

This report was prepared to aid mine owners, operators, and consulting engineers in the preparation and appraisal of mine permits. The report provides information for Area 34 which is in the southeastern part of the Interior Coal Province, Eastern Region. Area 34 includes the entire Western Coal Field in Kentucky and consists of parts of the Green and Ohio River basins and the entire Pond, Tradewater, Mud, and Rough River basins; an area of 6,592 square miles.

Most of Area 34 is underlain by sandstones, siltstones and shales of Pennsylvanian age. The more important coal beds are in the Tradewater and Carbondale Formations.

Coal production during 1978 was 39.5 million tons, of which 68 percent was from Muhlenberg, Ohio, and Hopkins Counties. Coal mining in Area 34 is gradually shifting from surface mining to underground mining because the more accessible surface coal beds have been stripped.

Water-use data for 1975 show that domestic and public use accounted for 54 percent of the water withdrawals. Most of the water is obtained from streams and lakes; however, in the valley of the Ohio River, ground water is used for industrial and municipal supplies.

Hydrologic data show that on unregulated streams the flow varies seasonally with precipitation

and evapotranspiration. These seasonal variations are minimized by the regulated flows of the Green, Nolin, and Rough Rivers. Most of the streams draining less than 100 square miles go dry occasionally. Flooding, however, is frequently severe due to intense precipitation and the flat lowlands. The magnitude and frequency of floods are affected by the drainage area, topography and geology.

The chemical and physical characteristics of the waters in some streams draining Area 34 are affected by mining activities. In streams draining mined areas, dissolved solids such as sulfate, iron, manganese, and some trace constituents, are higher than in streams not affected by mine drainage. Lowering of the pH in water receiving mine drainage is evident in some streams. Acid waters are common in streams draining intensely-mined areas in the upper Tradewater and Pond Rivers, and Cypress Creek.

Ground water occurs in sandstones and in unconsolidated deposits of sand and gravel in the valleys of the Ohio River and its tributaries. Ground-water levels fluctuate seasonally in response to precipitation and evapotranspiration. Well yields may be inadequate for domestic use or as much as 4,000 gallons per minute. Generally, water quality is characterized by great variability with no readily discernible areal patterns.

1.0 INTRODUCTION

1.1 Objective

Area 34 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" (hereafter called the Act) was signed into law as Public Law 95-87, August 3, 1977. This need is partially met by this report which broadly characterizes the hydrology of Area 34, a large subbasin in the Western Coal Field area of Kentucky (figure 1.1-1). This report is one of a series that covers the coal provinces nationwide. The report contains a brief text with an accompanying map, chart, graph, or other illustration for each of a number of water-resources related topics. The summation of the topical discussion provides a description of the hydrology of Area 34.

The hydrologic information presented, or availa-

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

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



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

Figure 1.1-1 Location of Area 34.

1.0 INTRODUCTION

1.1 Objective

1.0 INTRODUCTION--Continued

1.2 Project Area

Area Located in the Southeastern Part of the Eastern Region, Interior Coal Province

Area 34 includes 6,592 square miles mostly in the Green and Tradewater river basins in northwestern Kentucky.

The Eastern Region of the Interior Coal Province is divided into 11 hydrologic reporting areas (see cover). The divisions are based on drainage boundaries, location of basins, size, hydrology, and mining activities. Several drainage basins or parts of basins are combined to form one reporting area (fig. 1.2-1). Area 34 is in the southeastern part of the Eastern Region, Interior Coal Province, in northwestern Kentucky and southwestern Indiana. Its area is 6,592 square miles.

Area 34 includes all of the Western Coal Field physiographic region within the State of Kentucky as well as a part of the Mississippian Plateau region (fig. 1.2-2). A small part of the area is within the Ohio River valley in the State of Indiana. The area includes all or parts of Barren, Breckinridge, Butler, Caldwell, Christian, Crittenden, Daviess, Edmondson, Grayson, Hancock, Hardin, Hart, Henderson, Hopkins, Larue, Logan, McLean, Muhlenberg, Ohio, Todd, Union, Warren, and Webster Counties in Kentucky, and part of Posey and Vanderburgh Counties in Indiana.

All of Area 34 is drained by the Ohio River and its tributaries. The Green River is the principal tributary, and it drains about 80 percent of the area. Major tributaries to the Green River within the area are the Pond, Mud, Nolin, and Rough Rivers, and Cypress and Panther Creeks. The Barren River joins the Green River within the study area, but its entire drainage basin is outside of the study area. The Tradewater River is the only sizable stream in the study area which is not a tributary to the Green River. It flows directly into the Ohio River.

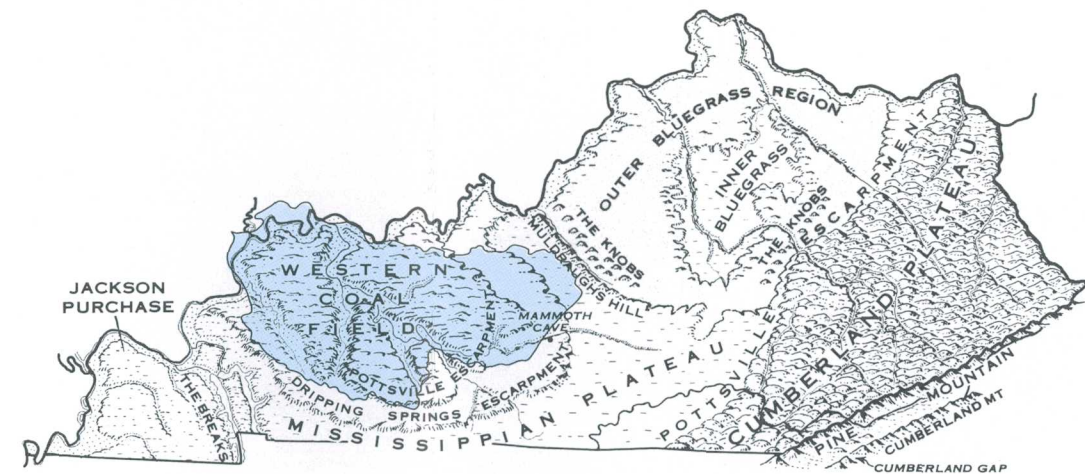
The principal cities in Area 34 are Owensboro (54,000), Henderson (23,000), Madisonville (17,000) and Elizabethtown (13,000). The total population of the area (1980 census) was about 380,000. Population increases related to coal-mining activities were evident in Muhlenberg and Ohio counties, the principal coal-producing counties in the area. Increases in population in these counties from 1970-80 averaged about 16 percent.



EXPLANATION

 Drainage basin boundary

Figure 1.2-1 Drainage basins.



From Kentucky Geological Survey

Figure 1.2-2 Physiographic diagram of Kentucky.

1.0 INTRODUCTION--Continued

1.3 Hydrologic Problems Related to Surface Mining

Hydrologic Environment can be Adversely Altered by Surface Mining

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

Surface mining may drastically alter the environment of undisturbed areas and may cause detrimental changes. 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 (fig. 1.3-1).

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.

A common and troublesome water-quality problem is acid-mine drainage. Mining accelerates weathering of newly exposed iron-bearing minerals (pyrite and marcasite, for example) and this produces sulfuric acid that accelerates dissolution of minerals. Water draining such a mined area generally has low pH (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 corrosive-

ness of water, limitations on the use of water for domestic and industrial purposes, and reduction of recreational uses and aesthetic values.

The adverse effects are most apparent on and near the mine site. Receiving streams for surface and seepage drainage at the mine site usually are 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. 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 (fig. 1.3-3).

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, distance to the mine site, time elapsed since mining began, and time elapsed since reclamation 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.



Figure 1.3-1 The man in the left photo stands at the edge of a reclaimed spoil bank in western Kentucky. Just beyond is land mined before reclamation laws were passed in Kentucky. In great contrast to the scene on the left, the right photo shows western Kentucky land that was stripped, reshaped, and is ready for seeding.

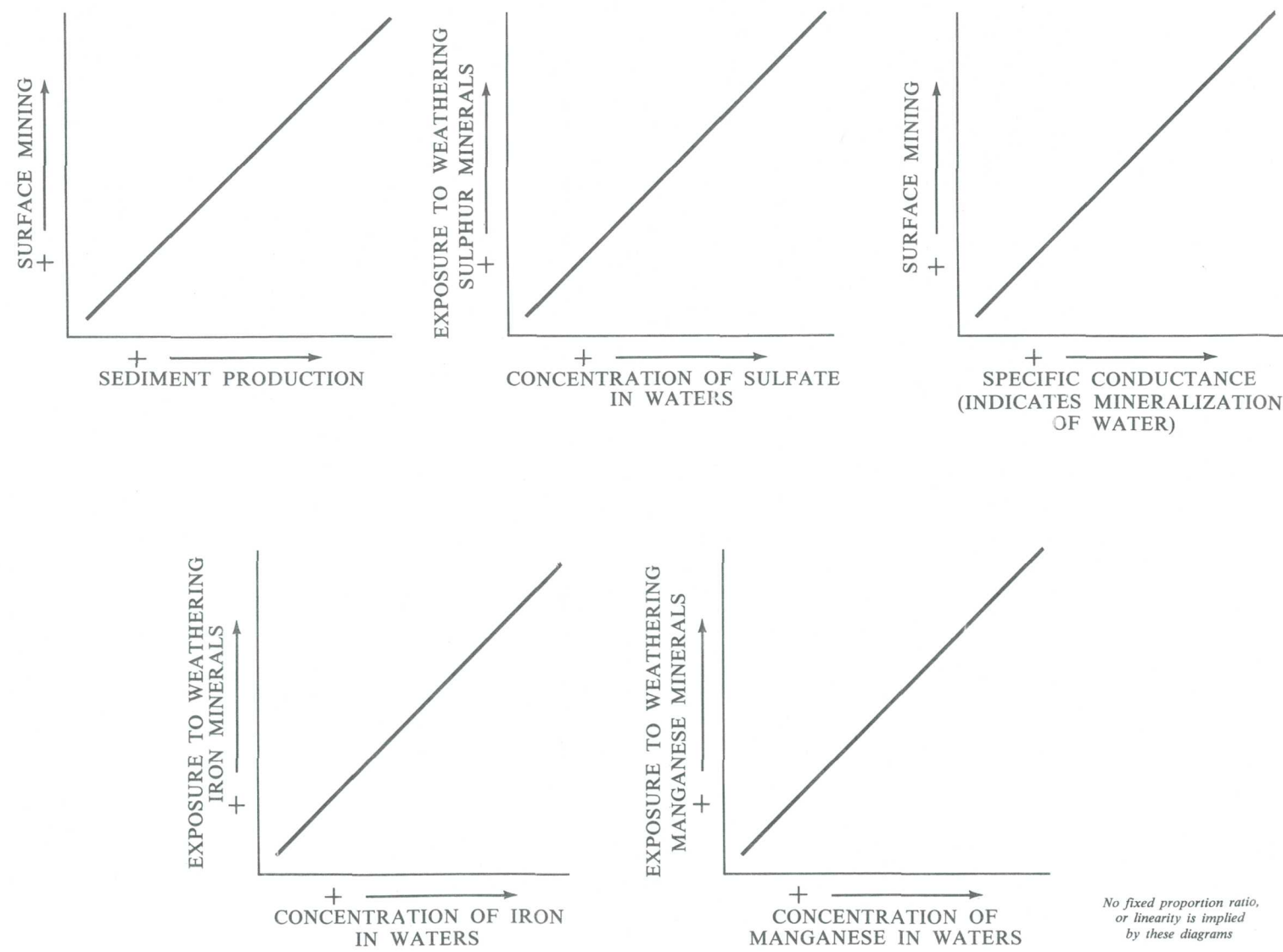


Figure 1.3-2 Example relations and trends that can result from surface coal mining.

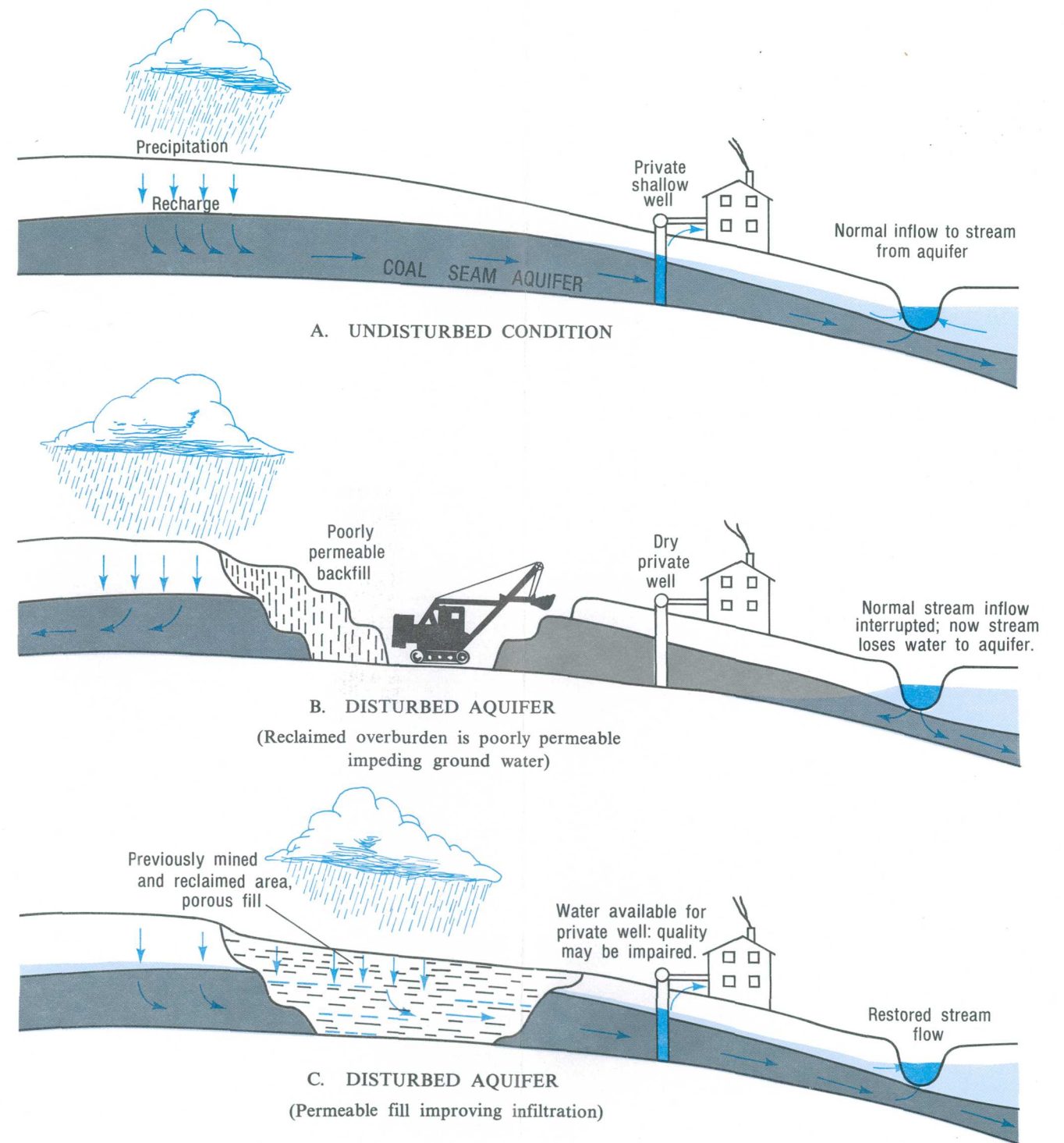


Figure 1.3-3 Sketch of possible impact of mining aquifers.

2.0 GENERAL INFORMATION

2.1 Land Forms

Area Within Shawnee Section of Interior Low Plateau

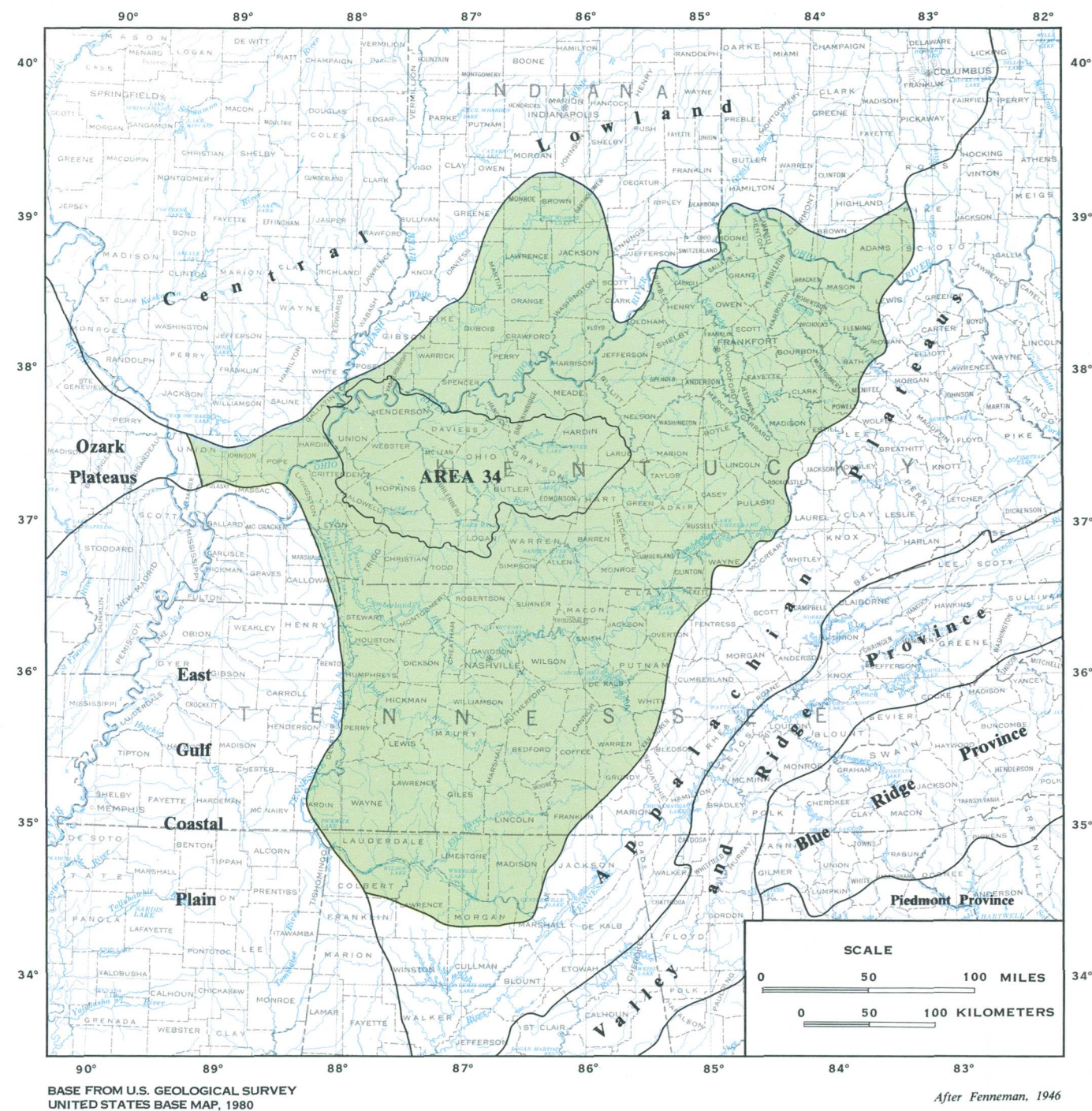
Rolling uplands and belts of hills comprise most of Area 34.

Area 34 is physiographically within the Shawnee Section of the Interior Low Plateau province (Fenneman, 1938) (fig. 2.1-1); geologically it is in the southeastern part of the Eastern Interior (or Illinois) basin. The Western Coal Field of Kentucky comprises most of the area.

Most of the land is a rolling upland 400 to 550 feet above sea level in the area underlain by Pennsylvanian age rocks. The periphery of the Pennsylvanian rock outcrop, is a belt of rugged hills (Pottsville Escarpment), with altitudes more than 800 feet, that generally coincides with the outcrop of the lowermost Pennsylvanian rocks (fig. 2.1-2). Another belt of hills lies in an east-west direction along the Rough Creek

fault system which extends along the northern part of the area. The valleys of the major streams and their tributaries are commonly wide and filled with thick lake deposits of glacial age, causing some pre-glacial hills to stand as "islands", surrounded by fine-grained lake deposits.

Lower Mississippian limestones underlie a karst plain in the area surrounding the Pennsylvanian rocks in Kentucky. The more sandy and silty upper Mississippian rocks generally form a belt of rugged hills (Dripping Springs Escarpment) encircling the Western Coal Field.



EXPLANATION

Interior Low Plateaus

Figure 2.1-1 Location of Area 34 within Interior Low Plateau Province.

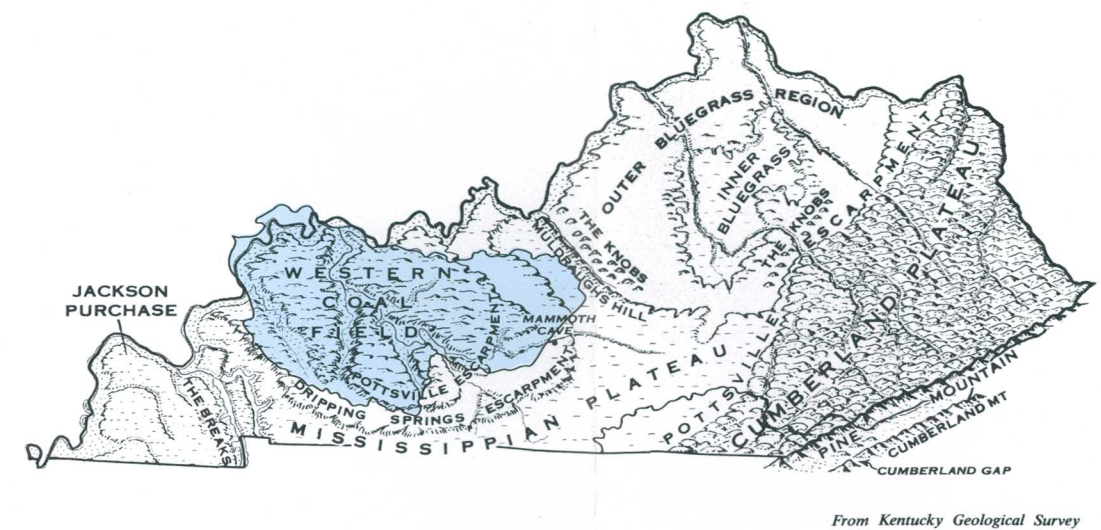


Figure 2.1-2 Physiographic diagram of Kentucky.

2.0 GENERAL INFORMATION--Continued

2.2 Geology

Types of Rock Extremely Variable in Area

Pennsylvanian shale, siltstone, and sandstone underlie most of Area 34. They contain valuable coal beds. Mississippian limestone and sandstone underlie the southern and eastern margin of Area 34.

Area 34 is predominately an area of Pennsylvanian rocks (fig. 2.2-1). Older Mississippian rocks are exposed in the southern and eastern margins of the area.

The Pennsylvanian rocks consist of carbonaceous siltstone and clay shale, generally medium-to-fine-grained sandstone, coal beds, and marine and non-marine limestone in beds less than 6 to more than 18 feet thick. Sandstone and siltstone constitute about 55 to 80 percent of the Pennsylvanian section, and silty shale and clay shale the remainder. Limestone beds constitute only about five percent of the section, but are an important tool for coal exploration and stratigraphic analysis (Rice and others, 1979, p. F22).

The Pennsylvanian strata are divided into four formations, in ascending order: the Caseyville, Tradewater, Carbondale, and Sturgis Formations (fig. 2.2-2). The Sturgis was formerly called the Lisman and Henshaw Formations (Kehn, 1973). In the eastern part of Area 34 only the Caseyville, or Caseyville and Tradewater Formations undifferentiated, is present (fig. 2.2-3).

Unlike geologic formations in most areas, the Pennsylvanian rocks above the Caseyville are not identified by their continuity of type of sediments or by similarity of composition; rather their boundaries are placed at regionally persistent coal beds. Even the Caseyville, generally a pebbly sandstone, may be shale or siltstone and unrecognizable from the overlying Tradewater Formation in large areas.

Sandstones are the best aquifers in the Pennsylvanian rocks. Because the sandstones were commonly deposited in deltaic conditions, they are laterally discontinuous and generally not traceable for more than several miles at most. In some areas, such as near Henderson, a sandstone aquifer may have local continuity. However, even here the formation thickens and thins abruptly and may be absent in places. Harvey (1956) mapped some shallow Pennsylvanian

aquifers in the Henderson area. Davis and others (1974) have mapped several deep sandstone aquifers in the central part of Area 34.

Mississippian limestone underlies the easternmost part of Area 34. Sinkholes, springs, and caves are common. In the southern and eastern part of the area, adjacent to the Pennsylvanian outcrop, Mississippian sandstones, shales, and limestone crop out. Generally, they are poor aquifers. Devonian age black shale is present at shallow depth in the eastern part of Larue County.

Because Area 34 is the southern part of a large structural basin centered in Illinois, the rocks dip gently inward from the margin of the area, except in the northwest part (fig. 2.2-4). The gentle dip and outcrop pattern are offset by faulting at many places.

The deepest part of the basin, not affected by severe faulting, is in Hopkins County where about 1,900 feet of Pennsylvanian deposits are present. However, in a downdropped fault block in Union County, 3,258 feet of Pennsylvanian strata have been drilled (Smith and Smith, 1967). Fossil fusulinids of Early Permian age occur in the uppermost part of the strata here (Rice and others, 1979, p. F21).

Glacial outwash deposits of sand and gravel, overlain by fine-grained silt and clay, occupy the valley of the Ohio River. The outwash is an excellent aquifer. Tributary stream valleys are filled with lake deposits of Pleistocene and Holocene age. These silt and clay lake deposits, with some sand and gravel near the base, are not generally large-yielding aquifers.

Detailed 7.5 minute geologic quadrangle maps are available for Area 34. These may be obtained from the U.S. Geological Survey, Branch of Distribution, 1200 South Eads Street, Arlington, VA 22202, or the Kentucky Geological Survey, 311 Breckinridge Hall, University of Kentucky, Lexington, KY 40506.

2.0 GENERAL INFORMATION--Continued

2.3 Surface Drainage

The Green River and its Tributaries Drain 80 Percent of Area 34

Nolin, Barren, Mud, and Pond Rivers, and Panther Creek are the main tributary streams of the Green River in Area 34. Tradewater River and Highland and Canoe Creeks are other principal streams in Area 34.

The Green River and its tributary streams drain 5,292 mi² or 80 percent of Area 34 (fig. 2.3-1). The remainder of the study area is drained by the Tradewater River, and Highland and Canoe Creeks. Figure 2.3-2 shows the generalized surface-drainage system and drainage areas of streams in the area.

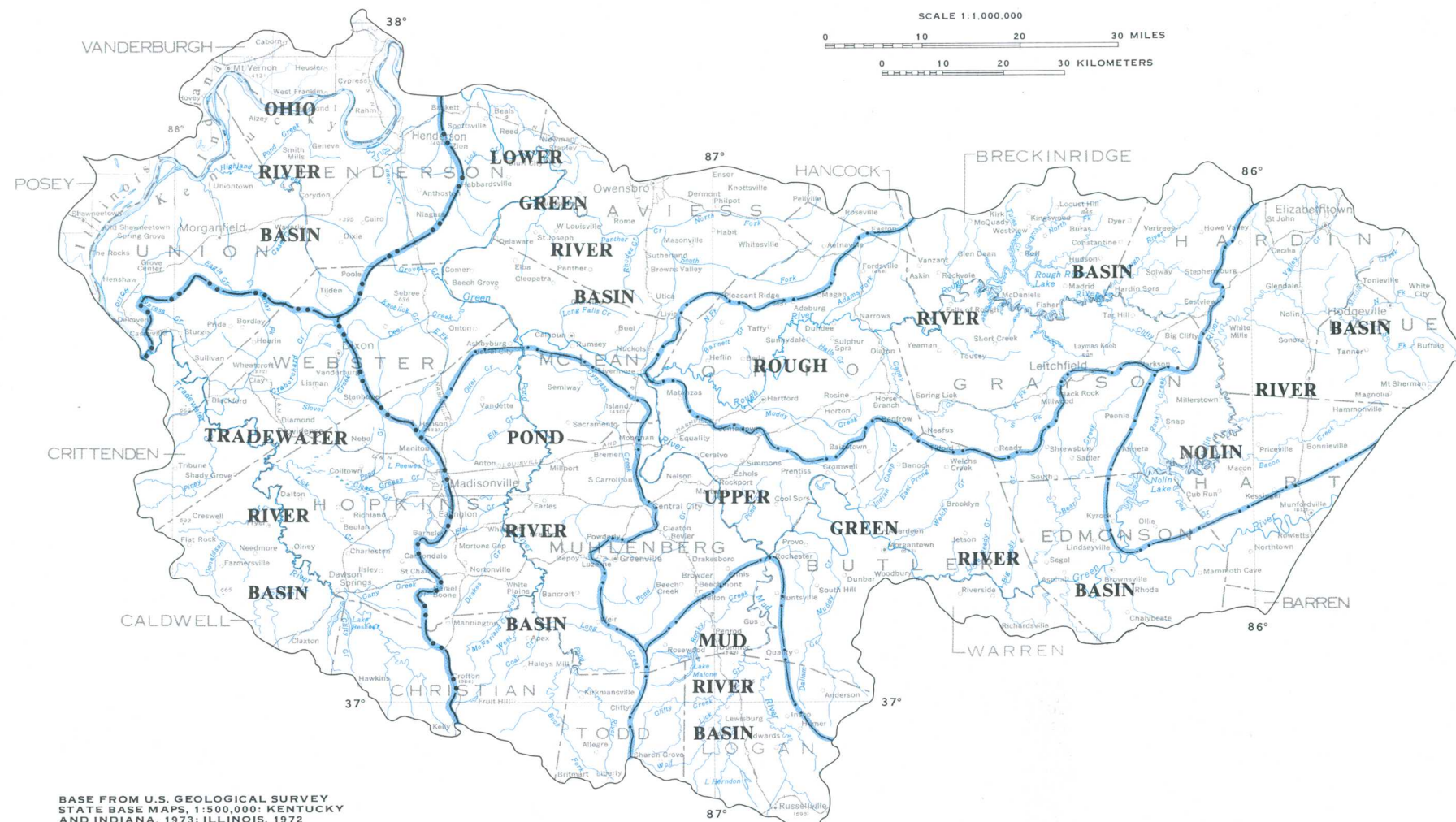
Streamflow in the Green River is regulated by two navigation dams in its lower reaches, by one multiple-purpose dam in its headwaters in Taylor County, and by three multiple-purpose dams in the headwaters of its major tributaries. Total capacities of the reservoirs at spillway level are shown below.

The Green River enters Area 34 near Munfordville. It is joined by numerous small tributary

streams and by the following major tributary streams, in successive downstream order: Nolin, Barren (not in study area), Mud, Rough, and Pond Rivers, and Panther Creek. The Green River flows into the Ohio River near Henderson, nearly 225 river miles downstream from the eastern edge of the area.

The Tradewater river is the only major stream in Area 34 that is not a tributary to the Green River. It flows into the Ohio River near Caseyville, between Crittenden and Union Counties. The flat lands of the northwestern part of Area 34 are drained by Highland and Canoe Creeks which drain directly into the Ohio River.

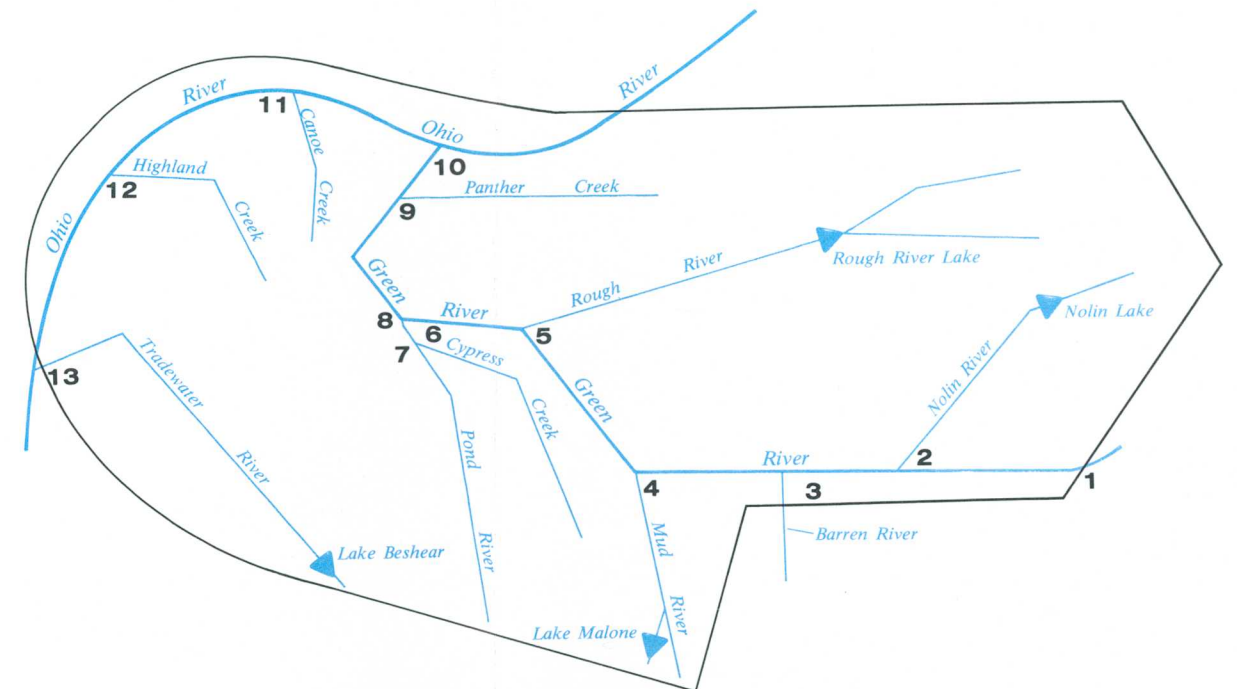
Reservoir	River	Capacity in acre-feet
Green River Lake (east of study area)	Green	723,200
Nolin Lake	Nolin	609,400
Barren River Lake (south of study area)	Barren	815,200
Rough River Lake	Rough	334,400



EXPLANATION

- Drainage basin boundary
- Drainage subbasin boundary

Figure 2.3-1 Principal streams.



EXPLANATION

River basin or boundary and drainage area	Drainage area In square miles	River basin or boundary and drainage area	Drainage area In square miles
1 Green River at Munfordville	1673	8 Pond River at mouth	799
2 Nolin River at mouth	727	9 Panther Creek at mouth	374
3 Barren River at mouth	2264	10 Green River at mouth	9230
4 Mud River at mouth	375	11 Canoe Creek at mouth	120
5 Rough River at mouth	1081	12 Highland Creek at mouth	237
6 Cypress Creek at mouth	153	13 Tradewater River at mouth	943
7 Pond River at junction with Cypress Creek	645		

Modified from U.S. Department of Agriculture, 1975

Figure 2.3-2 Generalized surface-drainage system.

2.0 GENERAL INFORMATION--Continued
2.4 Land Use

Crops and Forests are the Main Land Uses

Cropland accounts for about 40 percent of the land use, followed by forests with about 35 percent and pastureland with about 16 percent.

The land in Area 34 varies from hilly country in the east and south to the flat floodplains of the Ohio River in the north. The land in the central and northern part of the area is rich and suitable for agriculture. Corn, soybeans, hay, and tobacco are the principal crops, accounting for about 40 percent of the land use (fig. 2.4-1). Most of the farmland is concentrated in Breckinridge, Grayson, Daviess, McLean, and Henderson Counties (Table 2.4-1).

Forests are the second most important land use, occupying about 35 percent of Area 34. Most of the

hilly country in the eastern half of the area, in parts of Breckinridge, Ohio, Butler, Muhlenberg, and Hopkins Counties, is forested. The forests are a rich blend of species of oak, pine, birch, basswood, cypress, and others. Timber harvesting is widespread. Strip-mining has reduced the forested acreage in the area.

Pastureland accounts for about 16 percent of the land use and is concentrated in the eastern part of Area 34.

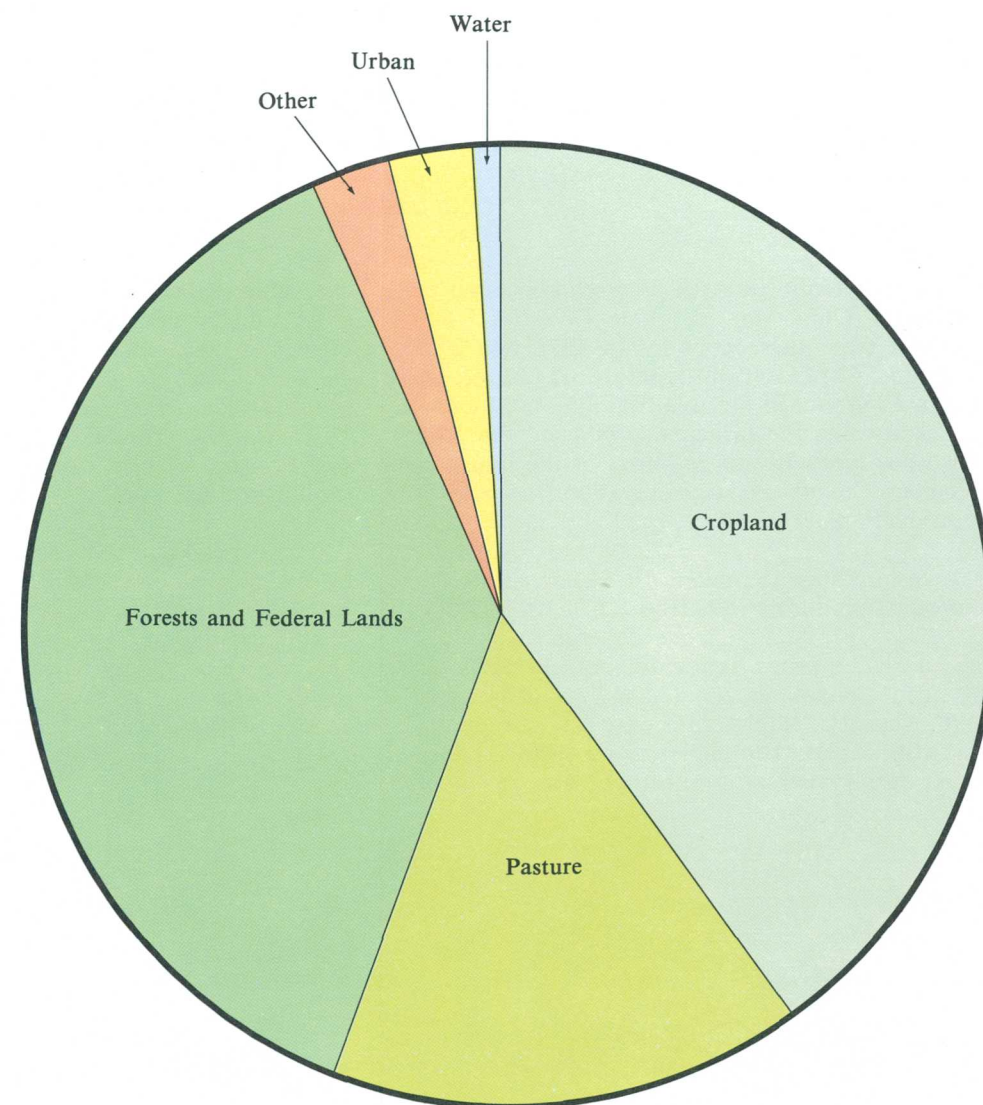


Figure 2.4-1 Percentages of principal land uses.

Table 2.4-1 Land use in 1967.

COUNTY ¹	CROP LAND	PASTURE	FOREST	OTHER ² LAND	FEDERALLY ³ OWNED NON-CROPLAND	URBAN AND BUILT-UP	WATER AREAS	TOTAL	
BRECKINRIDGE	114 31.5	67.8 18.8	160 44.3	9.2 2.5	0 0	8.2 2.3	2.1 .6	361 100	Acres, in thousands Percent
BUTLER	75 26.4	50 17.6	136 47.8	16.3 5.7	0 0	4.9 1.7	2.0 .7	284 100	
CALDWELL	111 48.5	11.8 5.2	79.2 34.6	6.4 2.8	0 0	19.1 8.3	1.4 .6	229 100	
CHRISTIAN	221 47.6	72.2 15.6	131 28.2	3.9 0.8	19 4.1	14.0 3.0	2.8 0.6	464 100	
CRITTENDEN	62.4 26.7	67.7 28.9	87.8 37.5	9.0 3.8	0 0	5.1 2.2	1.6 .7	234 100	
DAVIESS	172 58.1	32.5 11.0	66.2 22.4	10.0 3.4	0 0	14.3 4.8	.7 .2	296 100	
EDMONSON	36.4 18.7	35.5 18.2	67.8 34.8	6.6 3.4	43.9 22.5	3.8 1.9	.7 .4	195 100	
GRAYSON	95.4 29.1	100 30.5	116 35.4	3.5 1.1	6.7 2.0	5.7 1.7	.6 .2	328 100	
HARDIN	161 40.1	40 10.2	100 25.4	8.3 2.1	68 17.3	14.3 3.6	2.3 .6	394 100	
HART	77.9 28.6	61.6 22.6	108 39.7	10.3 3.8	7.8 2.9	5.2 1.9	1.5 .6	272 100	
HENDERSON	157 56.7	33.7 12.2	61.3 22.1	12.1 4.4	2.0 .7	9.2 3.3	1.9 .7	277 100	
HOPKINS	114 32.3	30 8.5	160 45.3	35.2 10.0	0 0	12.9 3.7	1.3 .4	353 100	
LARUE	63 38.0	36.3 21.9	55.7 33.6	6.9 4.2	.2 .1	3.6 2.2	.5 .3	166 100	
LOGAN	150 41.6	80.2 22.2	110 30.5	10.5 2.9	0 0	9.3 2.6	.9 .2	361 100	
MCLEAN	94.3 57.1	14.4 8.7	45.5 27.6	4.9 3.0	0 0	4.2 2.5	1.2 .7	165 100	
MUHLENBERG	99.5 32.3	38.2 12.4	141 45.8	22.1 7.2	0 0	6.3 2.0	.9 .3	308 100	
OHIO	117 30.7	42.7 11.2	196 51.4	12 3.1	0 0	12.4 3.3	1 .3	381 100	
TODD	146 60.6	24.6 10.2	61.7 25.6	3.3 1.4	0 0	5.3 2.2	.2 .1	241 100	
UNION	106 48.6	35 16.1	37.6 17.2	4.8 2.2	26.8 12.3	6.2 2.8	1.2 .6	218 100	
WEBSTER	111 51.2	20.8 9.6	67.8 31.2	6.1 2.8	4.0 1.8	5.6 2.6	1.3 .6	217 100	
TOTALS ⁴	2284 40.0	895 15.6	1989 34.6	201 3.5	178 3.1	170 3.0	26 .5	5744 100	

1 Includes total area of county.

2 Non-Federally owned rural land not classified as cropland, pasture, forest woodland, or urban and built-up areas.

3 Land use status not given in source; considered by authors to be mostly forest land in Mammoth Cave National Park, Edmonson and Hart Counties, and Military bases with varied land use in other counties.

4 Because of rounding off numbers, sums of the land uses do not agree with the total land area.

Land use data from State Conservation Needs Inventory Committee (1970).

2.0 GENERAL INFORMATION--Continued
2.5 Coal Production

Coal Production in 1979 was 39.5 Million Tons

Muhlenberg County was the principal coal producer in Area 34 in 1978 with 10.8 million tons. Surface mining accounted for 54 percent of the total coal production.

Coal production in Area 34 is concentrated in Muhlenberg, Ohio, and Hopkins Counties. The production from these counties in 1978 was 27.0 million tons, 68 percent of the total coal production of 39.5 million tons in the area (fig. 2.5-1). Muhlenberg County was the principal producer with 10.8 million tons from 20 mines. Most of the mines in Muhlenberg County are large operations resulting in high production per mine.

Surface mining accounted for 54 percent of the coal production during 1978 (fig. 2.5-2). In Muhlenberg County production from underground mines exceeded surface production until about 1958. After 1958, surface mining accelerated and reached a peak in 1970, when 21.5 million tons were produced in the county (fig. 2.5-3). Production from surface mines declined steadily thereafter, mostly because the more

accessible surface coal beds had been stripped. Underground production decreased slowly from 1958 through 1966, but increased sharply between 1967-68. Underground production has not increased significantly thereafter. The extreme decline from 1976 to 1978 reflects the additional effects of a workers strike which closed most of the mines. A similar trend is typical of other counties in Area 34.

Coal production in Area 34 declined from its peak of 53.0 million tons in 1975 to 39.5 million tons in 1978 due to soft markets. The stripping of the more accessible surface coal beds will probably cause an increase in underground mining of extensive reserves. The total recoverable reserves (surface and underground) were estimated in 1977 to be more than 7,450 million tons (Harvey, 1977).

2.0 GENERAL INFORMATION--Continued

2.6 Soils

Soils are Derived from Silt, Clay, Sandstone, and Shale

Most of the soils in Area 34 are silt or clay and are formed on shale, sandstone, and siltstone. Most soils in the areas where coal is mined are part of the Zanesville-Frontdorf association.

The general characteristics of the principal soil associations in Area 34 are shown in table 2.6-1. About 50 percent of the soils are those of the Zanesville-Frontdorf association (fig. 2.6-1). Most of the coal deposits underlie the areas with this association. These deep and moderately deep, well-drained soils were formed in residuum from acid shales, siltstones, and sandstones with most areas having a thin loess mantle on hilly uplands and undulating broad ridge tops. The soils have slopes ranging from 2 to 50 percent. Most of the steep slopes are in the eastern part of Area 34, in the Rough River basin, and in the upper Tradewater River basin.

The second most common soil association in Area 34 is the Caneyville-Zanesville-Frontdorf. These soils occur along a belt in the upper Mud and Green River basins. The soils are very similar to the Zanesville-Frontdorf association, except that calcareous material is more abundant. Most of the area where

these soils are present does not contain significant coal deposits.

The soils along Panther Creek, Tradewater, Pond, and the lower Green and Rough Rivers are mostly loamy or clayey alluvium on flood plains and terraces (Belknap-Karnak association). These are deep, poorly drained, nearly flat-lying soils used extensively for agriculture.

The Grenada-Loring and Memphis-Loring soil associations extend across a large area in the lower Tradewater and Green Rivers. These soils are on upland plains as well as terraces on shale, sandstone, siltstone, and alluvium.

Eleven other soil associations within Area 34 occur in terrain as diverse as flat alluvial plains to karst hills (shown as mixed soils in fig. 2.6-1). There are no significant surface-mineable coal deposits in these areas.

2.0 GENERAL INFORMATION--Continued

2.7 Precipitation

Annual Precipitation Averages 46 Inches

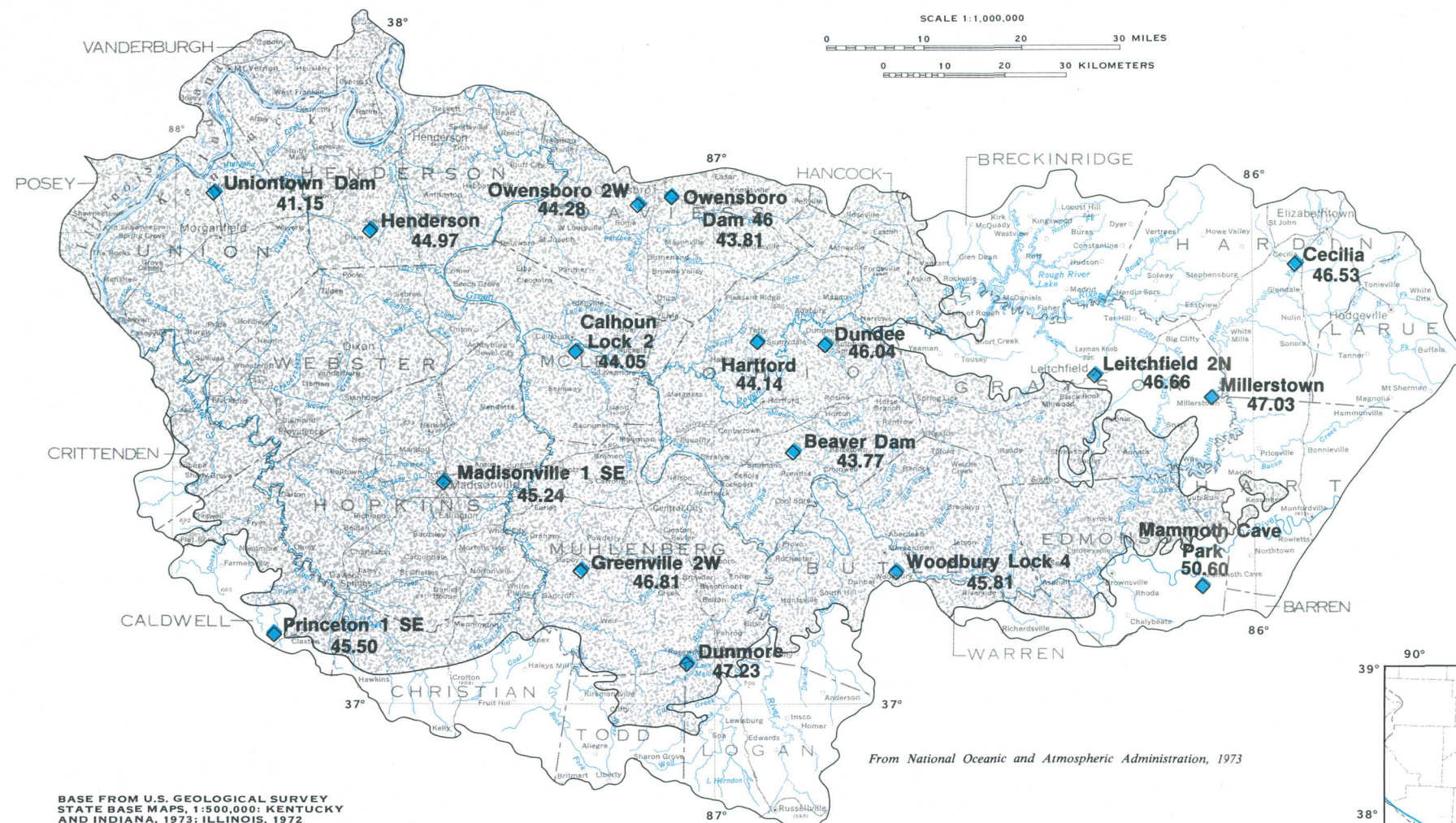
Average precipitation at 18 long-term stations in Area 34 ranges from 41 to 51 inches per year. The 24-hour 10-year frequency rainfall averages 4.8 inches.

Precipitation throughout the State of Kentucky is produced mainly by low-pressure westerly systems entraining southerly winds bearing moist, warm air from the Gulf of Mexico. Periodically, high pressure systems from the north also cause rain, snow, and sleet. Annual average precipitation across the State ranges from 40 to 50 inches per year, although locally it may reach 54 inches (fig. 2.7-1). Average annual precipitation varies as much as 30 percent from one year to the next.

Average annual precipitation in Area 34 is about 46 inches, but ranges from 41 to 51 inches, decreasing from south to north (fig. 2.7-2). Precipitation occurs

about 120 days per year. Monthly normal averages (1941-70 period) from August through October are from 20 to 35 percent less than monthly precipitation during the remainder of the year (fig. 2.7-3). Snow and sleet average 20 inches per year, although up to 50 inches may occur during extreme years, contributing significantly to spring runoff.

Intense storms are fairly uniform throughout Area 34 and are usually produced by southerly storm systems that cover large areas. The 24-hour 10-year frequency rainfall throughout the area averages about 4.8 inches (fig. 2.7-4).



EXPLANATION

- ◆ Dunmore Long-term precipitation station
- 47.23 Average annual precipitation, in inches
- Coal-bearing rocks

Figure 2.7-2 Average annual precipitation at long term stations, 1941-70.

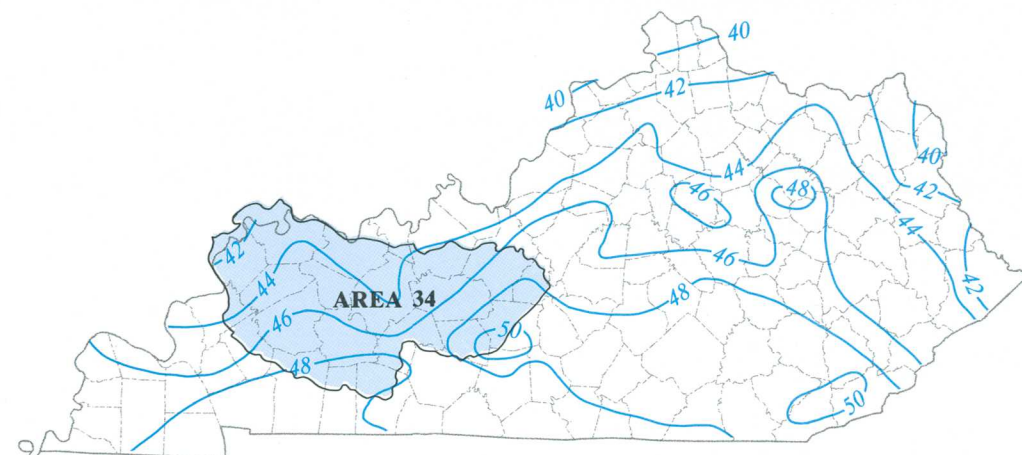


Figure 2.7-1 Average annual precipitation for Kentucky.

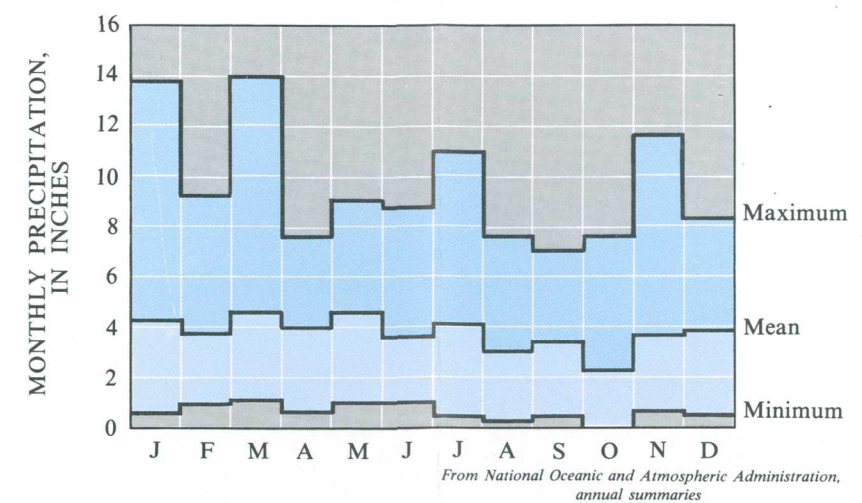
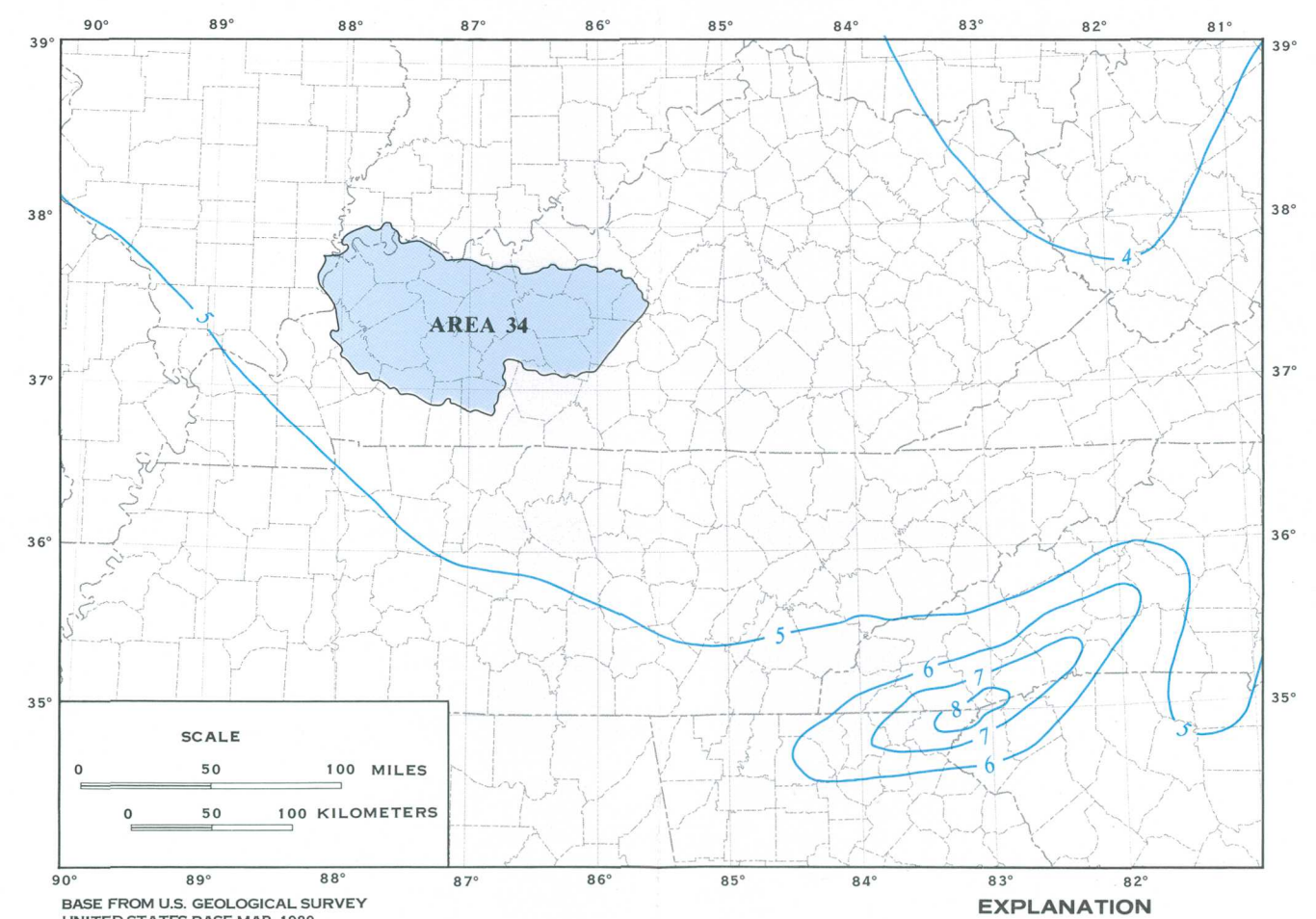


Figure 2.7-3 Monthly normal precipitation at Beaver Dam, Ohio County, Kentucky, 1941-70.



EXPLANATION

- 6 — 10-year, 24-hour rainfall frequency, in inches

Rainfall frequency from U.S. Department of Commerce, 1961

Figure 2.7-4 Rainfall frequency.

3.0 WATER USE

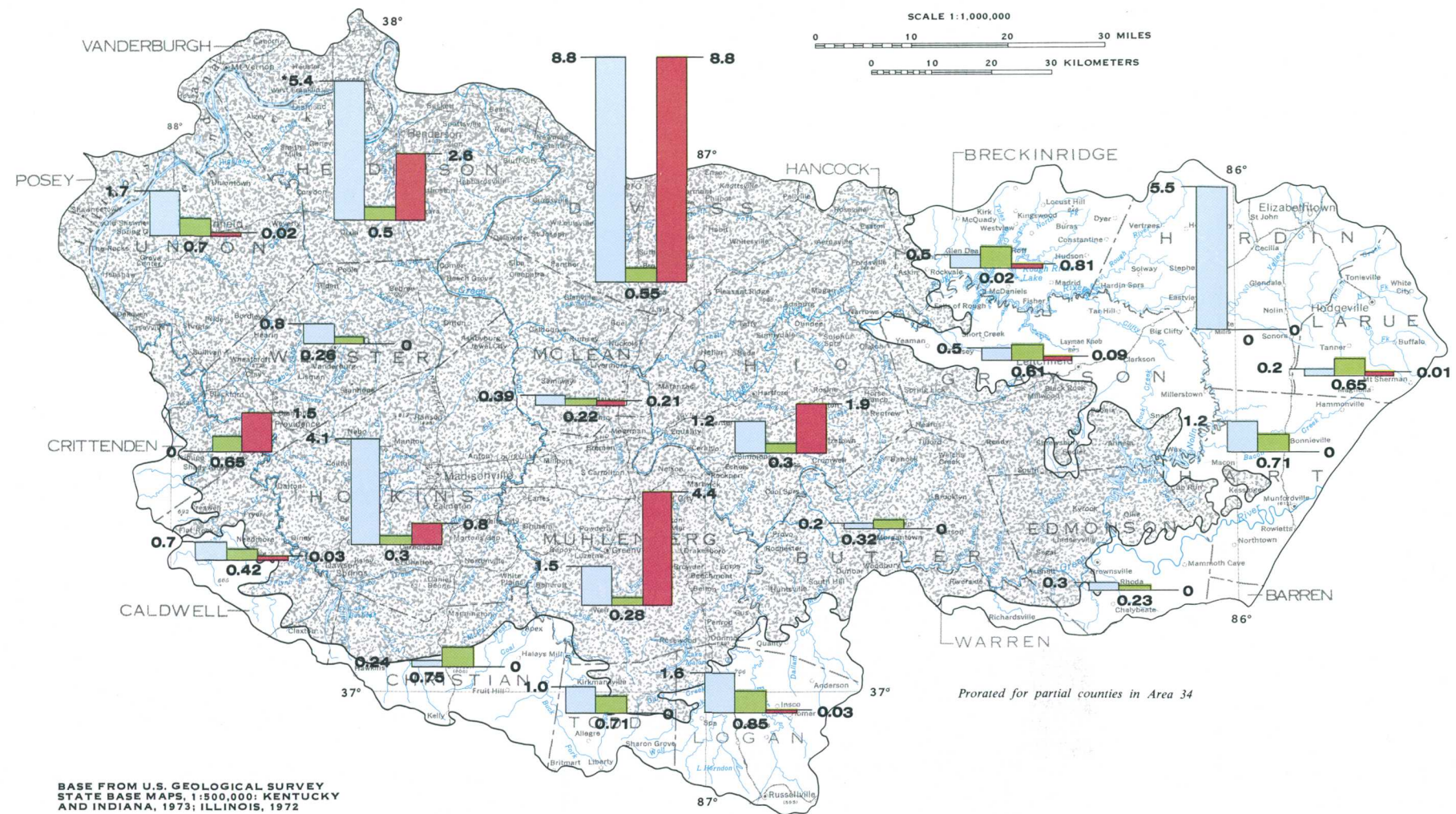
Domestic Use was 54 Percent of the Total in 1975

Water use in Area 34 during 1975 was about 66 million gallons per day. Domestic use accounted for 54 percent, followed by industrial uses with 31 percent, and agricultural uses with 15 percent.

During 1975 a total of 66 Mgal/d of water was withdrawn for domestic, industrial, and agricultural uses in Area 34. Domestic uses accounted for 54 percent (35.8 Mgal/d) of the total water use. Most of the domestic withdrawals were concentrated in Daviess, Henderson, Hopkins, and Hardin Counties, where the largest towns and cities in the area are located (fig. 3.0-1). Industrial uses, about 31 percent (20.4 Mgal/d) of the total (fig. 3.0-2), were concentrated in Daviess, Henderson, Muhlenberg, and Ohio Counties. Coal related activities are the principal industrial uses of water in Muhlenberg and Ohio Counties.

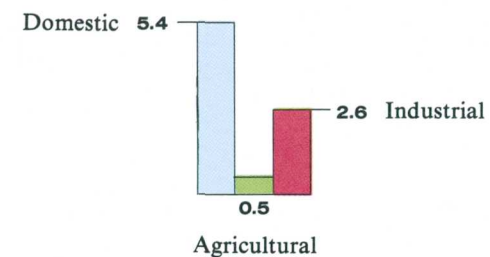
Water-use for agricultural purposes is fairly well distributed throughout Area 34. Corn, soybeans and livestock are the principal agricultural activities in the area, accounting for most of the 9.8 Mgal/d (15 percent) agricultural use.

Most of the water withdrawn in Area 34 is from surface water sources. Owensboro uses about 17.5 Mgal/d of ground water for industrial and domestic uses. In the agricultural areas, limited amounts of ground water are used for irrigation.



EXPLANATION

Water use, in million gallons per day



*Includes 1.7 million gallons per day in Mt. Vernon, Indiana



Figure 3.0-1 Water use in selected counties in 1975.

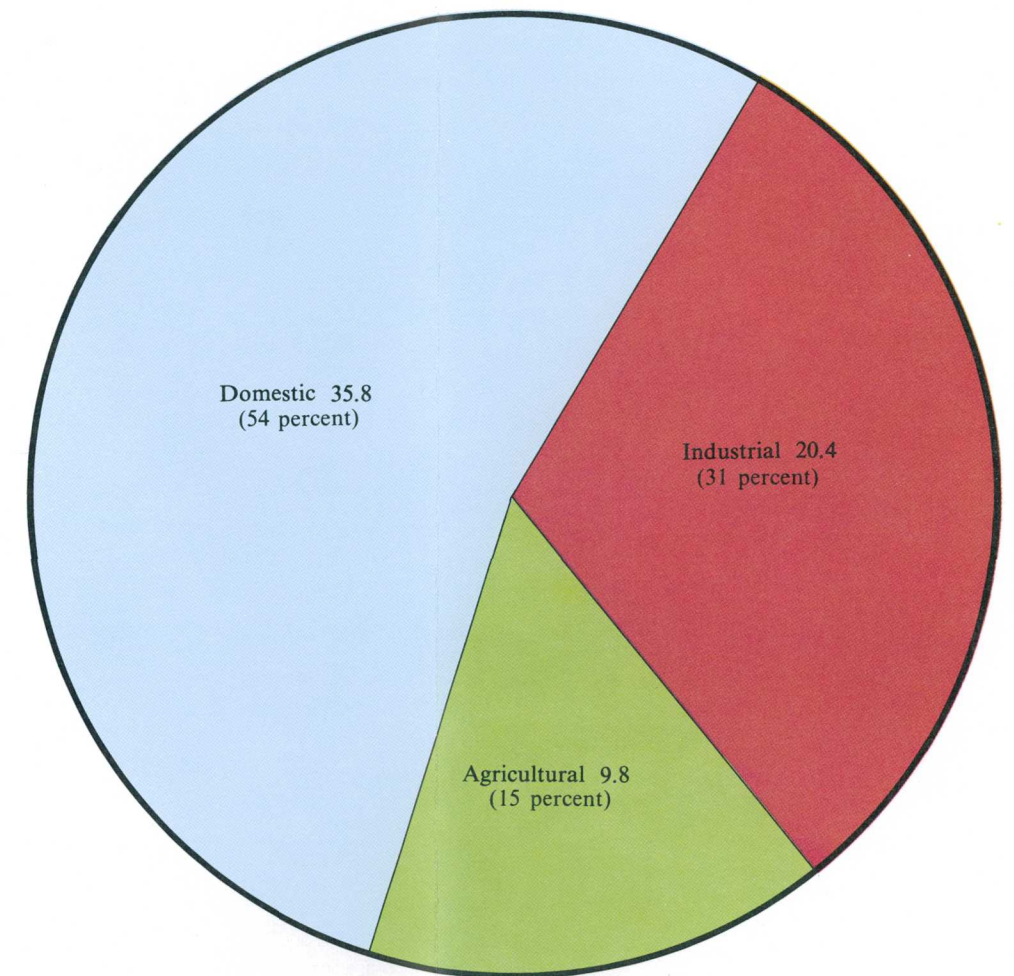


Figure 3.0-2 Water use, in million gallons per day, in 1975.

4.0 HYDROLOGIC DATA SYSTEMS

4.1 Surface Water

Information on Surface Water Available for 170 Sites

The U.S. Geological Survey surface-water data-collection effort in Area 34 was expanded in response to the Surface Mining Control and Reclamation Act of 1977. Information on surface water is now available for 115 active and 55 inactive sites.

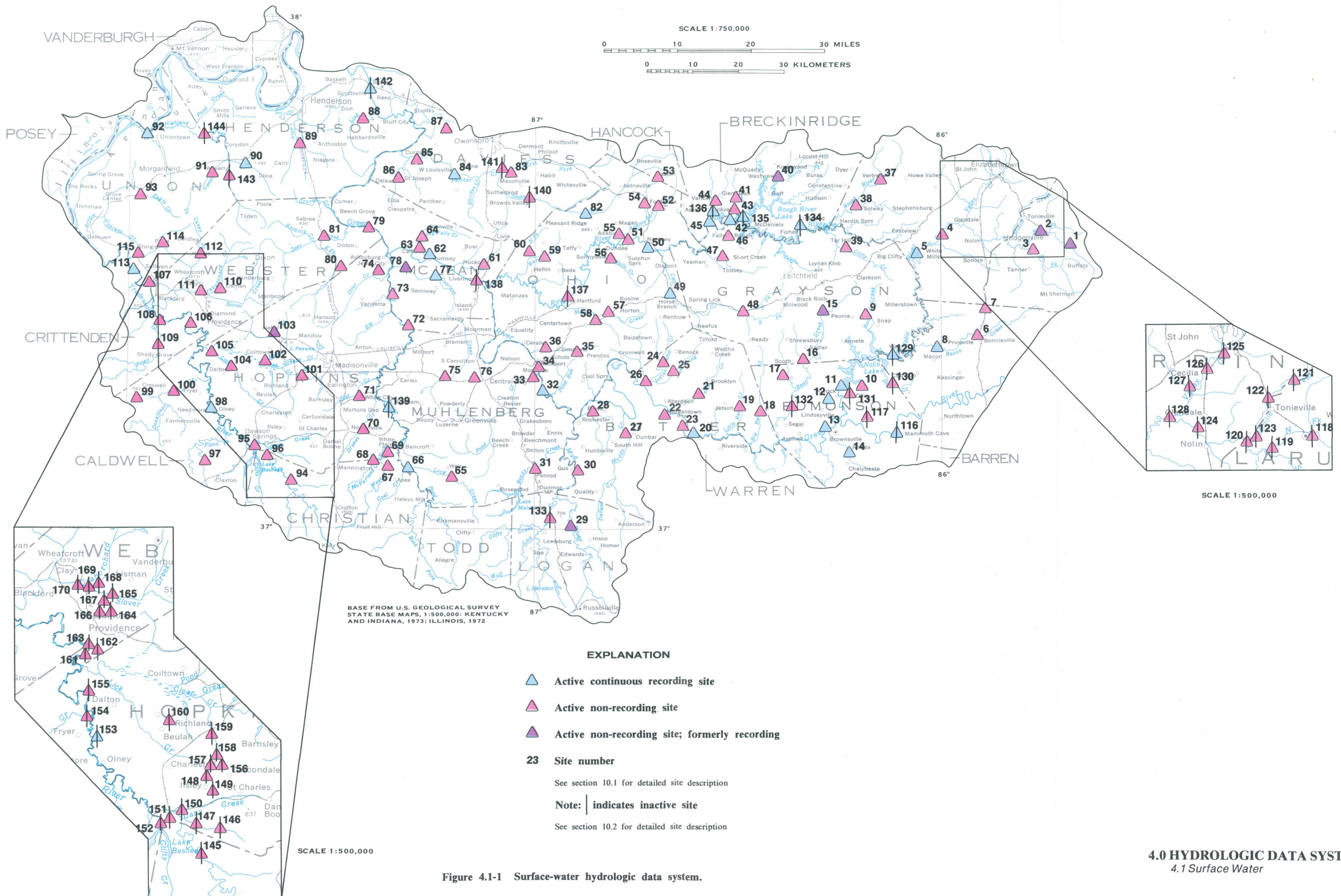
Records of stream stage and flow are valuable data used in analyzing the hydrology of basins and for planning structures and water uses of streams. Various data analysis techniques, such as flow duration curves, flood-frequency relations, and low-flow analyses (to be presented in subsequent sections) rely on a record of stage and discharge relation with time.

At the time of the passage of the Act there were 18 streamflow recording sites, 48 non-recording sites, and one chemical and biological sampling site in Area 34. In 1979, in response to the Act, the data-collection activities were expanded to 115 sites (21 recording and 94 non-recording). The continuous-recording sites, as shown on figure 4.1-1 and in section 10.1, are sites where a continuous record of stream stage and flow is recorded. The non-recording sites are generally on small streams where streamflow measurements are made several times a year (fig. 4.1-1 and section 10.1).

Historical data from inactive sites are useful in various flow analyses in understanding the hydrology of the area. Fifteen inactive recording sites of which six are now active non-recording sites and 46 inactive non-recording sites are shown (fig. 4.1-1 and section 10.2). The historical data, as well as data on active sites, are published in the annual reports "Water

Resources Data for Kentucky." The information is also readily available through the National Water Data Exchange (NAWDEX) as described in section 9.2.

Water-quality data, as well as flow data, are needed to assess existing hydrologic conditions and changes that may result from changing land uses and disturbances. In 1979 the number of water-quality collection sites was also increased (sections 10.1 and 10.2). This expansion of sites took place in two ways: collection on a regular six-week interval of water-quality data at or near 12 selected sites where streamflow was recorded continuously, and collection of water-quality data at 54 supplemental sites on streams where streamflow was not recorded continuously. Streamflows were measured and water samples were collected at the supplemental sites at approximately three-month intervals in order to determine seasonal quality and quantity variations. All water quality collecting was done as simultaneously as possible to provide area-wide water-quality data during a particular flow condition. Surface-water quality data are available from the previously mentioned "Water Resources Data" reports for Kentucky or from NAWDEX.



4.0 HYDROLOGIC DATA SYSTEMS--Continued

4.2 Ground Water

Eighteen Reports Describe Ground-Water Hydrology of the Area

Chemical analyses of ground water are available for most of Area 34. Twenty-four wells monitor ground-water levels and five wells monitor ground-water quality.

Data on ground-water availability and quality have been published in 18 reports that include all of Area 34 (fig. 4.2-1). The reports, both detailed and reconnaissance, show depth of wells, reported or measured water levels, yields of wells, reported or analyzed quality of ground water, data on chemical analyses of ground water, and contain a general discussion of the geology and ground-water hydrology of the report area.

Chemical analyses of water from wells and springs and maps showing their locations in Area 34, and all of Kentucky, have been published by Faust and others (1980). Data from the analyses in Area 34 were used in the summary of ground-water quality in Section 8.0. Table 4.2-1 lists the number of sites for which analyses are available in each county that is within or partially within Area 34. Many of the

analyses have also been published in one of the 18 previously cited reports that describe the area.

Long-term water-level information is currently available from 24 wells in Area 34 (fig. 4.2-2 and section 10.3). These wells provide information on the artesian and water-table aquifers. Five wells (fig. 4.2-2) are sampled periodically, generally annually, for chemical and physical analyses. Data on these wells are listed in section 10.3.

The ground-water data collected during 1980, as well as historical data, are published in the annual report "Water Resources Data for Kentucky". The information is also readily available through the National Water Data Exchange (NAWDEX) as described in section 9.2.

Table 4.2-1 Number of wells and springs for which chemical analyses of ground water are available in counties within or partially within Area 34.

County	No. of sites with chemical analyses	County	No. of sites with chemical analyses
Barren	45	Henderson	125
Breckinridge	61	Hopkins	65
Butler	17	Larue	40
Caldwell	46	Logan	16
Christian	76	McLean	20
Crittende	23	Muhlenberg	46
Davies	90	Ohio	38
Edmonson	38	Todd	13
Grayson	23	Union	42
Hancock	39	Warren	112
Hardin	122	Webster	29
Hart	92	Total	1,222

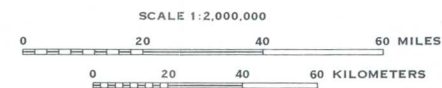
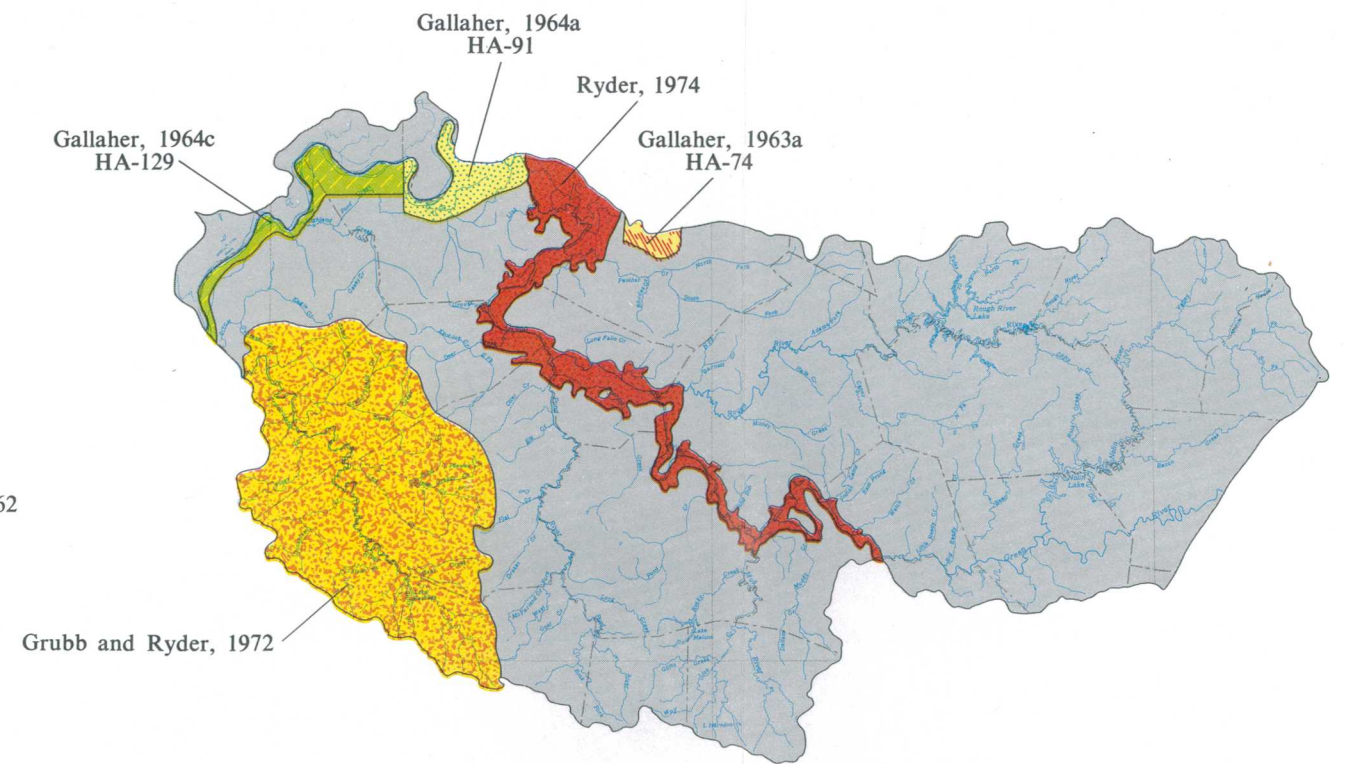
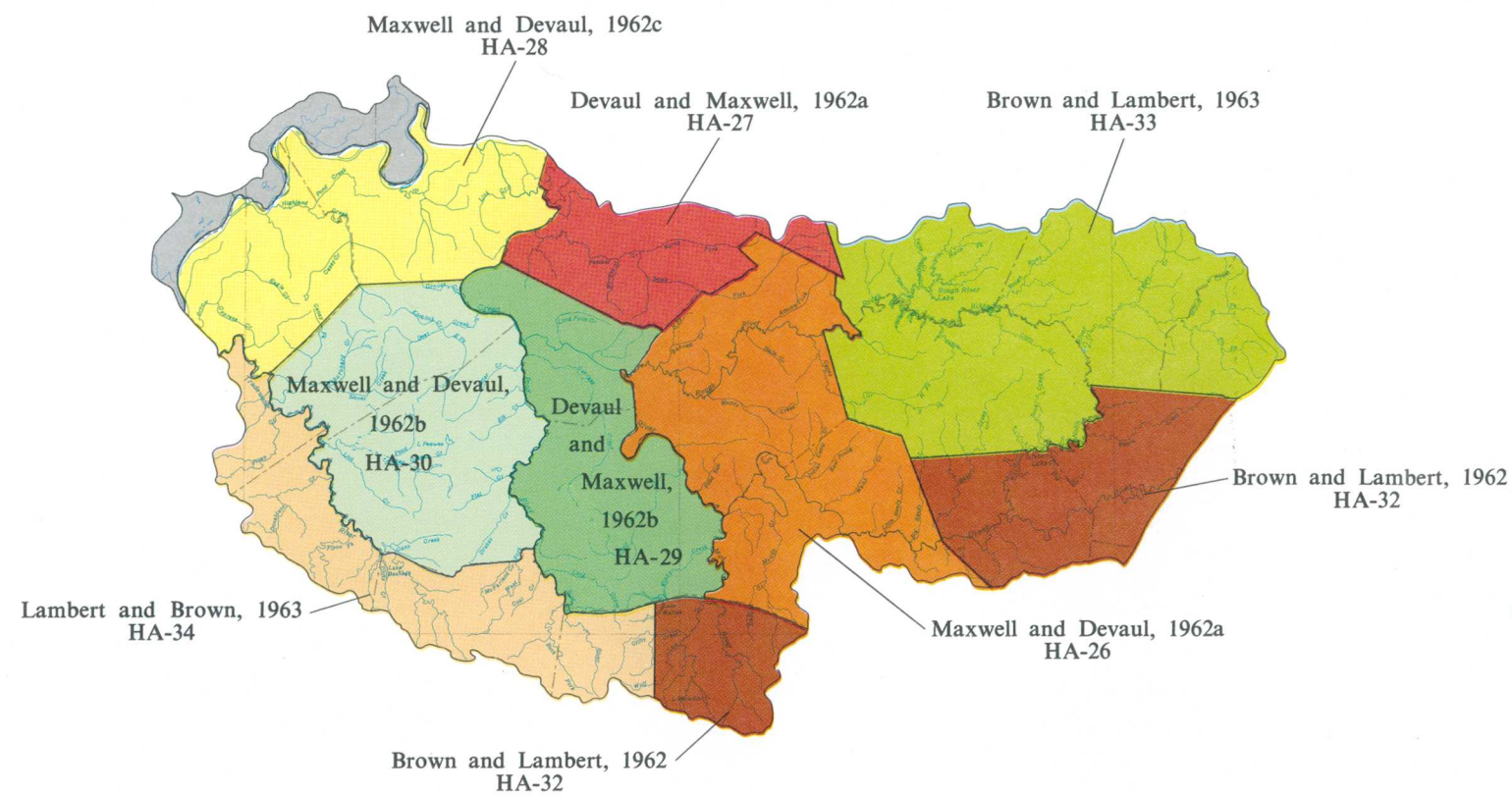
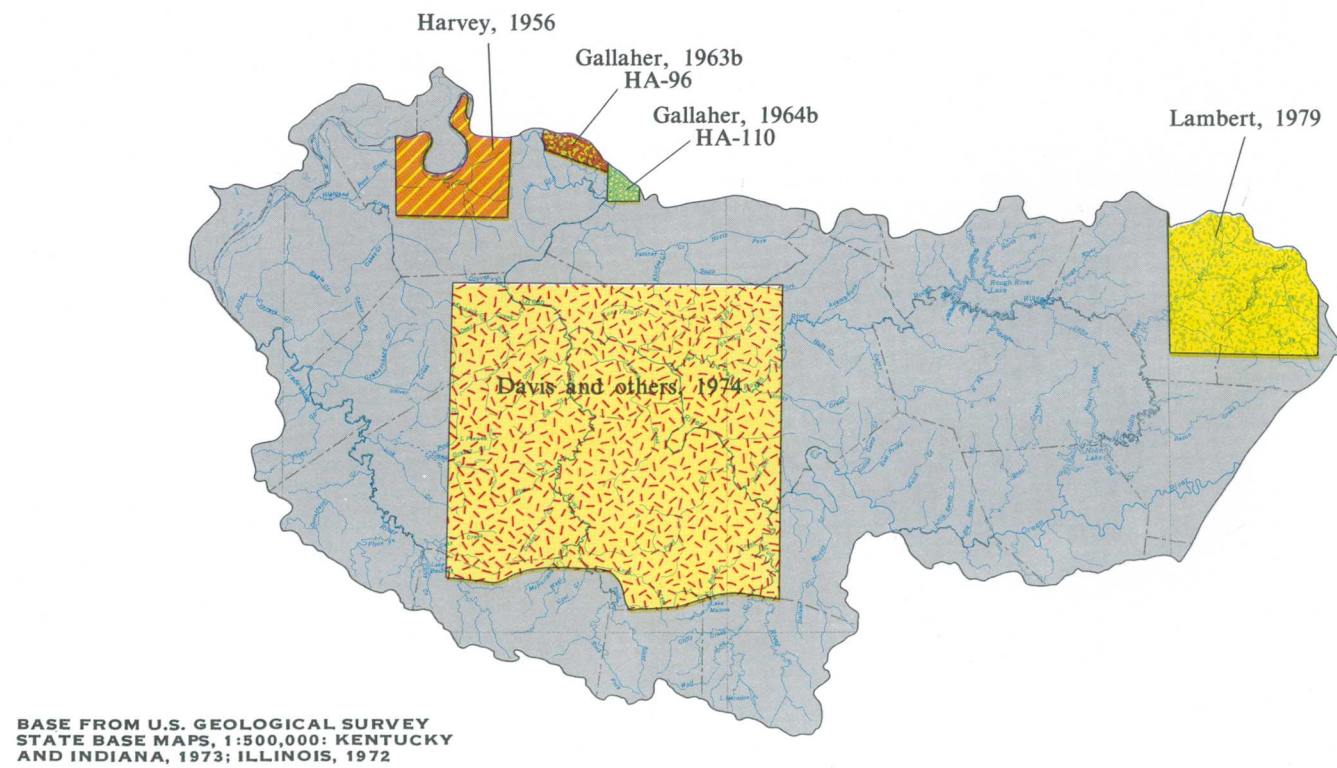


Figure 4.2-1 Reports on ground water -- continued.



BASE FROM U.S. GEOLOGICAL SURVEY
STATE BASE MAPS, 1:500,000: KENTUCKY
AND INDIANA, 1973; ILLINOIS, 1972

Figure 4.2-1 Reports on ground water.

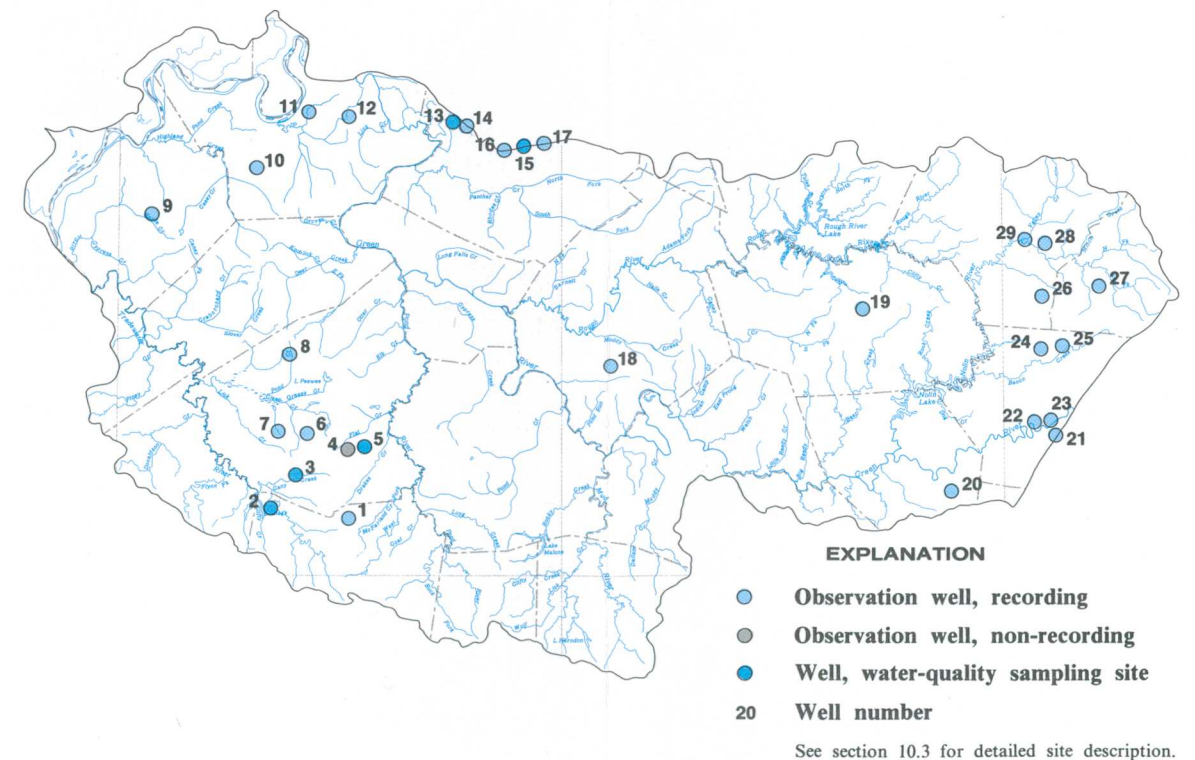


Figure 4.2-2 Location of observation wells.

5.0 SURFACE WATER

5.1 Mean Daily Streamflow

Streamflow Varies Seasonally

Mean daily discharges of unregulated streams fluctuate seasonally with precipitation and evapotranspiration. Streamflows on the Green River and some of its main tributaries are affected by regulation.

Natural streamflow throughout Area 34 varies seasonally with precipitation and evapotranspiration. Flows of the Green, Nolin, Barren, and Rough Rivers are affected by regulation.

The yearly cycle of streamflow is considered to begin in October, normally the month of least precipitation and lowest streamflow (fig. 5.1-1 to 5.1-3). Streamflow usually increases during November as precipitation increases and evapotranspiration decreases. Increasing precipitation, both as rain or snow, augments flows through the winter months. Spring thunderstorms help to maintain a relatively high runoff through May, but at the same time increasing evapotranspiration tends to decrease streamflow. The low-flow season begins around June and extends to about September or early October (fig. 5.1-1 to 5.1-3). Summer thunderstorms temporarily reverse the trend of low streamflow during this season.

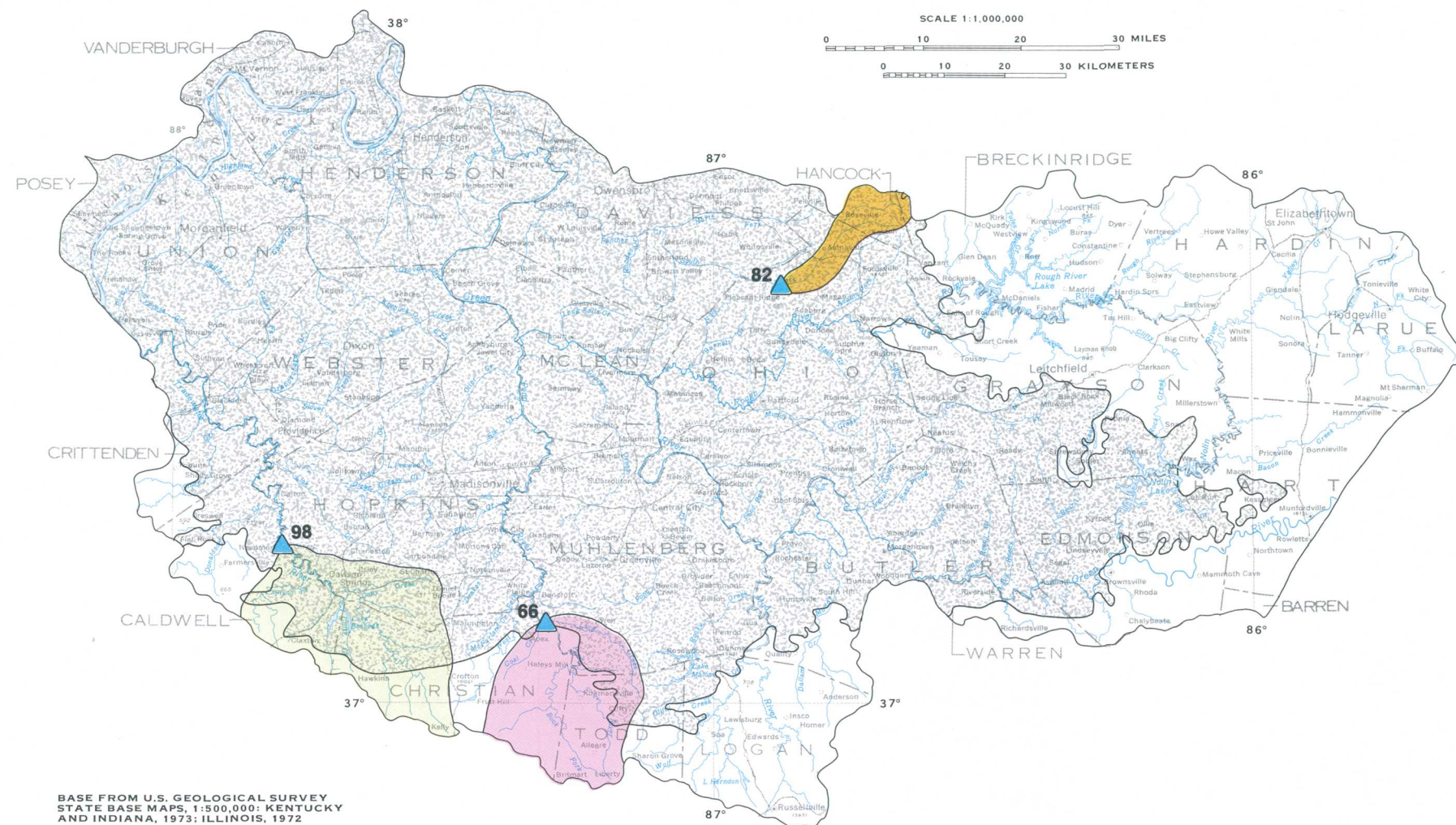
Although the three streams shown in figures 5.1-1 to 5.1-3 flow on rocks of different geologic

ages, the flow patterns for the years 1969-79 are not significantly different. The table below shows the mean discharge in cubic feet per second and in cubic feet per second per square mile for each drainage area. All streams flow in an area of siltstone, sandstone, and shales, but the mean discharge of South Fork of Panther Creek near Whitesville, in an unmined area, is greater per square mile than the mean discharge of Tradewater River at Olney, draining an intensively strip-mined area, or the Pond River near Apex draining an unmined area of pre-Pennsylvanian rocks. The reason for the difference is not readily apparent as the land use, (except for mining), vegetation, and soils of the three areas are similar.

About 20 percent of the Green River basin is regulated by reservoirs on the Green, Nolin, Barren, and Rough Rivers. Low navigation dams on the Green River provide additional regulation. The mean daily discharge of the Green River at Calhoun ranged from 780 to 73,800 ft³/s during the 1979 water year.

Mean discharges of Tradewater and Pond Rivers and South Fork of Panther Creek

Stream and site number	Mean discharge (1969-79)	
	In ft ³ /s	In ft ³ /s/mi ²
Tradewater River at Olney (site 98; drainage area 255 mi ²).	387	1.52
Pond River near Apex (site 66; drainage area 194 mi ²).	304	1.57
South Fork Panther Creek near Whitesville (site 82; drainage area 58.2 mi ²).	99.4	1.71



EXPLANATION

- 82  Site and number
See section 10.1 for detailed site description
-  Coal-bearing rocks

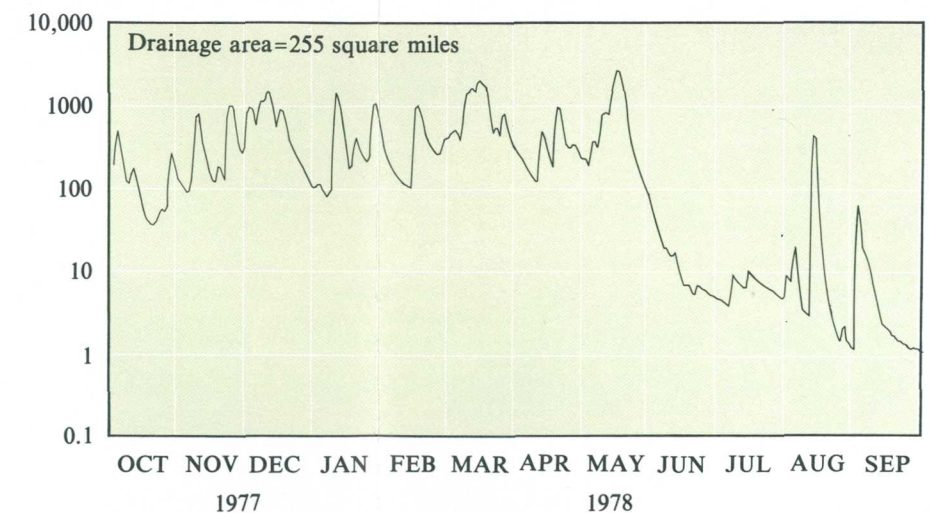


Figure 5.1-1 Tradewater River at Olney, Kentucky.

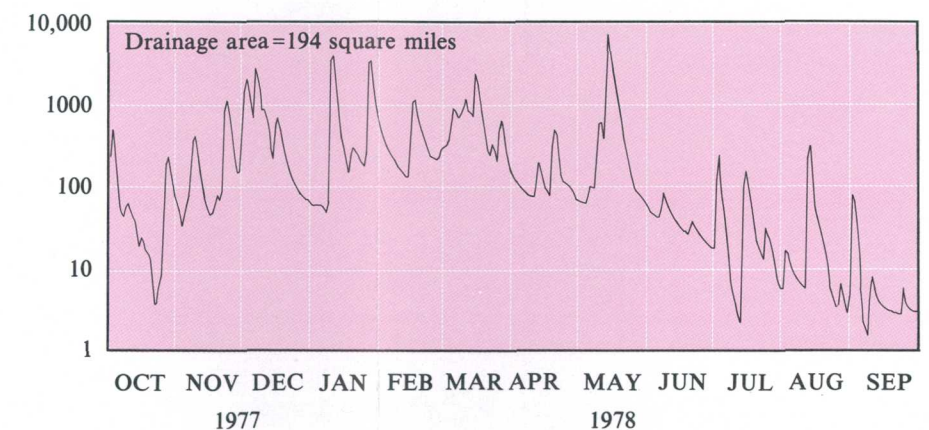


Figure 5.1-2 Pond River near Apex, Kentucky.

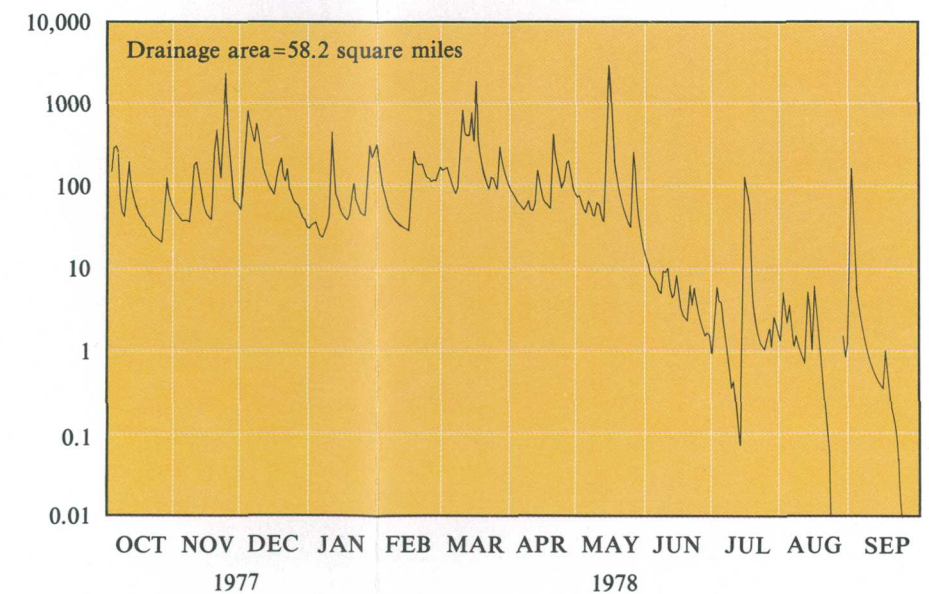


Figure 5.1-3 South Fork Panther Creek near Whitesville, Kentucky.

5.0 SURFACE WATER--Continued

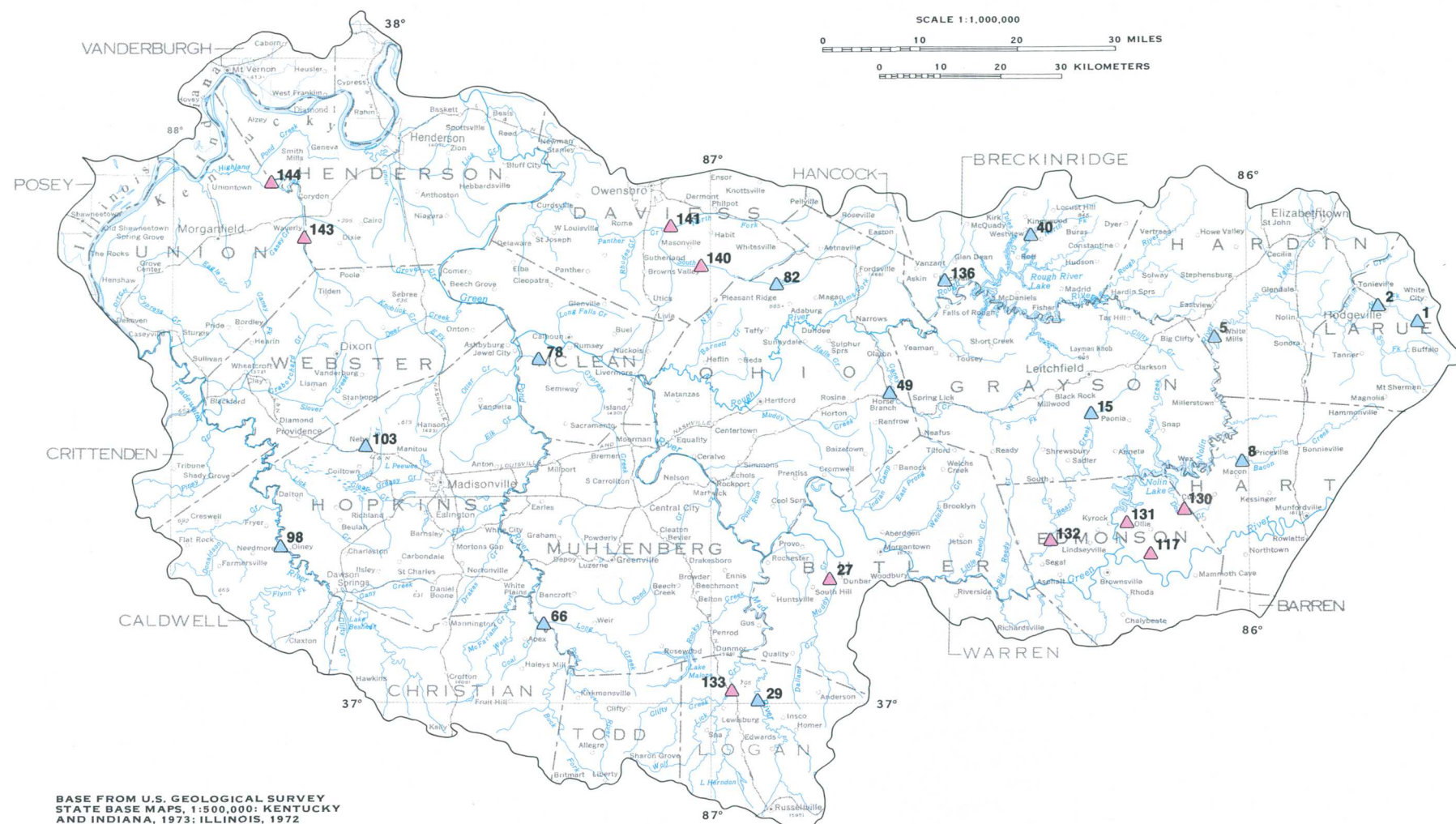
5.2 Low Flow

Most Streams Draining Less Than 100 Square Miles Go Dry During Droughts

The 7-day 10-year recurrence interval minimum flow is zero for most of the streams draining less than 100 square miles in Area 34.

The discharge of streams during low flows is the ground-water contribution to streamflow. The permeability and water-storage characteristics of most of the Pennsylvanian and pre-Pennsylvanian rocks in Area 34 are low; therefore, after long periods of little or no precipitation, many streams in the area become dry. In order to calculate the low-flow characteristics of streams, a network of low-flow sites on unregulated streams has been in operation in the area for many years (fig. 5.2-1). The network includes sites where streamflow is continuously recorded and sites where streamflow measurements are made once or twice each year. Data on low-flow measurements of streamflow at non-recording sites are compared with data from recording sites to estimate low-flow characteristics at the non-recording sites. Partial results of the flow-frequency analyses at both gaged and ungaged sites were published by Swisshelm (1974) and Sullavan (1980).

An index of low flow commonly used is the 7-day 2-year and the 7-day 10-year discharge. The 7-day 2-year is the lowest average rate of flow for 7 consecutive days that occurs at an average interval of 2 years; the 7-day 10-year discharge has a recurrence interval of 10 years. The analyses of the low-flow data show that at most sites where the drainage area is less than 100 mi², the 7-day 2-year recurrence interval minimum flow is near zero; the 7-day 10-year recurrence interval minimum flow is zero (Table 5.2-1). This is not typical of sites near Mammoth Cave National Park, in Edmondson County. In this area a complex underground drainage system has formed in Mississippian limestone. Several sites with much less than 100 mi² drainage area show significant discharges for the indicated recurrence intervals. The effective underground drainage area contributing flow at these sites is probably much larger than the measurable surface area of the basin.



EXPLANATION

▲ Recording site

▲ Non-recording site

78 Site number

See section 10.1 for detailed site description.

See section 10.2 for detailed site description.

Figure 5.2-1 Low-flow network.

Table 5.2-1 7-day 2-year and 7-day 10-year low flows.

SITE NUMBER	DRAINAGE AREA (SQUARE MILES)	7-DAY 2-YEAR DISCHARGE (CUBIC FEET PER SECOND)	7-DAY 10-YEAR DISCHARGE (CUBIC FEET PER SECOND)
1	5.34	0.2	0
2	36.4	0.3	0
5	357	48	36
8	85.4	9.0	5.7
15	30.8	0.3	0
27	94.3	0	0
29	90.5	1.0	0
40	42.0	0.2	0
49	124	0	0
66	194	0	0
78	149	0	0
82	58.2	0.1	0
98	255	0.2	0
103	2.1	0	0
117	2.26	1.0	0.8
130	8.12	1.6	1.1
131	5.16	0.6	0.4
132	137	0.9	0.5
133	116	0.3	0
136	20.1	0	0
140	109	0	0
141	88.3	0	0
143	62.3	0	0
144	166	0	0

5.0 SURFACE WATER--Continued

5.3 Flood Flows

Flooding Severe

Severe flooding occurs frequently in Area 34. Intense storms produce flash flooding in the headwaters of streams; backwater from the Ohio River floods large areas in the valleys.

Area 34 is affected by frequent flooding. Intense storms in the hilly areas in the east and south cause flash flooding in headwater areas of streams. Flooding occurs almost every year in the wide, flat valleys in the north and along the flood plain of the Green and Ohio Rivers. Backwater from the Ohio River, combined with spring runoff in the Tradewater and lower Green Rivers, floods large areas in the wide, flat valleys. Floods peak slowly at sites where the stream gradient and relief are gentle, such as in the upper Tradewater River basin (fig 5.3-1). The gentle slope of the Tradewater River (about one foot per mile for 50 miles upstream from Olney) and many of its tributaries is responsible during flood periods for the slow rise in stage, broad flattened peak, and slow recession. Floods peak quickly on small streams in the central and eastern parts of the area where the stream gradient is steeper (about four feet per mile

for 14 miles upstream from the gage near Whitesville) (fig. 5.3-2). Flash flooding also occurs in small basins in headwater areas as on the Pond River where the stream gradient is about two feet per mile for 25 miles upstream from Apex (fig. 5.3-3).

Peak discharges of streams and precipitation data have been recorded since about 1930 at many sites in Area 34. Maximum known instantaneous peak discharges at long-term recording stations range from 17 to 117 (ft³/s)/mi². However, the lowest values occur in the Green River, where significant regulation reduces the magnitude of flood peaks. At unregulated sites, peak discharges normally exceed 50 (ft³/s)/mi². About 75 percent of the annual floods occur from January to April (McCabe, 1962). No annual flood has ever been recorded during October.

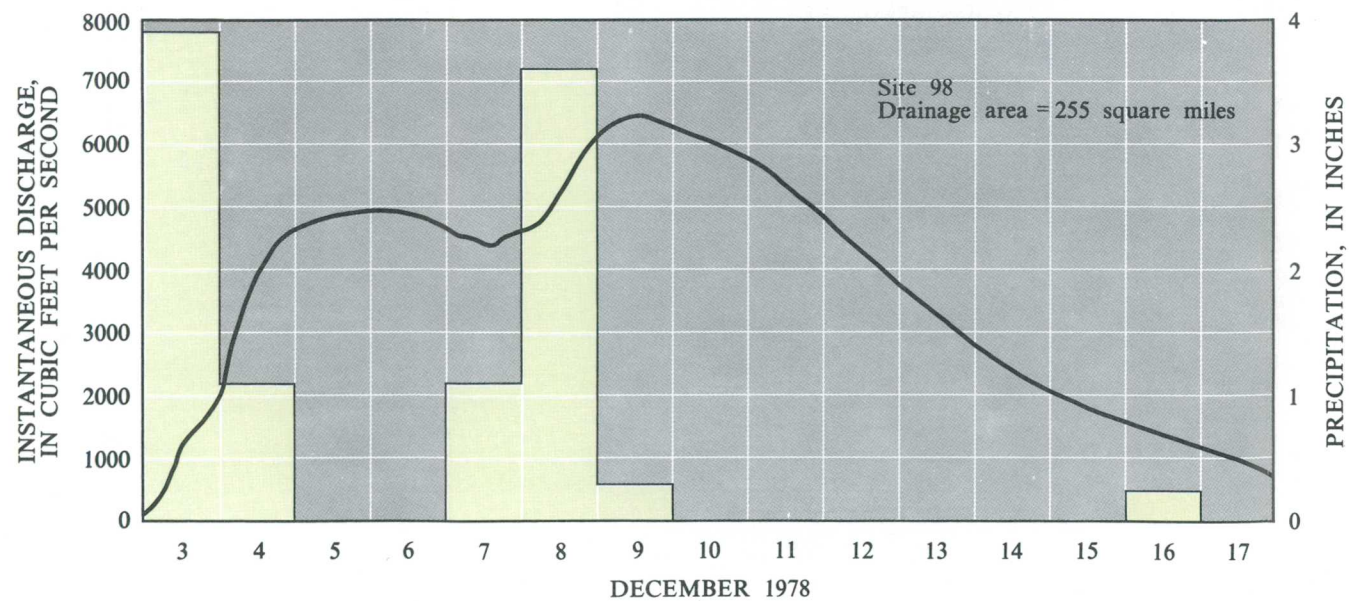
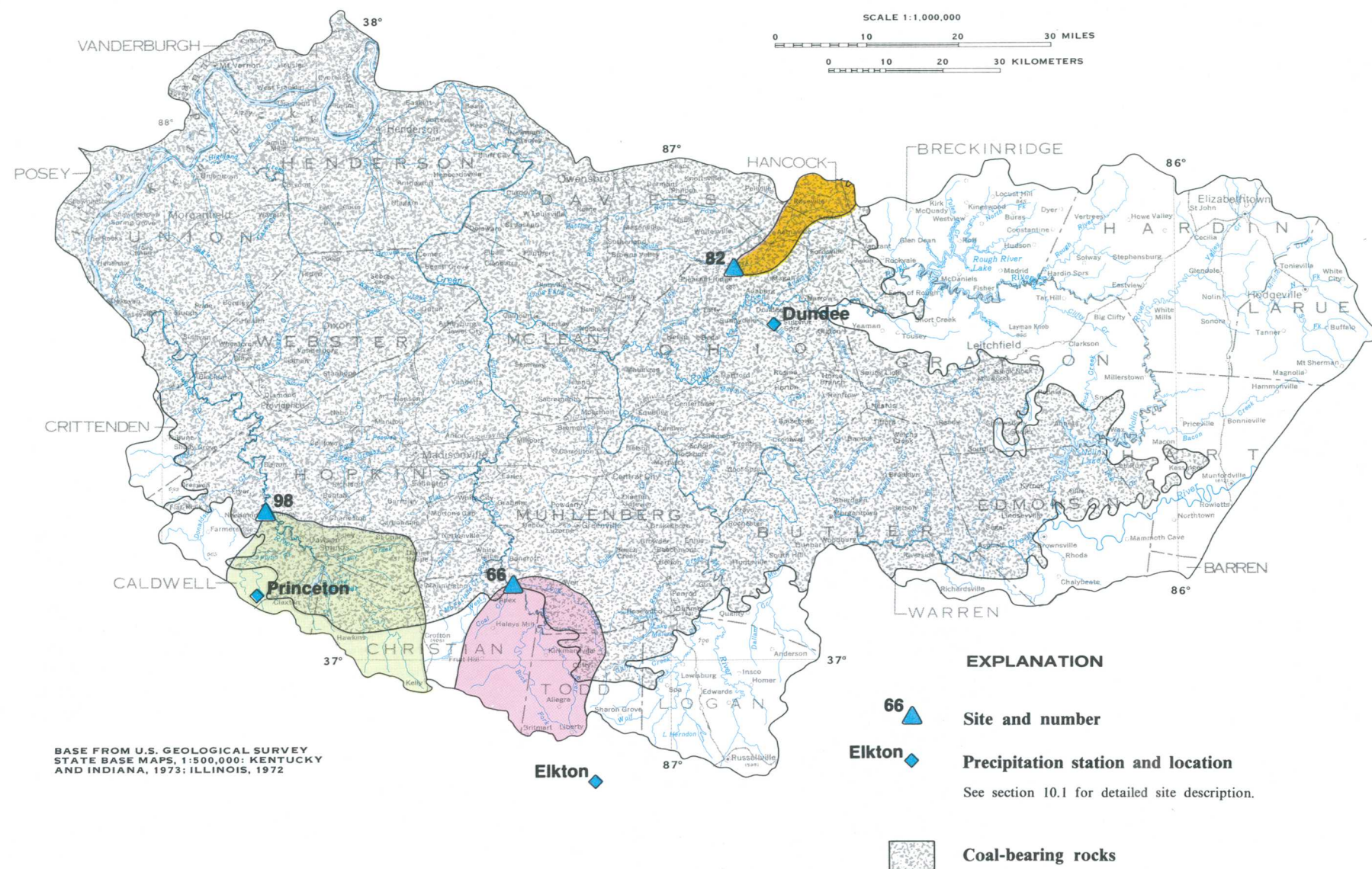


Figure 5.3-1 Streamflow hydrograph of Tradewater River at Olney and daily precipitation at Princeton, December 1978 flood.

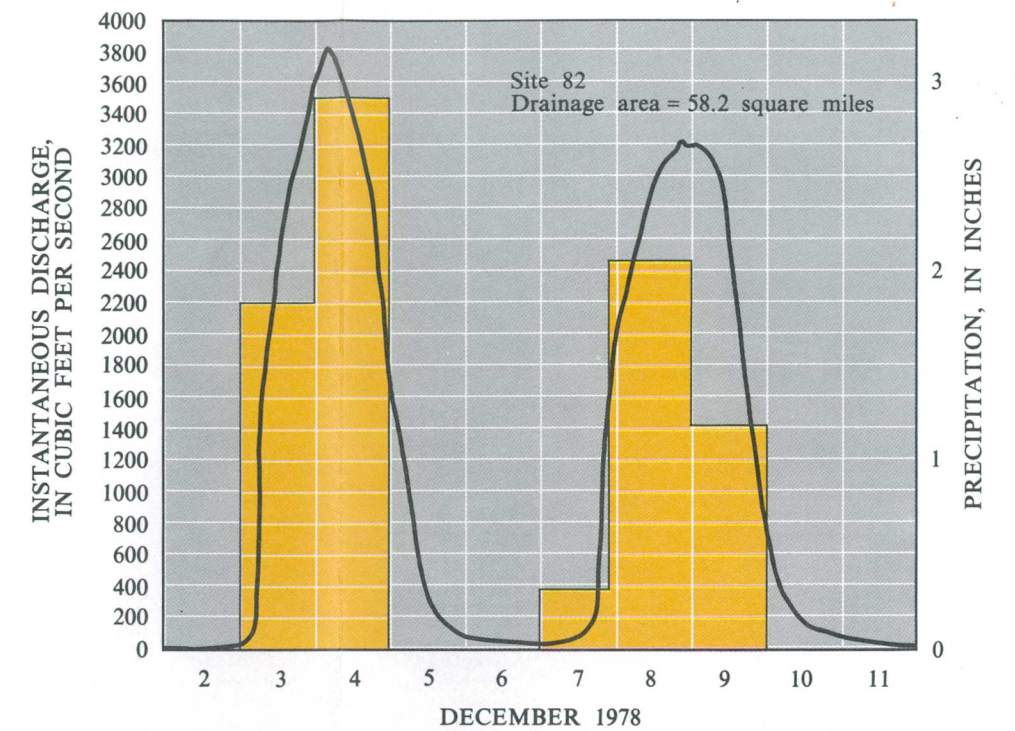


Figure 5.3-2 Streamflow hydrograph of South Fork Panther Creek near Whitesville and daily precipitation at Dundee, December 1978 flood.

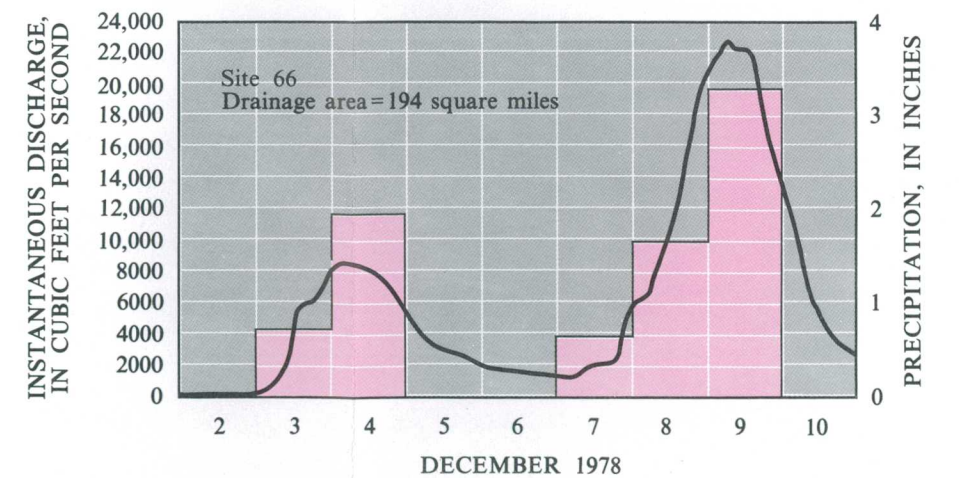


Figure 5.3-3 Streamflow hydrograph of Pond River near Apex and daily precipitation at Elkton, December 1978 flood.

5.0 SURFACE WATER--Continued

5.4 Frequency of Floods

Floods Vary with Drainage Area, Topography, and Geology

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

Flood-frequency analysis is important for the design of structures in flood plains. Flood frequencies are expressed as a probability of occurrence, or recurrence interval. The 50-year recurrence interval flood means that during any given year there is a 0.02 probability (two percent chance) that a flood of similar magnitude will be equaled or exceeded. The 50-year flood (Q_{50}), therefore, could be expected, on the average, to occur once in 50 years but this does not preclude the probability of 50-year floods occurring in consecutive years.

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:

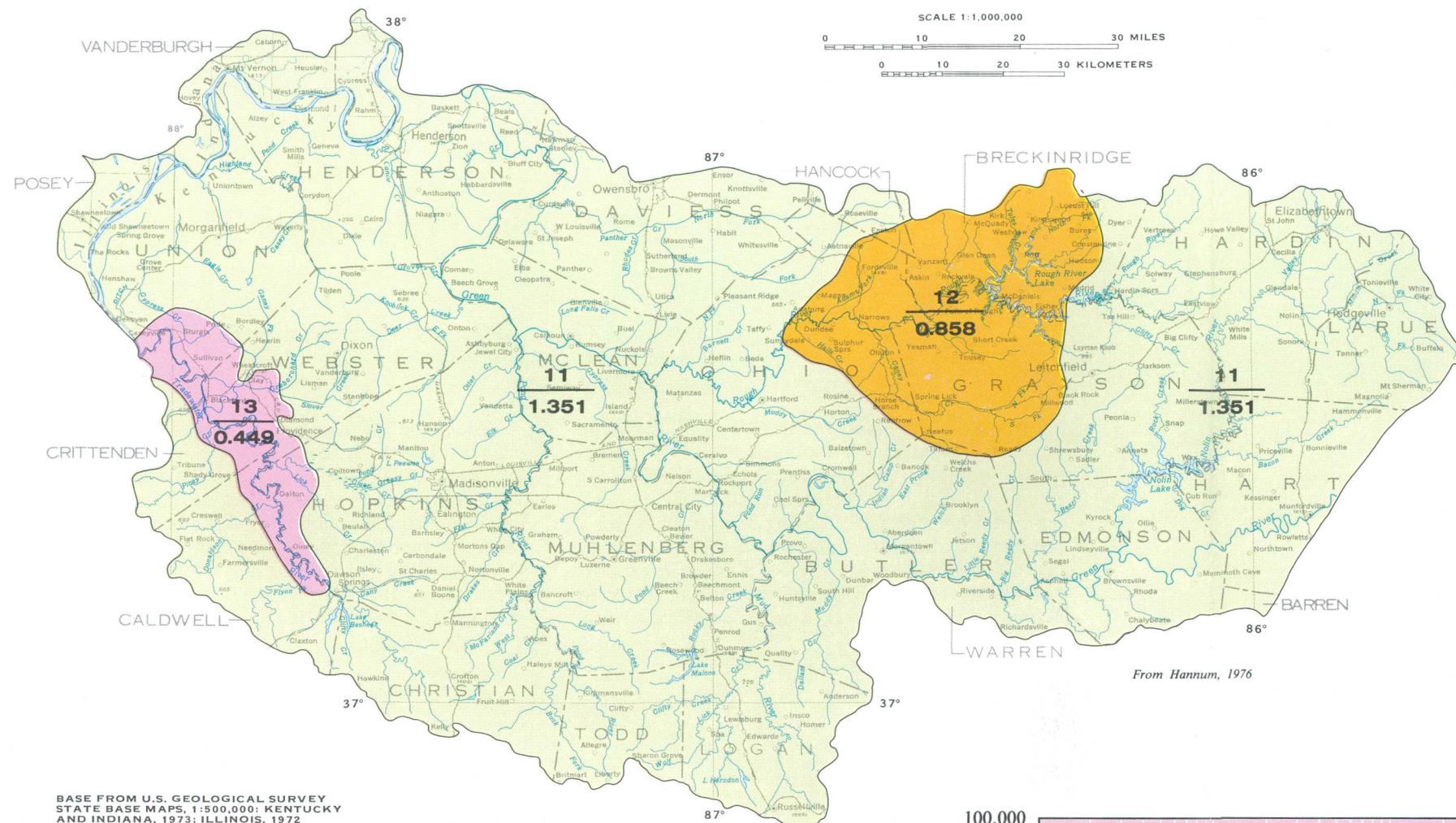
$$Q_{50} = 638A^{0.663}R^{1.040}$$

where Q_{50} = discharge of 50-year flood in cubic feet per second, A = drainage area, in square miles, and R is a geographical factor related to the geology and topography. A threefold difference in the R factors occurs between the Tradewater and Rough River basins. For most of Area 34, an R factor of 1.351 predominates. The locations of the geographical-factor areas and graphical solutions to the regression equations, simplifying the estimation of selected flood frequencies are shown in figures 5.4-1.

Summary of regression equations.

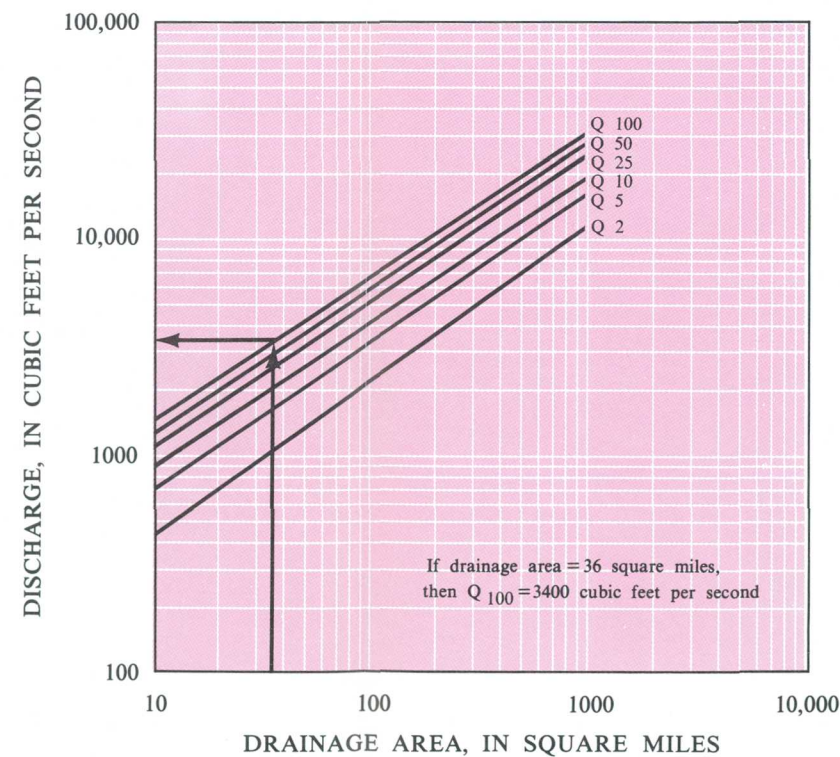
Frequency of floods (years)	Magnitude of floods (ft ³ /s)	Standard error of estimate (percent)
2	$Q_2 = 187A^{0.703}R^{0.965}$	31.8
5	$Q_5 = 318A^{0.685}R^{0.991}$	29.5
10	$Q_{10} = 412A^{0.677}R^{1.006}$	29.5
25	$Q_{25} = 540A^{0.668}R^{1.025}$	30.6
50	$Q_{50} = 638A^{0.663}R^{1.040}$	31.8
100	$Q_{100} = 740A^{0.659}R^{1.051}$	33.3

Q_2 - 2-year flood
 A - Contributing drainage area
 R - Geographical factor

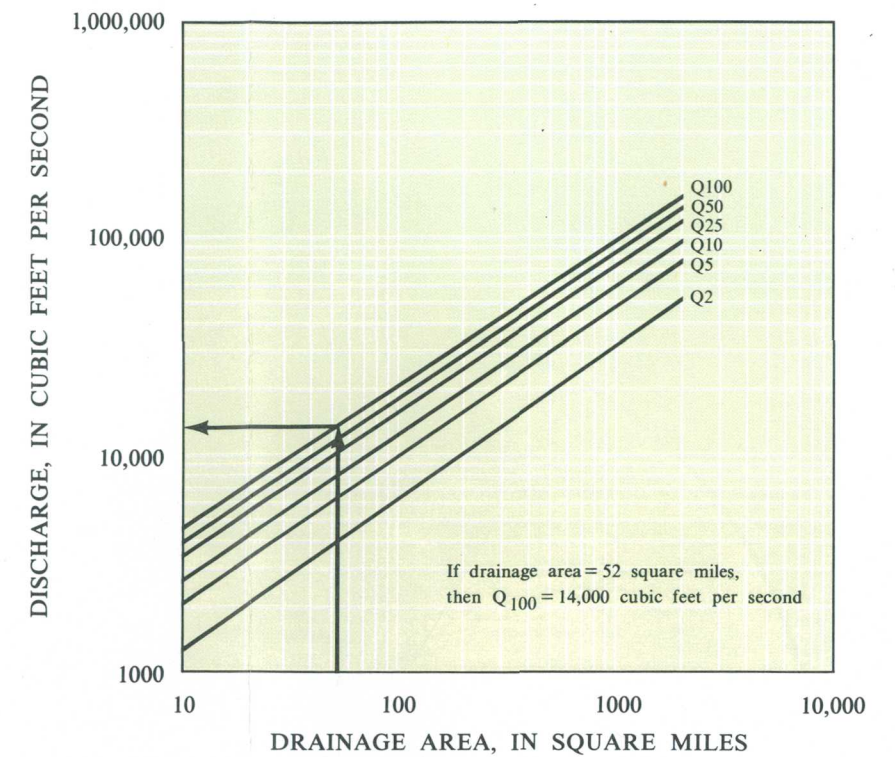


EXPLANATION

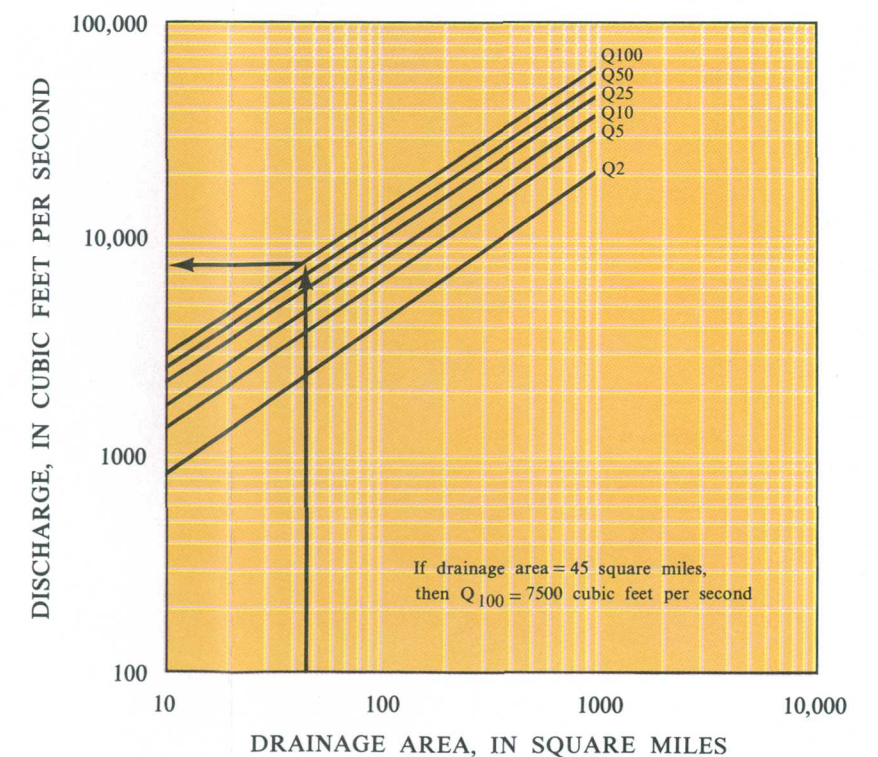
12	Geographical area number
0.858	Geographical area factor (R)



Geographical solution of discharge equations,
geographical area 13.



Geographical solution of discharge equations,
geographical area 11.



Geographical solution of discharge equations,
geographical area 12.

Figure 5.4-1 Areas of geographical factors (R) for calculating magnitude and frequency of floods.

5.0 SURFACE WATER--Continued
5.5 Flood-Prone Areas

Maps Defining Flood-Prone Areas Available

The limits of the 100-year recurrence interval flood or the maximum known flood are shown on 50 maps for part of Area 34.

The National Flood Insurance Act of 1968, and the Flood Disaster Protection Act of 1973, established programs for delineating 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 later modified to define the 100-year flood in areas identified as subject to flooding.

Maps for 50 flood-prone areas within Area 34, as delineated by the U.S. Geological Survey, are available (fig. 5.5-1). These include 39 maps where the 100-year flood has been defined and 11 maps where only the maximum known flood has been delineated. Most of the maximum-flood maps available are along the Ohio River on the northwestern part of the area. Areas that may be subject to flooding are outlined on 7.5-minute quadrangle topographic bases at a scale of 1:24,000 (1 in = 2,000 ft.).

Kentucky Geological Survey
University of Kentucky
Lexington, KY 40506

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

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



Figure 5.5-1 Flood-prone areas mapped.

5.0 SURFACE WATER--Continued

5.6 Flow Duration

Flow-Duration Data Available for 16 Stations

Flows are generally poorly sustained at most of the unregulated streams in Area 34. There is no significant difference in the flow per unit area between mined and unmined basins.

The flow-duration curve is a cumulative frequency curve that shows the percent of time that a discharge was equaled or exceeded. Mean daily discharges are particularly suitable for flow-duration analysis and 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.

Flow-duration data are available for 16 sites in Area 34 (fig. 5.6-1 and table 5.6-1). Length of records range from 6 to 52 years. Several of the sites are affected by regulation of discharge by dams. Regulation generally decreases the magnitude of peak flows and increases the magnitude of low flows (fig. 5.6-2). Most of the sites for which flow-duration data are available are on streams in the eastern part of the area where there are no significant coal deposits. Two sites on the mainstem of the Green River are affected by significant regulation and flows from outside of Area 34.

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.

The shape of a flow-duration curve is commonly affected by the geology of a basin upstream from the gaging site. Figure 5.6-2 shows flow-duration curves for Tradewater River (site 98), South Fork Panther Creek (site 82), and Rough River before and after regulation (site 45). The geology upstream from sites 98 and 82 is predominately Pennsylvanian shales and sandstones that have little permeability. The shape and slope of both curves are very similar. The slopes of the curves for site 45 are different from the flow-duration curves for the other two streams. The geology upstream from this site is pre-Pennsylvanian shale, sandstone, and limestone. The greater low-flow discharge before regulation probably is sustained by discharge of ground water from permeable limestone in the headwaters of the Rough River. Discharges after regulation are controlled amounts of water released from storage in the reservoir, except during floods.

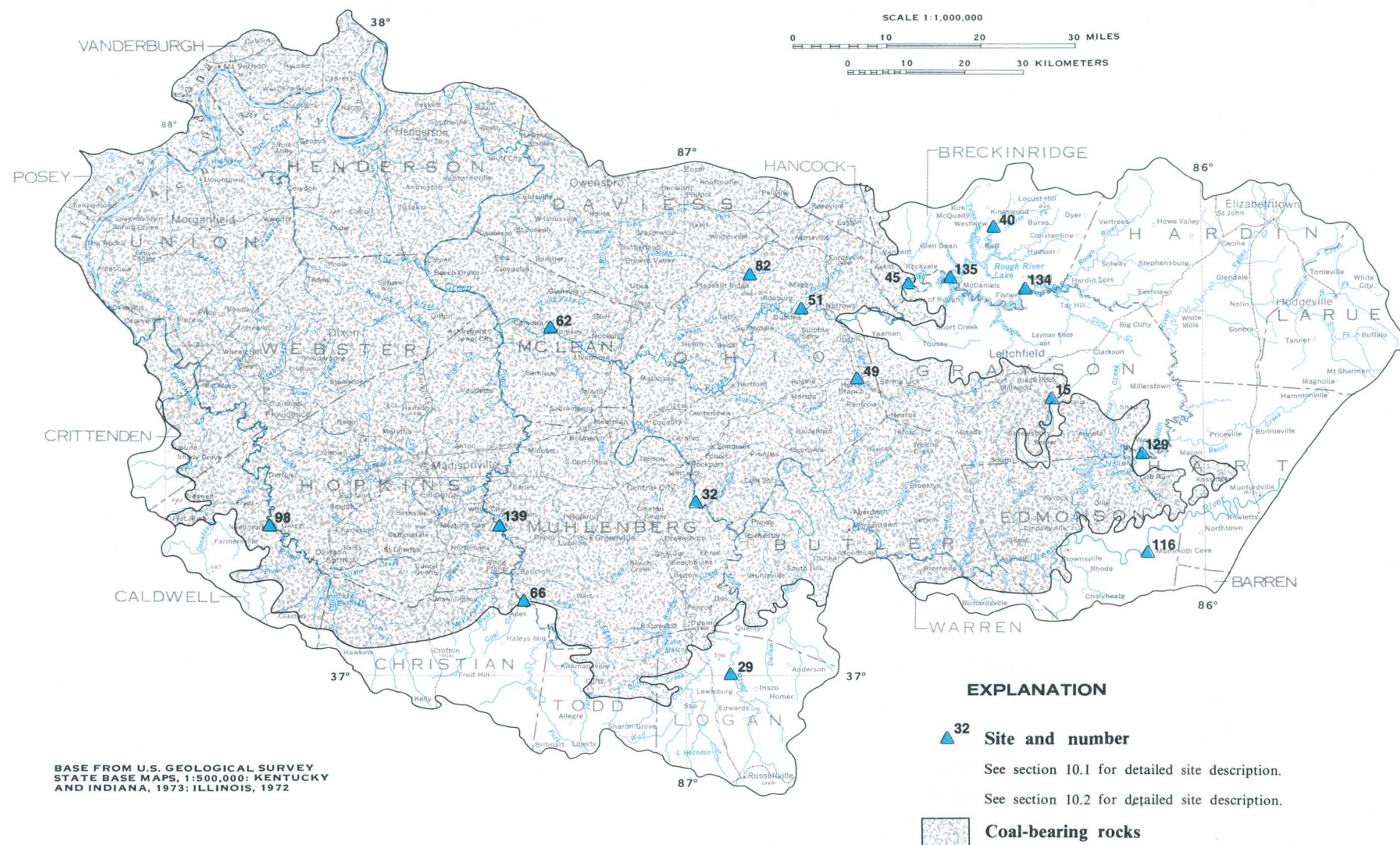


Figure 5.6-1 Sites with flow-duration data.

Table 5.6-1 Flow-duration data for 16 streams in Area 34.

SITE NUMBER	PERIOD OF RECORD	PERCENTAGE OF THE TIME INDICATED DISCHARGE WAS EQUALLED OR EXCEEDED (CUBIC FEET PER SECOND)									REMARKS
		1	5	10	25	50	70	75	90	95	
15	1950-71	715	163	84	28	6.4	1.8	1.4	0.5	0.2	
29	1940-72	2040	625	350	130	34	9.7	6.7	2.0	0.4	
32	1940-62	58900	38500	27000	9700	3100	1400	1200	640	510	B.R.
	1964-78	45450	31800	24000	14000	5400	2900	2400	1300	950	A.R.
40	1954-73	470	147	84	30	7.6	2.3	1.6	0.4	0.3	N.R.
45	1949-59	7500	4270	2400	690	220	75	55	24	18	B.R.
	1960-79	2820	2130	1950	1230	390	110	89	59	48	A.R.
49	1957-78	2000	725	480	150	32	5.4	2.6	0.1	0.0	N.R.
51	1939-79	8910	5770	4500	1300	290	110	85	50	32	
62	1960-79	49400	39500	30600	16200	5890	3000	2500	1400	1100	A.R.
66	1942-79	3540	1320	750	210	46	9.8	6.0	0.7	0.0	
82	1968-78	1160	350	180	80	22	4.4	2.9	.05	0.1	
98	1941-75	2900	1800	1100	290	56	14	6.7	0.7	0.1	N.R.
116	1939-50	27000	12170	7200	3000	1000	460	380	200	160	
129	1937-62	7100	2920	1800	860	330	160	140	83	69	
134	1939-59	3980	1230	690	300	99	40	32	19	16	N.R.
135	1940-51	6900	2750	1700	570	170	65	50	24	17	
139	1929-40	4200	1980	1200	370	30	7.8	5.6	1.1	0.2	

A.R.—After regulation
B.R.—Before regulation
N.R.—No regulation

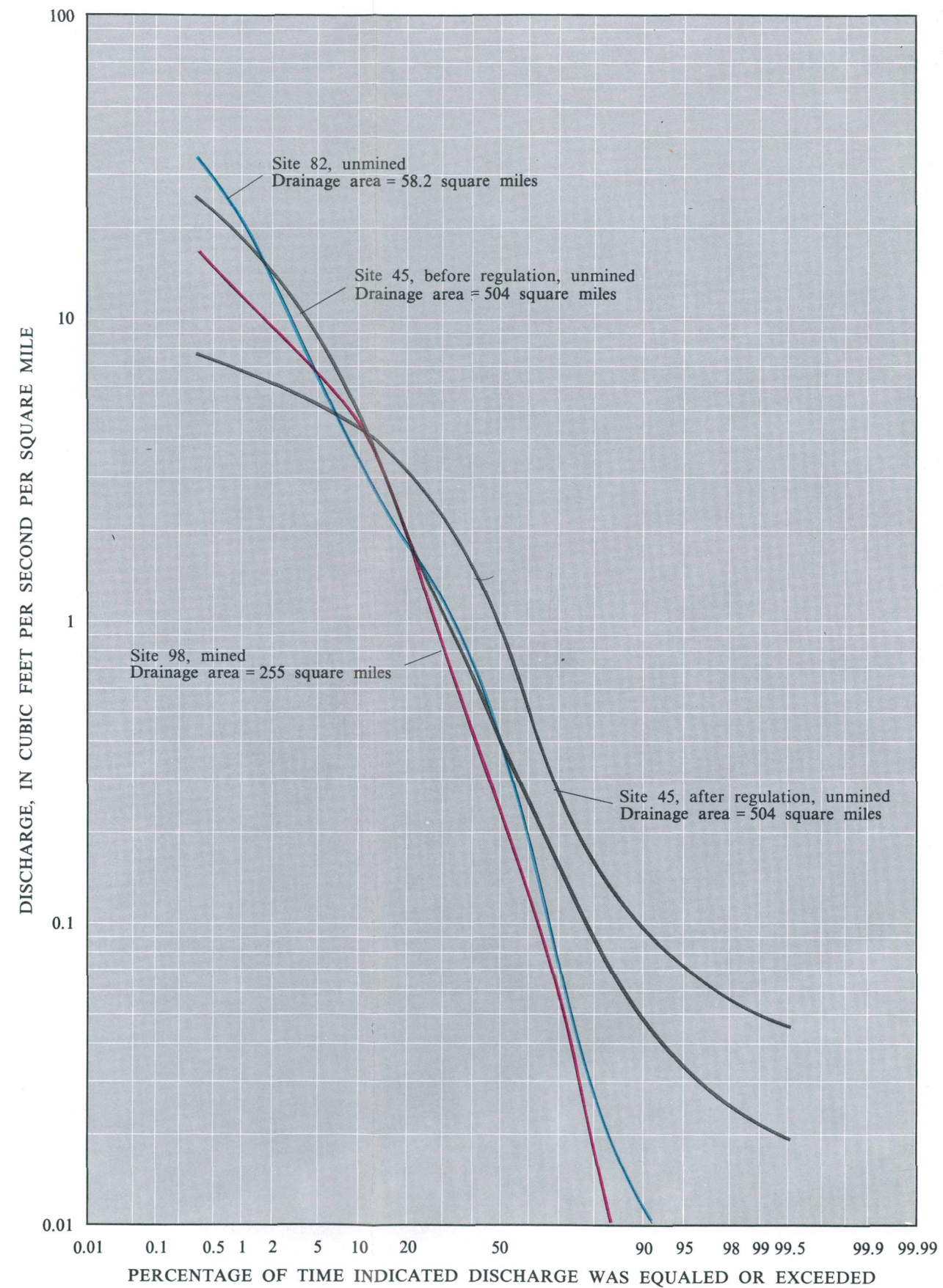


Figure 5.6-2 Flow-duration data for three streams with different basin characteristics.

6.0 QUALITY OF SURFACE WATER

6.1 Sampling Program

Water-Quality Data Available at 66 Active Sites

Existing data provide a general view of surface water quality in Area 34.

Water-quality data frequently show the effects of surface-coal mining as well as other land-use activities. The Act establishes a series of maximum permissible limits for a number of water-quality constituents and physical properties in effluents draining mined areas. These are:

- pH range from 6.0 to 9.0 units.
- Total manganese concentration of 4,000 micrograms per liter.
- Total iron concentration of 7,000 micrograms per liter.
- Total suspended-solids concentration of 70 milligrams per liter.

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

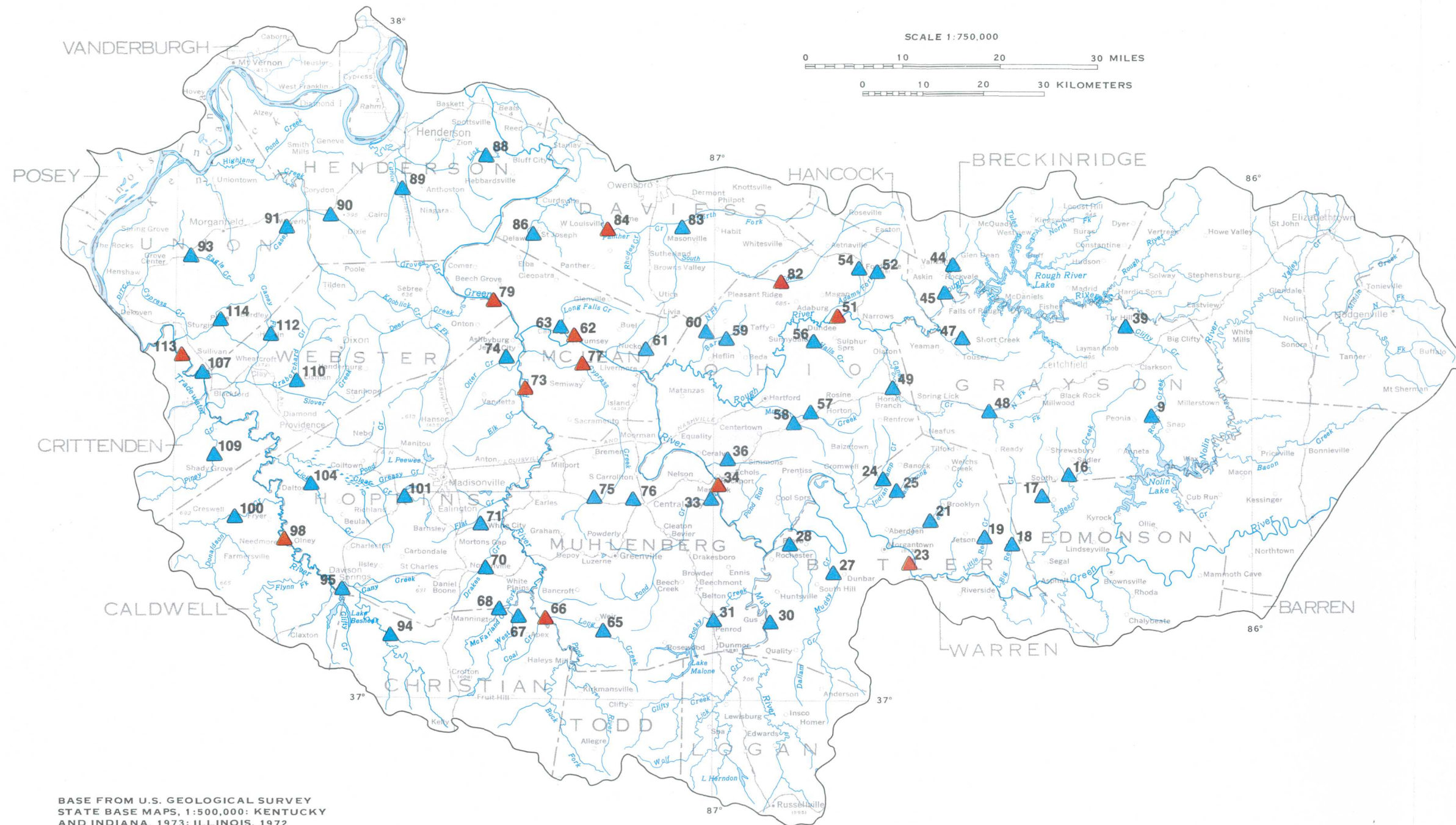
Water-quality data were collected in 1979-80 at 66 active sites in Area 34 (fig. 6.1-1 and section 10.1). Samples were collected at various frequencies (every 6 to 8 weeks at or near continuously recording sites and 4-times per year at non-recording sites) at each site for the determination of pH, specific conductance, alkalinity, temperature, iron and manganese concentrations (total and dissolved), sulfate, dis-

solved solids, and suspended-sediment concentrations.

Additional constituents were determined from samples collected annually during low streamflow 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 per cent of coal in bottom material.

In addition to data collected at the 66 active sites, limited water-quality data have been collected in the past at inactive sites on streams in Area 34. Analyses of the historical data, plus the data collected in 1979-80 are presented in the following sections of this report.

Samples were collected in 1979-80 during the spring, summer, and fall seasons in an effort to determine surface-water quality during several flow regimes (low, medium, and high flow conditions). The data represent water-quality conditions during extreme low, medium, and some high flows; extreme high-flow conditions were not encountered. Several streams in July and September of 1980 were dry. The data collected provide a near instantaneous or synoptic view of water quality during a particular flow condition.



BASE FROM U.S. GEOLOGICAL SURVEY
STATE BASE MAPS, 1:500,000: KENTUCKY
AND INDIANA, 1973; ILLINOIS, 1972

EXPLANATION

▲ Water samples collected every six to eight weeks; suspended-sediment samples collected one to three times per week and during storms; streamflow recorded continuously or continuously-recording site sufficiently close to extrapolate streamflow data.

▲ Water samples collected four times per year and during storms; miscellaneous suspended-sediment samples collected; streamflow measurements made four times per year.

48 Site and number

See section 10.1 for detailed site description

Figure 6.1-1 Water-quality sampling sites.

6.0 QUALITY OF SURFACE WATER--Continued

6.2 Specific Conductance and Dissolved Solids

Specific Conductance and Dissolved Solids Reflect Different Land Uses

Highest dissolved solids and specific conductance values are in the intensely mined parts of the upper Tradewater and lower Pond Rivers and Cypress Creek.

Specific conductance is a general indicator of the amount of dissolved solids (Hem, 1970); therefore it is commonly used to estimate specific ion concentrations. At many sites correlations may be developed between specific conductance and dissolved solids, chloride, hardness, and sulfate concentrations.

Correlation analyses between specific conductance and dissolved solids are highly significant at both mined and unmined sites and in coal-bearing and non-coal bearing rocks in Area 34 (fig. 6.2-2). The relations at Pond River near Apex (site 66, draining an area of Mississippian rocks south of the coal field) and Tradewater River at Olney (site 98, mined and within the coal field), are not significantly different except for the steeper slope at the site affected by mining. At Pond River near Apex (site 66), the range of specific conductance and dissolved solids values is lower than at Tradewater River at Olney (site 98). The site on the South Fork of Panther Creek (site 82) is one of the few sites in an unmined basin in the coal field. The specific conductance and dissolved-solids data plot similar to that of the other sites shown in Figure 6.2-2. For a given specific conductance value, the dissolved-solids con-

centration is higher at the site affected by mining than at the site in the unmined basin.

A general relation between specific conductance and dissolved-solids concentration was developed from all the data available at sites in Area 34 (fig. 6.2-2). The relation for the entire area closely resembles the relation at Tradewater River at Olney (site 98). The relation can be used to estimate the dissolved solids concentration at most unsampled sites.

Specific conductance values of water samples in Area 34 range from 48 to 4750 $\mu\text{mhos/cm}$ (fig. 6.2-1 and table 6.2-1). Minimum values for all stations range from 48 to 2,400 $\mu\text{mhos/cm}$; maximum instantaneous values range from 92 to 4,750 $\mu\text{mhos/cm}$.

Dissolved-solids concentrations in Area 34 range from 46 to 4,520 mg/L. Minimum values range from 46 to 2,390 mg/L; maximum values range from 56 to 4,520 mg/L. The highest specific conductance and dissolved-solids values occur in samples collected in the headwaters of Tradewater River and lower part of the Pond River and Cypress Creek, where mining is intense.

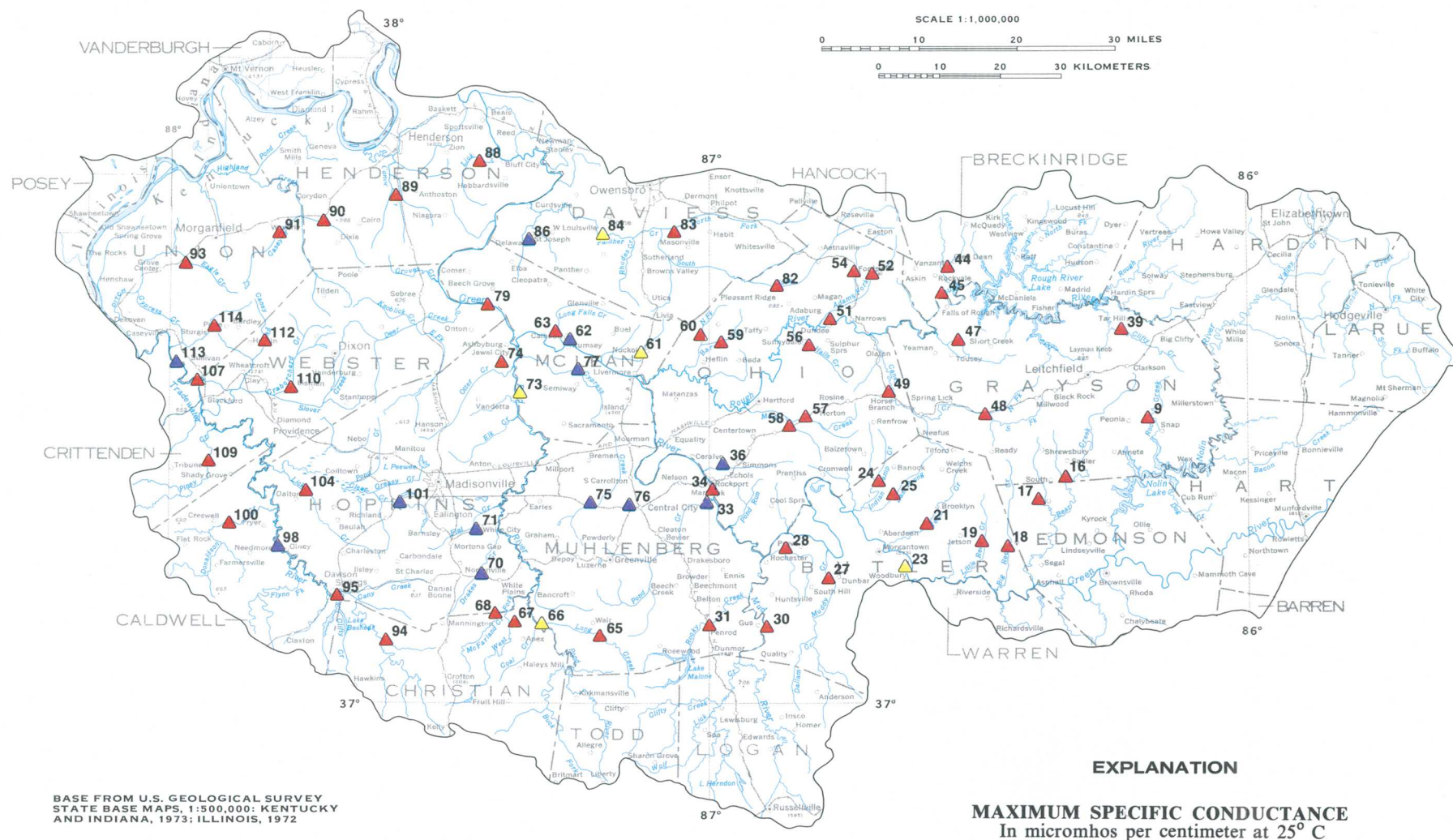


Figure 6.2-1 Specific conductance and dissolved solids sampling sites.

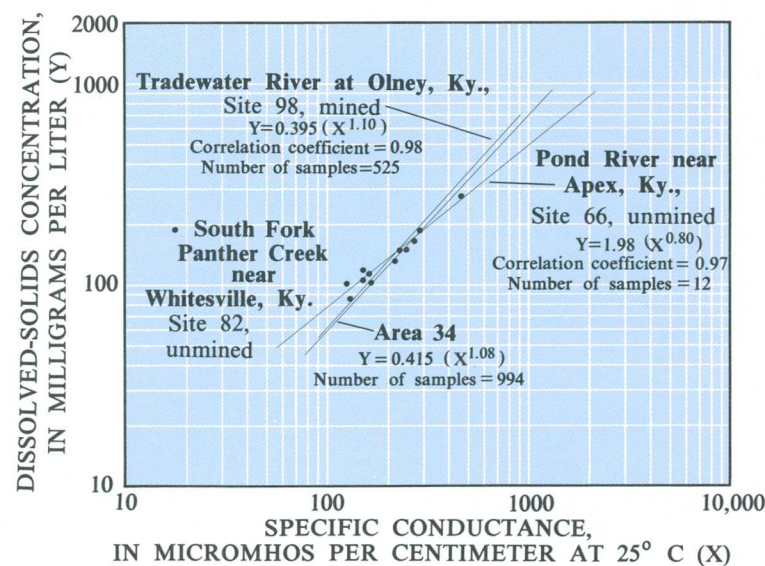


Figure 6.2-2 Relations between specific conductance and dissolved-solids concentrations.

Table 6.2-1 Summary of specific conductance data, in micromhos per centimeter.

Site Number	Number of Samples	Minimum	Maximum	Mean	Median
9	6	150	230	200	205
16	6	140	330	220	215
17	6	90	135	113	117
18	5	75	92	86	85
19	5	75	330	131	80
21	5	90	148	122	120
23	116	117	1630	430	371
24	5	120	190	158	155
25	5	85	130	106	95
27	12	166	382	236	212
28	4	135	205	164	158
30	8	230	420	317	304
31	5	75	125	101	105
33	8	815	4460	2300	2180
34	12	220	430	283	278
36	6	865	3120	2240	2280
39	5	170	235	206	205
44	5	197	335	286	330
45	34	160	280	225	226
47	5	295	400	355	350
48	5	95	195	145	145
49	33	70	240	160	155
51	13	155	260	200	200
52	6	105	450	218	175
54	4	130	210	181	192
56	5	110	155	135	140
57	5	160	533	320	280
58	6	140	210	176	180
59	5	130	254	198	210
60	5	190	460	330	360
61	5	480	2720	2010	2600
62	27	150	364	264	263
63	6	650	3150	2620	2980
65	5	200	440	330	350
66	45	140	1300	333	310
67	5	185	449	356	365
68	2	145	183	--	--
70	5	400	2400	1600	1830
71	3	1400	2660	--	--
73	10	275	1250	665	548
74	4	250	570	360	314
75	4	1600	3380	2460	2420
76	4	1900	4750	3580	3840
77	11	719	2260	1430	1400
79	170	130	500	394	460
82	26	120	447	218	180
83	5	180	564	318	260
84	14	230	2260	718	471
86	5	1475	2950	2375	2300
88	5	180	460	314	310
89	6	205	478	381	415
90	24	95	750	446	480
91	6	300	625	496	510
93	4	239	497	381	394
94	4	128	170	146	144
95	3	395	598	--	--
98	541	50	2480	482	405
100	2	237	351	--	--
101	5	2400	3900	2900	2650
104	2	420	843	--	--
107	5	280	780	577	601
109	4	200	330	264	264
110	3	182	292	--	--
112	3	193	360	--	--
113	12	280	2500	904	680
114	5	480	559	525	521

Table 6.2-2 Summary of dissolved solids data, in milligrams per liter.

Site Number	Number of Samples	Minimum	Maximum	Mean	Median
9	4	121	144	133	134
16	4	93	204	154	159
17	4	63	88	75	74
18	3	48	56	--	--
19	3	46	62	--	--
21	3	50	110	--	--
23	116	62	806	237	206
24	3	68	104	--	--
25	3	60	85	--	--
27	7	100	254	167	168
28	3	89	122	--	--
30	8	174	300	208	190
31	3	60	85	--	--
33	6	581	4520	2440	2540
34	12	132	278	180	178
36	4	710	3240	2130	2290
39	4	101	130	115	114
44	3	137	200	--	--
45	7	118	148	131	132
47	3	170	273	--	--
48	3	74	125	--	--
49	7	79	116	100	102
51	12	101	157	127	126
52	4	67	223	133	121
54	2	112	162	--	--
56	3	72	87	--	--
57	3	105	373	--	--
58	4	83	123	104	104
59	3	78	136	--	--
60	3	125	286	--	--
61	3	292	1820	--	--
62	14	129	226	182	176
63	4	438	2700	1810	2060
65	3	143	305	--	--
66	12	125	282	200	190
67	3	131	239	--	--
68	2	98	116	--	--
70	3	266	1820	981	858
71	2	2080	2500	--	--
73	10	174	1160	524	412
74	2	202	237	--	--
75	4	1440	3540	2480	2460
76	4	1750	8930	4460	3580
77	10	491	2060	1160	1010
79	68	88	325	192	185
82	13	84	250	141	128
83	3	116	342	--	--
84	14	143	2070	557	293
86	3	1140	1980	--	--
88	3	129	220	--	--
89	4	192	293	242	242
90	2	202	455	--	--
91	4	303	407	--	--
93	3	135	310	--	--
94	3	80	124	--	--
95	1	--	--	297	--
98	526	48	2400	361	274
100	1	--	--	203	--
101	2	2390	2630	--	--
104	1	--	--	324	--
107	3	152	585	402	470
109	2	117	186	--	--
110	2	106	202	--	--
112	2	129	232	--	--
113	4	168	1840	787	570
114	3	306	335	--	--

6.0 QUALITY OF SURFACE WATER--Continued

6.3 pH

pH of Streamflow in Near Neutral at Most Sites

The pH of water samples at most sites in Area 34 is in the near-neutral range of 6 to 8 units. Low pH values were observed at several sites in the Tradewater and lower Pond Rivers and Cypress Creek basins where mining is intense.

A pH value of 7.0 is neutral water. Values less than 7.0 are acidic; values greater than 7.0 are alkaline. Natural acidity usually is caused by the presence of dissolved carbon dioxide or hydrolysis of salts of weak acids and strong bases. Sources of these substances include rainfall, weathered rocks, and organic matter in soils.

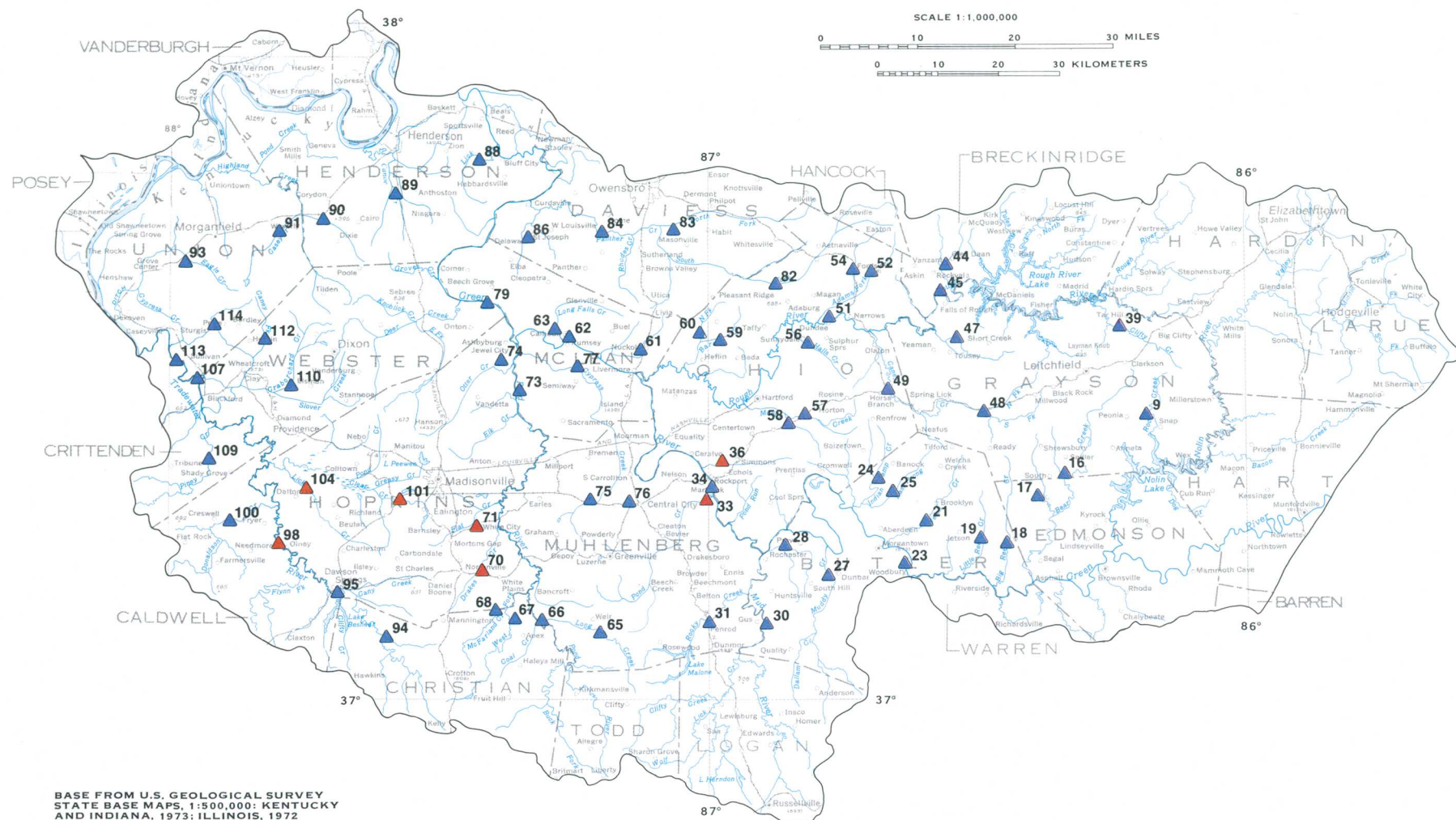
The pH of waters draining areas affected by surface coal-mining may be altered by chemical reactions with sulfurous minerals in mining spoils. The oxidation and hydrolysis of pyrite, marcasite, and other minerals containing sulfur results in the production of sulfuric acid. The Act established a permissible range of pH from 6.0 to 9.0 units for effluents draining mined areas. Acidic mine-drainage may have pH values that range from about 2.0 to 5.0 units. Unless the acid mine-drainage is neutralized, the pH of water in receiving streams may be lowered below natural levels.

Data for pH are available from 66 sites through-

out Area 34 (fig. 6.3-1 and table 6.3-1). Long-term data are available from only three sites (23, 79, and 98); short-term data, beginning in 1979, are available from most of the other sites. All of the data represent instantaneous measurements of pH.

The pH at stream sites in Area 34 ranges from 2.7 to 9.6 units (table 6.3-1). Median values ranged from 3.3 to 8.1 units, but most are in the near-neutral range of 6 to 8 units.

Rocks in much of Area 34 contain calcareous minerals, such as calcite, that naturally neutralize acidic water. However, very acidic waters occur at several sites. These sites are in the upper Tradewater River (sites 98, 101, 104), lower Pond River (sites 70, 71, 73), and Cypress Creek (sites 33 and 36). The sites are in Muhlenberg and Hopkins Counties, where surface mining is greatest. Neutralization of the acid-mine drainage at these sites is not as effective as in other parts of the area.



BASE FROM U.S. GEOLOGICAL SURVEY
STATE BASE MAPS, 1:500,000; KENTUCKY
AND INDIANA, 1973; ILLINOIS, 1972

EXPLANATION

MINIMUM pH VALUE In units

▲ 2.0 to 4.9

▲ 5.0 and greater

70 Site number

See section 10.1 for detailed site description

Figure 6.3-1 pH sampling sites.

Table 6.3-1 Summary of pH values, in units.

Site Number	Number of Samples	Minimum	Maximum	Median
9	6	7.3	8.3	7.8
16	6	7.0	7.6	7.2
17	6	6.5	7.1	6.8
18	5	6.5	8.2	7.2
19	5	6.5	7.4	6.8
21	5	6.6	7.2	6.8
23	116	6.4	8.2	7.3
24	5	6.6	7.3	7.2
25	5	6.6	7.4	7.3
27	10	6.8	8.0	7.4
28	4	6.6	7.1	6.8
30	8	7.0	7.9	7.6
31	5	6.4	6.9	6.8
33	8	2.7	7.4	6.2
34	12	7.0	7.9	7.6
36	6	3.5	7.0	5.1
39	5	7.0	7.8	7.4
44	5	7.1	7.6	7.6
45	10	7.0	7.8	7.4
47	5	7.3	8.1	7.6
48	5	6.7	7.4	7.1
49	9	6.4	8.0	7.7
51	12	6.7	8.3	7.6
52	6	7.0	7.4	7.2
54	4	6.7	7.7	7.4
56	5	6.1	7.6	7.4
57	5	6.2	7.2	6.8
58	6	6.5	8.0	7.5
59	5	6.7	8.0	7.5
60	5	6.9	8.2	7.5
61	5	7.4	7.8	7.5
62	15	6.9	8.0	7.8
63	6	7.2	8.3	8.1
65	5	7.2	7.8	7.7
66	15	6.5	8.0	7.4
67	5	6.8	7.4	7.2
68	1	—	—	7.0
70	5	2.9	4.9	3.4
71	3	3.2	3.6	—
73	10	5.8	7.3	6.9
74	4	6.6	7.5	7.2
75	4	7.1	7.9	7.5
76	4	7.3	7.7	7.5
77	11	6.6	7.8	7.3
79	165	6.0	8.5	7.5
82	13	6.9	7.8	7.2
83	5	7.4	7.9	7.6
84	14	6.7	8.1	7.4
86	5	7.4	8.2	8.0
88	5	7.3	8.1	7.6
89	6	7.2	8.2	7.6
90	4	7.2	7.8	7.5
91	6	7.4	9.6	8.0
93	4	7.2	7.8	7.6
94	4	6.8	7.0	6.9
95	3	6.5	6.9	—
98	492	3.5	7.9	6.4
100	2	7.0	7.6	—
101	5	3.1	3.6	3.3
104	2	3.2	4.1	—
107	5	6.1	4.0	6.7
109	4	6.6	7.8	7.4
110	3	7.4	8.3	—
112	3	7.2	8.6	—
113	4	6.9	7.1	7.0
114	5	7.3	8.5	7.8

6.0 QUALITY OF SURFACE WATER--Continued

6.4 Sulfate

Sulfate Concentrations are Generally High in Streams Draining Mined Areas

Sulfate is usually the highest in concentration and the most persistent dissolved constituent in coal-mine drainage. Sulfate concentrations at some sites can be estimated from specific conductance values.

High concentrations of dissolved sulfate in water are commonly considered to be indicative of coal-mine drainage. Surface mining disturbs the land and exposes rocks and soil containing sulfurous minerals to oxidation and hydrolysis. These reactions produce sulfuric acid which is generally neutralized near the mine site by calcareous minerals in rocks, soil, or water. However, sulfate ions remain in solution as the most persistent constituent of coal-mine drainage. Sulfate concentrations in streams draining non-coal bearing or slightly mined coal-bearing areas generally are less than 30 mg/L, but sulfate concentrations from intensively mined areas are highly variable and range from 20 to 2,700 mg/L.

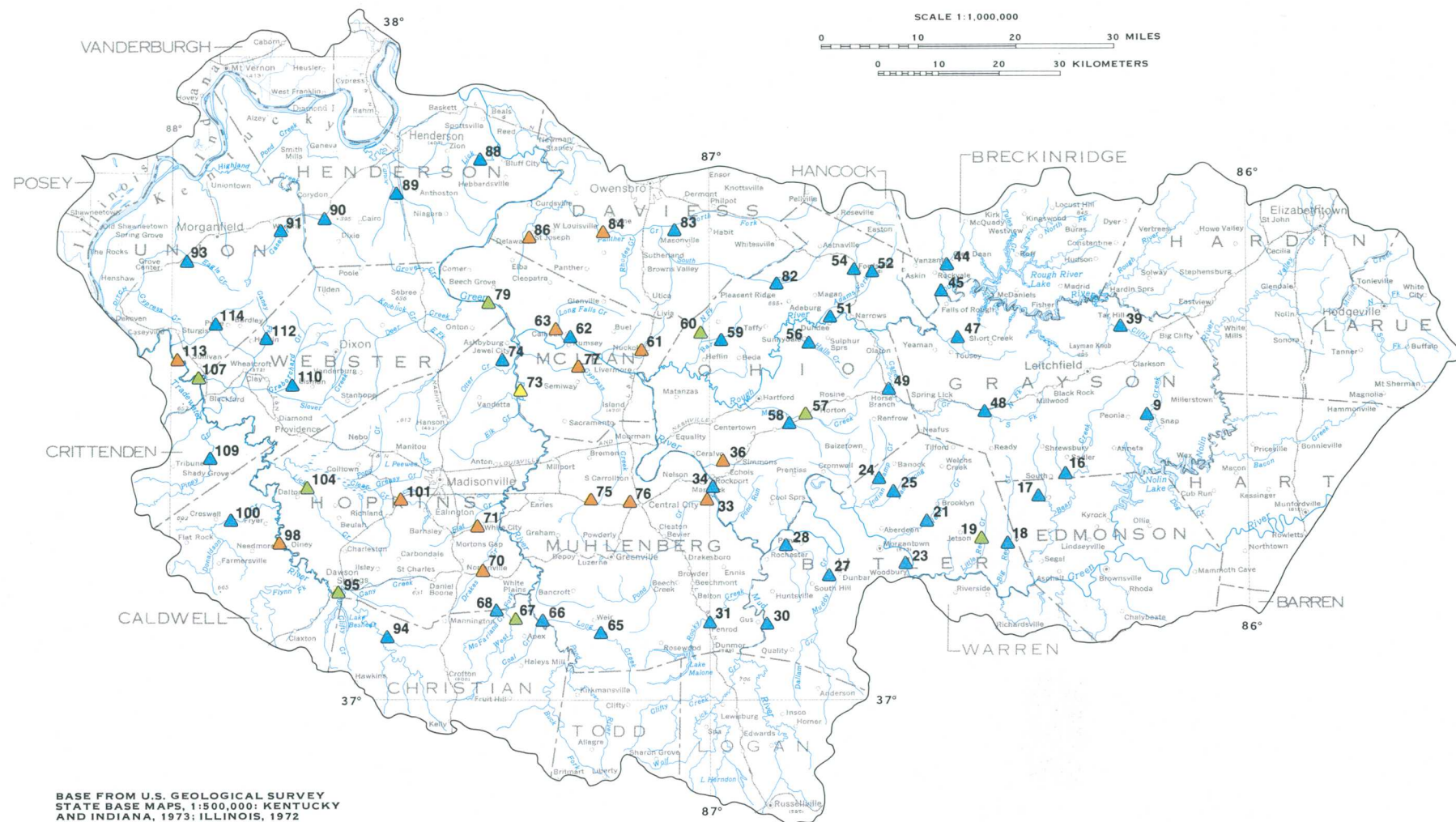
The variability of sulfate concentrations in streams draining mined areas is primarily due to the amount of reactive minerals in spoil material, the length of time of exposure of these materials to weathering, and the quantity of water leaving the mined areas. Sulfate concentrations are highest during low flow, when contact time with spoils is fairly long, and lowest during high flow when contact time is short and dilution occurs. A decrease in concentration occurs downstream due to dilution by increased streamflow.

Sulfate concentrations in Area 34 are highest in streams draining the headwaters of the Tradewater

River, the lower Pond River, and Cypress Creek (fig. 6.4-1). Concentrations at these sites range from 12 to 2,700 mg/L, and exceed 200 mg/L most of the time.

Sulfate concentration at some streamflow sites in Area 34 correlates significantly with specific conductance values (fig. 6.4-2). The correlations indicate a significant difference in the sulfate concentration between a mined site in the coal-bearing rocks (site 98), an unmined site in the coal-bearing rocks (site 82), and a site in the non coal-bearing rocks (site 66). Sulfate concentrations at the site affected by mining (site 98) are about 2 to 4 times higher than at an unmined site (site 66) for the same specific conductance value. No correlation exists between specific conductance values and sulfate concentration at the unmined site in the coal-bearing rock area (site 82).

A relation between sulfate concentrations and specific conductance values for all the sites in Area 34 was tested and found not to be highly significant. Estimates of sulfate concentration from the specific conductance-sulfate concentration relation are low for mined sites and high for unmined sites. The relations for site 98 and site 66, however, may be used to reasonably estimate sulfate concentrations at these respective sites. Similar relations may exist for other sites in the area.



BASE FROM U.S. GEOLOGICAL SURVEY
STATE BASE MAPS, 1:500,000: KENTUCKY
AND INDIANA, 1973; ILLINOIS, 1972

EXPLANATION

MAXIMUM SULFATE CONCENTRATION In milligrams per liter

- ▲ 0 to 99
- ▲ 100 to 499
- ▲ 500 to 999
- ▲ 1,000 and greater

See section 10.1 for detailed site description.

Figure 6.4-1 Sulfate sampling sites.

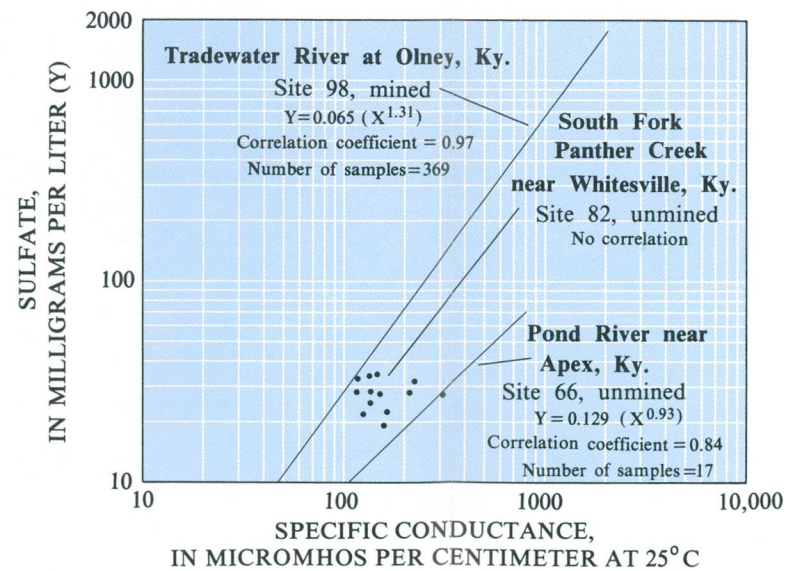


Figure 6.4-2 Regression of the sulfate concentrations and specific conductance values at selected sites in mined and unmined basins.

Table 6.4-1 Summary of sulfate concentrations, in milligrams per liter.

Site Number	Number of Samples	Minimum	Maximum	Mean	Median
9	6	7.4	15	10	10
16	6	15	32	22	22
17	6	12	22	17	18
18	5	13	23	17	16
19	5	15	130	40	18
21	5	19	38	25	20
23	115	8.4	35	16	15
24	5	23	39	31	31
25	5	14	21	18	19
27	12	12	55	24	19
28	4	39	50	43	42
30	8	16	41	26	26
31	5	13	20	16	14
33	8	370	2060	1260	1250
34	12	19	78	36	33
36	6	450	1600	1240	1350
39	5	7.5	17	11	10
44	5	20	60	40	39
45	9	7.6	29	15	15
47	5	23	52	34	29
48	5	16	29	21	20
49	9	2.0	30	20	20
51	12	13	34	19	17
52	6	5.9	17	14	14
54	4	22	26	24	23
56	5	21	26	23	22
57	5	53	190	115	110
58	6	15	26	22	24
59	5	20	97	40	28
60	5	46	120	87	88
61	5	110	1400	576	420
62	15	23	83	43	41
63	6	210	1600	1280	1500
65	5	30	88	61	55
66	15	15	43	26	25
67	5	27	120	77	64
68	2	25	38	--	--
70	5	160	1200	798	990
71	3	740	1500	--	--
73	10	79	690	297	220
74	4	26	64	42	38
75	4	930	2140	1540	1550
76	4	1000	2700	1980	2100
77	11	290	1300	731	700
79	68	16	120	55	50
82	14	19	35	29	28
83	5	32	66	49	47
84	14	22	1200	260	105
86	5	410	1300	882	860
88	5	24	37	28	25
89	6	11	38	29	30
90	4	26	45	33	30
91	6	31	98	61	58
93	4	18	32	25	26
94	4	18	24	21	20
95	2	25	210	--	--
98	370	12	1600	240	173
100	2	33	40	--	--
101	4	1400	1700	1550	1550
104	2	250	340	--	--
107	5	76	400	259	260
109	4	12	43	30	32
110	3	19	82	--	--
112	3	29	85	--	--
113	4	80	1100	462	335
114	5	35	55	44	39

6.0 QUALITY OF SURFACE WATER--Continued

6.5 Iron

Iron Concentrations Vary with Location and Discharge

Total iron concentrations in streams increase with flow and are generally higher at sites draining mined areas. The dissolved fraction near mined areas is relatively low, and decreases with increases in streamflow.

Iron is common in rocks, and in soils rich in organic material. Surface mining exposes iron-bearing minerals in rocks and soils to accelerated weathering, and produces iron compounds that enter streamflow. Most of the iron is transported in particulate form (Hem, 1970).

Dissolved and total iron (suspended plus dissolved) are important water-quality parameters in considering the suitability of water for domestic and industrial uses. Dissolved-iron concentrations in excess of 300 $\mu\text{g/L}$ (micrograms per liter) cause staining, impart an undesirable taste to water, and require treatment for most uses (U.S. Environmental Protection Agency, 1976). Dissolved iron in aerated streams may precipitate, producing "yellow boy" (an insoluble precipitate), which flocculates and settles on stream beds. This precipitate has an adverse effect on the bottom aquatic life.

Determinations of iron concentrations at some sites in Area 34 began in 1972. Most of the samples were collected in the Tradewater River basin (Grubb and Ryder, 1972). Additional samples for dissolved and total iron concentrations have been collected from 66 sites in the area since 1979 (fig. 6.5-1).

The data show that the dissolved and total iron concentrations vary with the amount of streamflow, site location, and suspended-sediment concentration. There is no significant pattern in the areal distribution of iron concentrations in the area; high total and dissolved iron concentrations are in samples collected in streams from mined and unmined basins (table

6.5-1). A few sites draining areas with little or no mining (sites 89-93) have had maximum total iron concentrations in excess of the maximum permissible concentration established by the Act (7,000 $\mu\text{g/L}$). This is evidently caused by high concentrations of iron-bearing minerals in the thick alluvial-filled valleys in which these streams flow.

Statistical analyses of the iron concentrations at sites in Area 34 do not indicate significant correlation with streamflow or other parameters such as specific conductance. However, correlations with the suspended-sediment concentration at site 77 indicates that most of the iron is transported with the suspended sediments (fig. 6.5-2). At most sites, the suspended-sediment load increases with increasing streamflow and as much as 75 percent of the annual suspended-sediment load may be transported in one storm. Consequently, most of the iron is also transported during periods of high runoff. Spot sampling for determination of iron loads is inadequate. Multiple samples must be collected during storms in order to define iron loads, unless a well defined relation between iron concentrations and suspended-sediment loads exists.

The data also show that dissolved iron is usually a small fraction of the total iron (table 6.5-2). There are no significant increases in the dissolved-iron concentration with large increases in flow at most of the sites. Dissolved-iron loads can be effectively estimated from spot samples collected during low-to-medium flows.

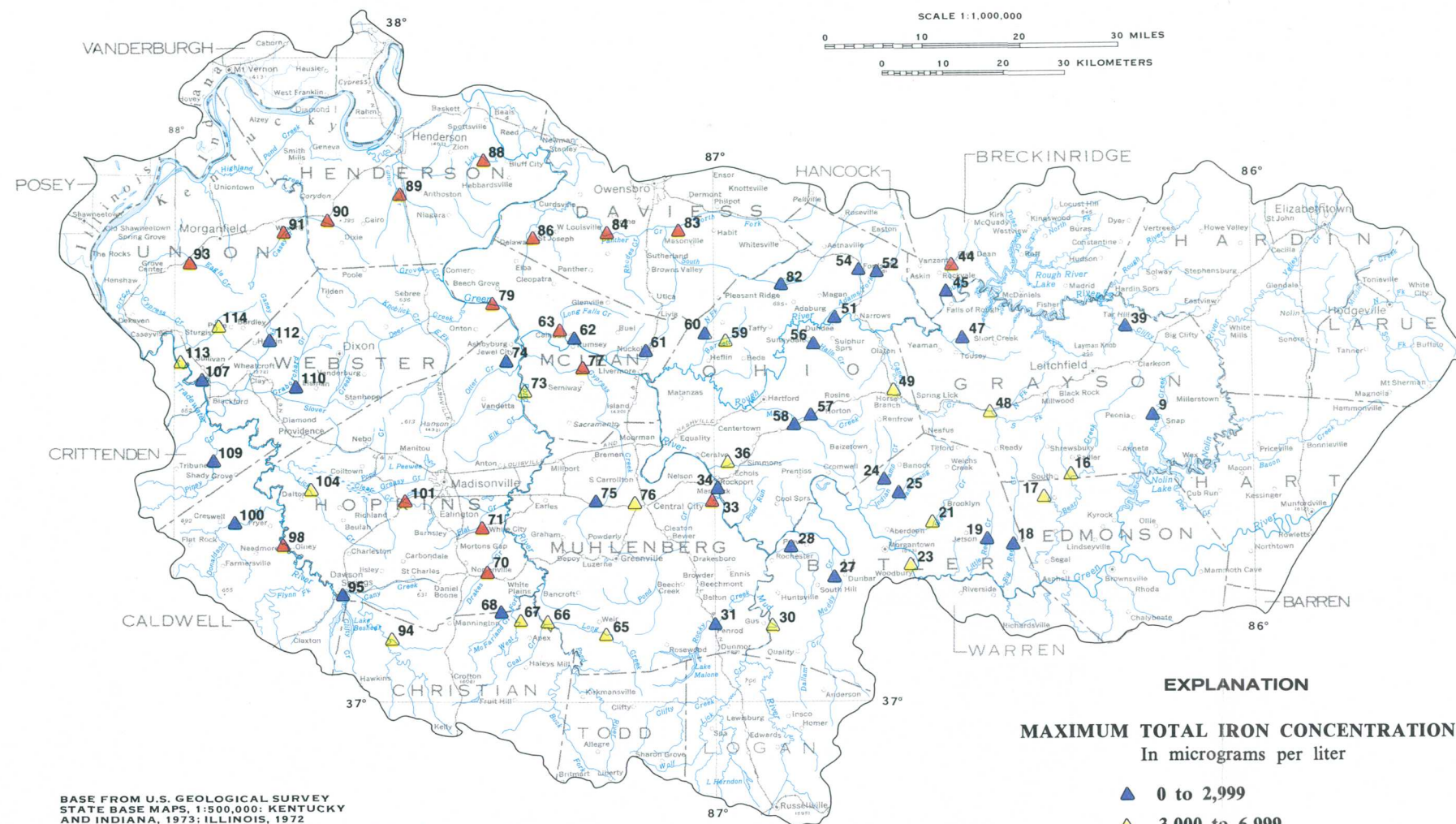


Figure 6.5-1 Iron sampling sites.

EXPLANATION

MAXIMUM TOTAL IRON CONCENTRATION
In micrograms per liter

▲ 0 to 2,999
▲ 3,000 to 6,999
▲ 7,000 and greater

75 Site number

See section 10.1 for detailed site description.

Table 6.5-2 Dissolved and total iron concentrations at various streamflows.

Station Name	Site Number	Streamflow (ft ³ /s)	Dissolved Iron (ug/L)	Total Iron (ug/L)
Tradewater River at Olney	98	1.0	20	490
		9.9	30	530
		101	60	800
		1170	80	10000
		2580	80	3100
Pond River near Apex	66	9.0	20	2300
		179	0	2100
		935	820	3900
		1890	80	9700
Cypress Creek near Calhoun	77	7.5	80	2000
		139	50	1600
		438	70	1900
		625	110	950
Panther Creek near Owensboro	84	4.2	60	1000
		72	130	1500
		949	500	7900
		1860	2200	4500

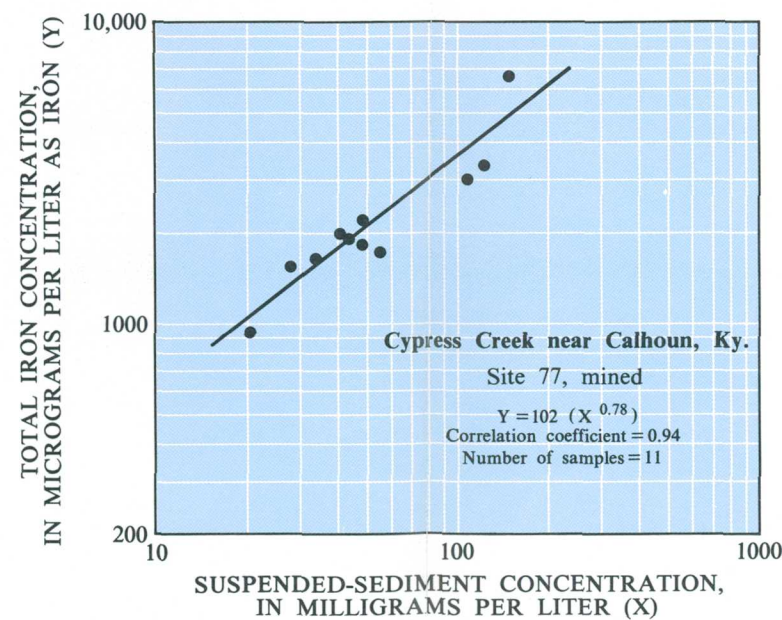


Figure 6.5-2 Regression of the total iron concentrations and the suspended-sediment concentrations for Cypress Creek near Calhoun, Kentucky.

Table 6.5-1 Summary of total iron concentrations, in micrograms per liter as iron.

Site Number	Number of Samples	Minimum	Maximum	Mean	Median
9	6	220	660	440	440
16	6	800	5700	2190	1650
17	6	430	5400	1710	860
18	5	880	2900	1650	1000
19	5	480	1300	852	840
21	5	1200	5400	2480	1700
23	12	350	5400	1310	875
24	5	620	2200	1290	1100
25	5	790	1300	975	960
27	6	530	2600	1650	1700
28	4	1100	2600	2000	2150
30	8	630	3900	1490	1150
31	5	840	1300	1020	990
33	6	920	7500	4890	5450
34	11	680	2000	1120	1000
36	6	1100	4300	2100	1850
39	5	550	990	725	800
44	5	1100	30000	7000	1300
45	6	710	2100	1190	895
47	4	140	6600	1900	435
48	5	1200	6300	2590	1500
49	6	410	5500	2680	2480
51	12	600	11000	2210	1600
52	6	630	1700	1060	1040
54	4	330	860	595	595
56	5	430	1400	720	540
57	5	450	2800	984	560
58	6	220	2300	917	775
59	5	640	6300	2480	990
60	5	560	1500	854	650
61	5	260	2000	892	750
62	10	610	2800	1460	1400
63	6	280	4100	1000	385
65	5	620	5200	2270	1100
66	10	790	3100	1770	1900
67	5	640	3100	1720	2000
68	2	780	1100	--	--
70	5	2900	35000	16400	18000
71	3	5900	7000	--	--
73	9	970	5500	1940	1600
74	3	1700	2600	--	--
75	4	480	1900	1000	805
76	4	510	4100	1540	780
77	10	950	7000	2610	2000
79	25	100	12000	3220	2000
82	10	450	5000	1370	1100
83	5	320	7200	2490	1100
84	14	1000	7900	3600	3200
86	5	480	8700	2240	720
88	5	580	10000	2810	970
89	6	1700	27000	7030	3200
90	4	520	18000	6280	3300
91	6	750	19000	7080	5750
93	4	1200	26000	8280	2950
94	3	1000	5500	--	--
95	3	380	1100	--	--
98	88	10	10000	410	195
100	2	5500	10000	--	--
101	4	7000	12000	8900	8300
104	2	540	3300	--	--
107	5	630	2300	1630	1900
109	4	480	1900	1240	1280
110	2	1400	1500	--	--
112	3	280	970	--	--
113	4	1400	3100	2150	2050
114	5	700	4800	1950	840

6.0 QUALITY OF SURFACE WATER--Continued

6.6 Manganese

Manganese Concentrations are Higher in Streams Draining Mined Basins

Manganese concentrations in water samples from intensely mined basins of the Tradewater, lower Pond and Mud River basins are higher than in samples from basins where mining is not as intense. Most of the manganese is dissolved, and the concentration decreases as streamflow increases.

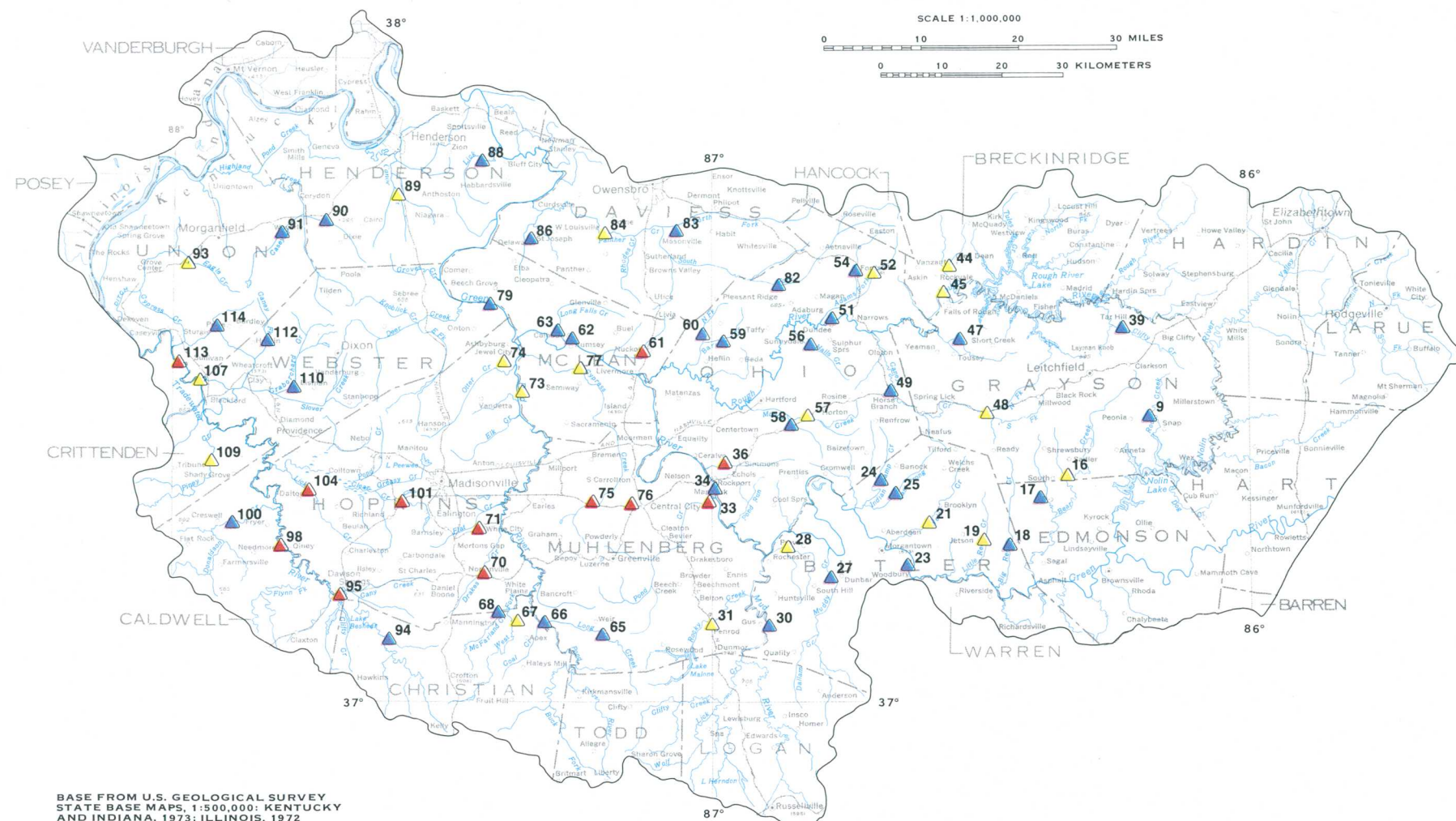
Manganese is one of the most common elements in soils and rocks. Soils rich in organic matter are one of the main sources of manganese in natural waters. Although dissolved manganese is an essential element for plant and animal metabolism, concentrations in water greater than 50 $\mu\text{g/L}$ produce an objectionable taste in water and cause staining of fabrics (U.S. Environmental Protection Agency, 1977).

The dissolution and transportation of manganese in natural waters are very similar to those of iron; significant amounts are suspended in particulate forms (Hem, 1970). Most water-quality criteria for water supply (U.S. Environmental Protection Agency, 1977) specify limits for dissolved manganese of 50 $\mu\text{g/L}$. The Act specifies 4,000 $\mu\text{g/L}$ as the maximum permissible concentration of total manganese (suspended plus dissolved) in effluents from mining activities.

Dissolved and total manganese concentrations were determined at 10 sites in Area 34 from 1972 to 1975. Early in 1979 the number of sampling sites was

expanded to 66 (fig. 6.6-1). In general, the data indicate a higher concentration of manganese (total and dissolved) at sites affected by surface mining in the Tradewater, Pond, and Mud River basins than in unmined basins (table 6.6-1). The maximum permissible concentration of total recoverable manganese (4,000 $\mu\text{g/L}$) is exceeded at about one-fourth of the sites. At many sites, the dissolved fraction constitutes most of the available manganese. Little or no change in the ratio between dissolved and total recoverable manganese occurs with increases in flow.

Statistical analyses of the data do not show any significant correlation between manganese concentration and other hydrologic parameters such as specific conductance, pH, streamflow, or suspended-sediment concentrations. However, the general trend of a decrease in the concentration of manganese with increasing streamflow is evident (table 6.6-2). Concentrations of manganese in streamflow in Area 34 can be estimated reasonably from spot samples collected during low to medium flow.



BASE FROM U.S. GEOLOGICAL SURVEY
STATE BASE MAPS, 1:500,000: KENTUCKY
AND INDIANA, 1973; ILLINOIS, 1972

EXPLANATION

MAXIMUM TOTAL MANGANESE CONCENTRATION In micrograms per liter

▲ 0 to 999

▲ 1,000 to 3,999

▲ 4,000 and greater

75 Site number

See section 10.1 for detailed site description

Table 6.6-2 Dissolved and total manganese concentrations at varied streamflows.
Analysis in Section 10.4

Station Name	Site Number	Streamflow (Ft ³ /s)	Dissolved Manganese (ug/L)	Total Manganese (ug/L)
Tradewater River at Olney	98	1.0	1800	1800
		9.9	5200	5300
		101	2200	2200
		1170	380	630
Pond River near Apex	66	2580	210	260
		9.0	120	260
		179	110	160
		935	130	180
Cypress Creek near Calhoun	77	1890	0	530
		7.5	1700	1900
		139	570	570
		438	920	920
Panther Creek near Owensboro	84	625	210	250
		4.2	1100	1100
		72	190	290
		949	250	290
		1860	200	200

Figure 6.6-1 Manganese sampling sites.

Table 6.6-1 Summary of total manganese concentrations,
in micrograms per liter.

Site Number	Number of Samples	Minimum	Maximum	Mean	Median
9	6	50	110	68	50
16	6	180	2100	772	360
17	6	70	780	328	190
18	5	50	140	112	120
19	5	140	3200	924	420
21	5	280	3100	970	330
23	14	40	200	95	100
24	5	230	770	452	400
25	5	130	380	226	190
27	6	130	260	188	190
28	4	410	1900	838	520
30	8	90	500	238	210
31	5	140	2100	730	370
33	6	2600	5100	4180	4550
34	12	100	180	140	135
36	5	4600	18000	9240	6800
39	5	80	450	264	310
44	5	140	1800	812	620
45	6	140	2200	923	795
47	4	50	620	218	100
48	5	360	2800	948	510
49	6	90	650	300	220
51	12	110	790	278	210
52	6	130	3500	850	365
54	4	90	490	258	225
56	5	80	140	114	120
57	5	870	2400	1690	1800
58	6	80	190	140	155
59	5	150	980	356	210
60	4	50	360	152	100
61	5	800	6600	2700	1700
62	11	140	810	263	210
63	6	380	920	583	530
65	5	180	280	212	190
66	10	90	1600	324	210
67	5	220	1300	762	980
68	2	200	220	--	--
70	5	2000	17000	9960	10000
71	3	8600	20000	--	--
73	10	420	3800	2060	1950
74	3	220	1100	--	--
75	4	180	6000	2690	2300
76	4	1400	5800	3550	3500
77	10	250	2200	1095	1010
79	24	70	840	315	280
82	10	150	440	279	305
83	5	80	400	198	170
84	14	170	1100	471	365
86	5	420	680	550	550
88	5	120	360	198	130
89	6	170	1200	477	350
90	4	100	410	215	175
91	6	200	450	358	385
93	4	420	1300	722	585
94	4	110	1000	395	235
95	3	1500	4900	--	--
98	170	10	39000	5000	3100
100	2	480	620	--	--
101	4	7400	11000	8820	8450
104	2	2000	6200	--	--
107	4	360	4000	2460	2750
109	4	180	1400	607	425
110	3	140	1000	--	--
112	3	70	130	--	--
113	4	220	5200	2880	3050
114	5	50	280	138	120

6.0 QUALITY OF SURFACE WATER--Continued
6.7 Sediment

**Sediment Data are Inadequate for Correlation
with Land Use**

Available suspended-sediment concentration data are representative only of low to medium-low flows. Data are insufficient for extrapolation of sediment discharge to other basins or to define relation between suspended sediment and land use.

Frequent sampling during the full range of flow is necessary to determine suspended-sediment yield from a basin. Sediment transport processes cannot be defined from random and intermittent sampling because one storm may transport most of the annual sediment load at a site.

The collection of sediment data in Area 34 has been limited. Grubb and Ryder (1972) correlated the suspended-sediment load of the Tradewater River at Olney (site 98) with coal production from strip mines in the basin. The sediment load increased 51 percent during a period when coal production increased 20 percent. However, the investigation was limited to the Tradewater River site, with no additional data collected throughout Area 34.

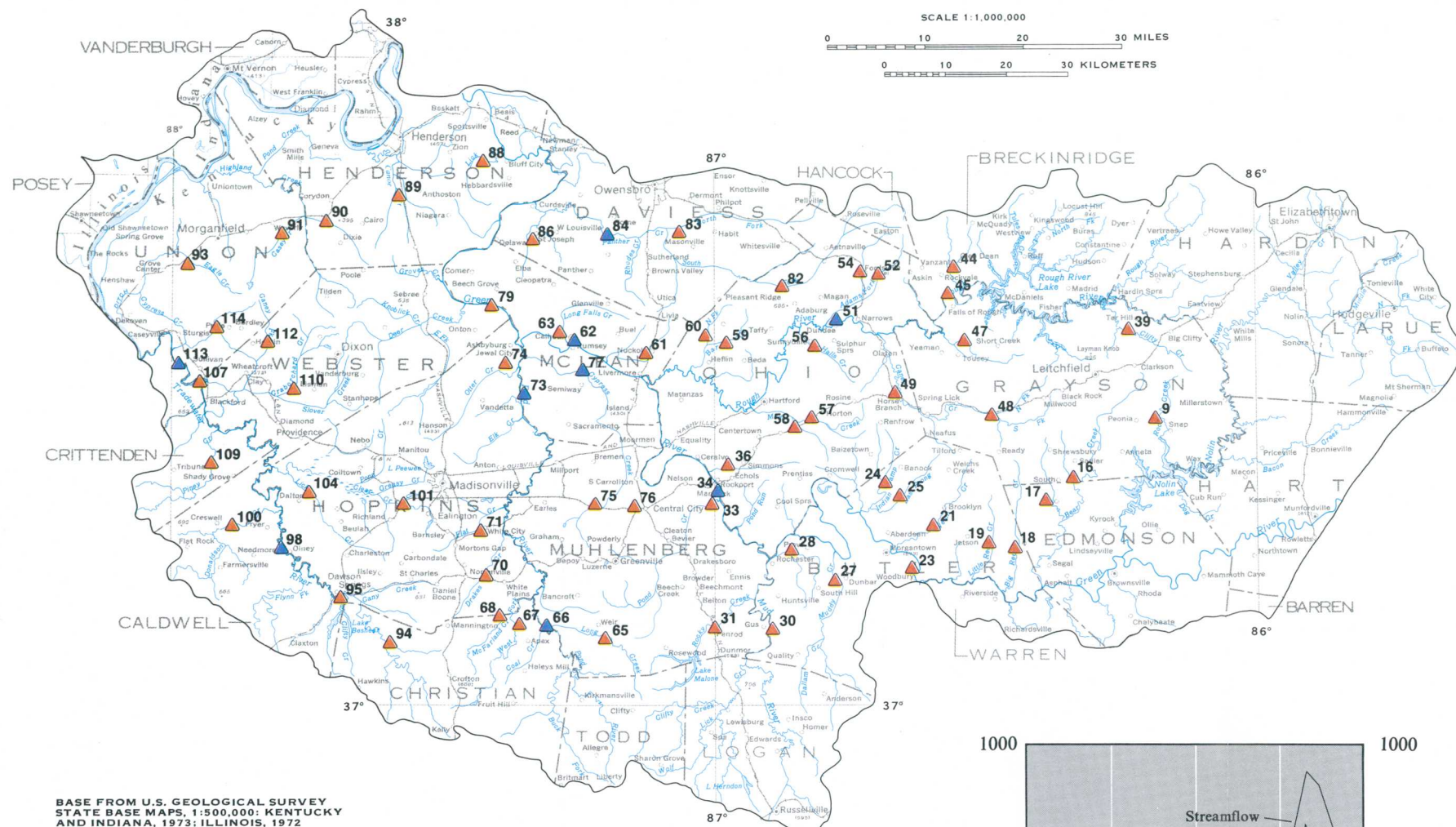
In response to the Act, the collection of suspended-sediment data was expanded in 1979 to 66 sites (fig. 6.7-1). At 10 sites samples were collected two to five times each week and during storms. At the other sites samples were collected four times each year during various flow conditions.

The data collected during 1979-80 represent low and medium-low flows and are inadequate to define

any relation between suspended-sediment and land use. However, preliminary sediment-transport curves have been defined and are available in the Kentucky District files for several of the sites that have sufficient samples.

An example of the relation between suspended-sediment load and streamflow is shown in figure 6.7-2. Similarly, the relation between suspended-sediment discharge and streamflow at several sites in different basins is shown in figure 6.7-3. There is no significant difference between the two curves for streams draining mined basins. The curve for the stream in the unmined basin is not appreciably different from the curves for the mined basins. However, the data show that the unmined basin contributes less suspended sediment per unit area at low flows than the mined basins. The data are insufficient to extrapolate this generalization to other basins in the area.

Suspended-sediment data for sites in Area 34 are published in the "Water Resources Data for Kentucky" annual reports. The information is also available in the Kentucky District office files.



EXPLANATION

FREQUENCY OF SAMPLING

- ▲ 2 to 5 times per week and during storms
- ▲ 4 times per year
- 17 Site number

See section 10.1 for detailed site description.

Figure 6.7-1 Suspended-sediment sampling sites.

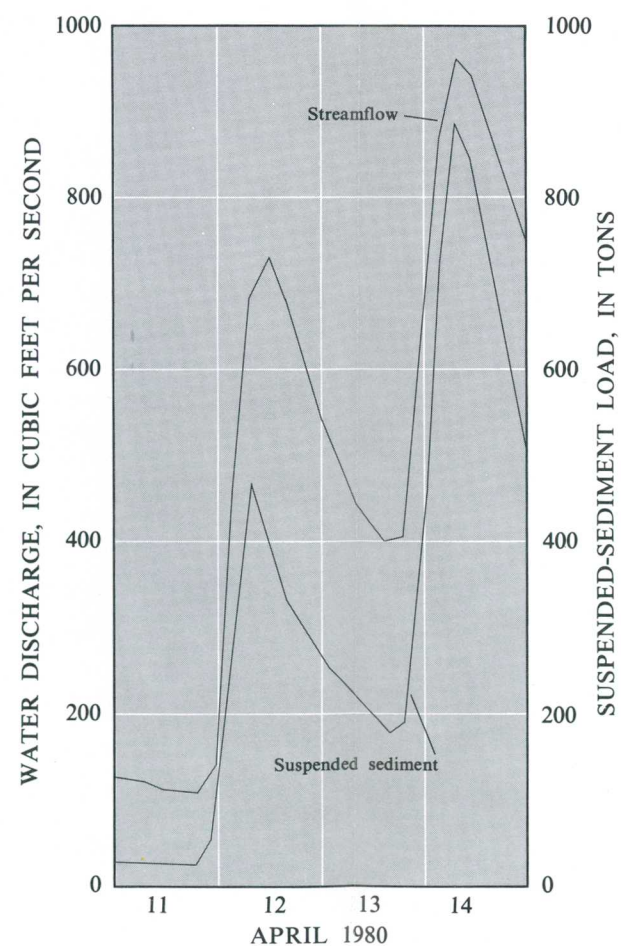


Figure 6.7-2 Relation between suspended-sediment load and water discharge at Cypress Creek near Calhoun, Kentucky.

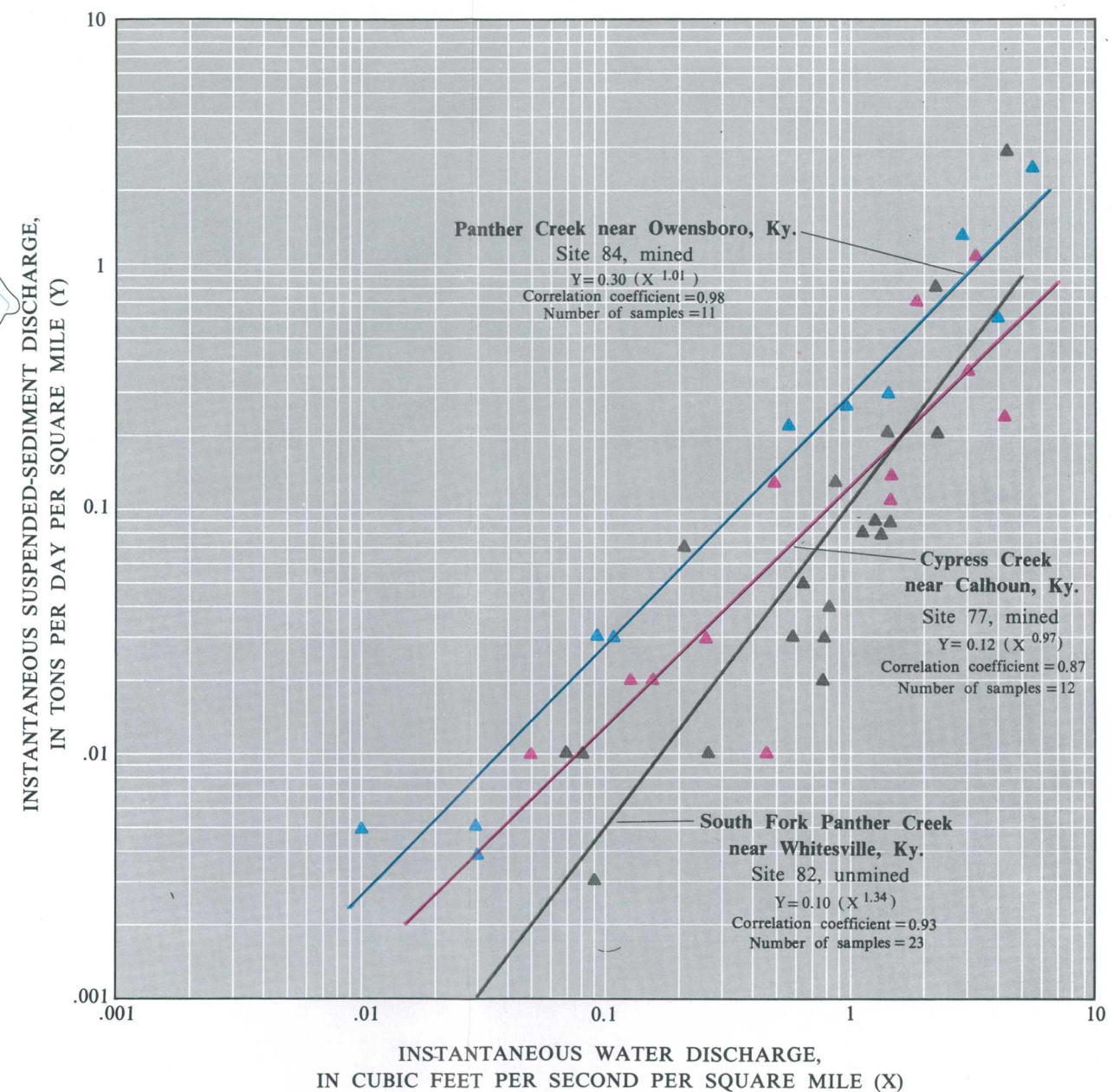


Figure 6.7-3 Relation between instantaneous water discharge and suspended-sediment loads at sites in Area 34.

6.0 QUALITY OF SURFACE WATER--Continued

6.8 Trace Constituents

Concentrations of Trace Constituents in Water and Stream-Bottom Sediments Generally Low, but Some Waters Exceed Limits

Maximum concentrations of mercury, lead, and cadmium in water at selected sites exceed recommended State and Federal limits for aquatic life and/or domestic water supply.

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

Trace metals are common in coal and associated rocks. The weathering of exposed sulfur minerals in mine spoils produces sulfuric acid. The acid accelerates the leaching of minerals and dissolution of salts, increasing the dissolved-solids concentration in water. Mine drainage, particularly when acidic, usually contains concentrations of trace constituents that exceed background levels. When the mine-drainage is neutralized, the trace constituents as well as iron and manganese are precipitated and concentrated in stream bottom deposits (such as "yellow boy").

Concentrations of selected trace constituents in water and bottom sediments at selected sites in Area 34 are shown in figure 6.8-1 and tables 6.8-1 and 6.8-2. The data in table 6.8-1 includes only sites with more than one sample. Additional data for other sites in the area that have one analysis are in section 10.4 and are published in "Water Resources Data for Kentucky" (U.S. Geological Survey, 1980). The single samples were collected during periods of low streamflow.

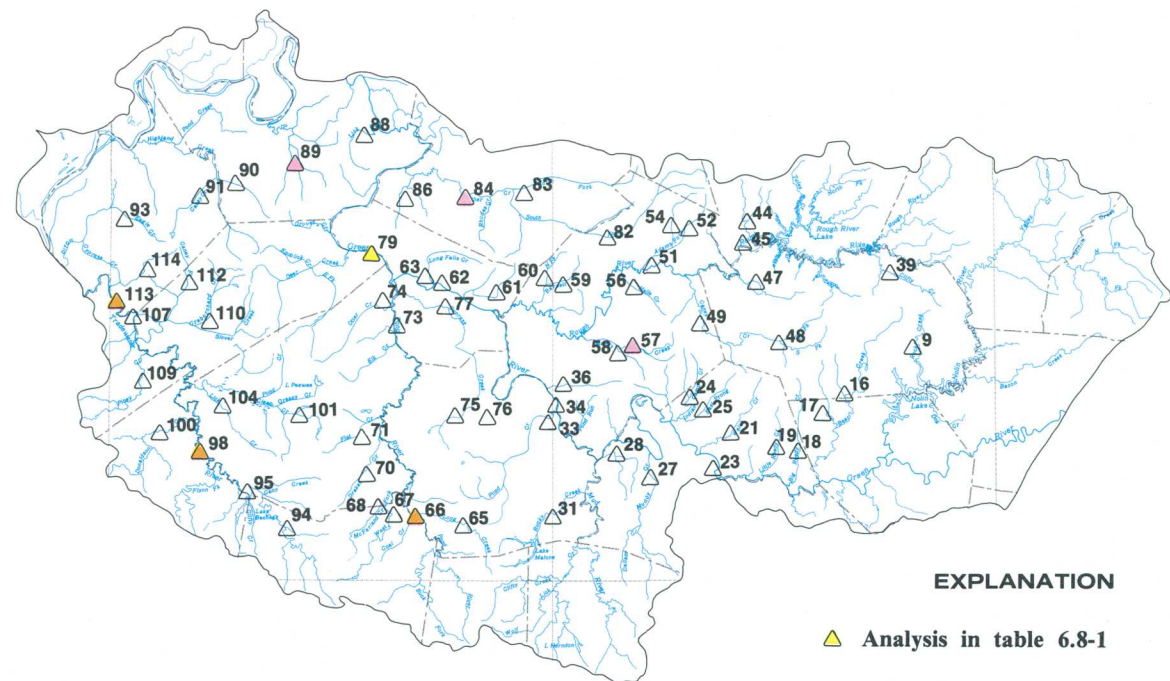
The available data show that dissolved and total

concentrations of mercury in water at all but one site (site 3) exceeded Federal and State recommended limits of $0.05 \mu\text{g/L}$ for aquatic life (table 6.8-1), but is still within the limit of $2.0 \mu\text{g/L}$ for drinking water. The greatest mercury concentrations (in excess of $0.5 \mu\text{g/L}$) occurred in water from streams in the coal-bearing rocks.

Concentrations of other trace constituents such as cadmium and lead occasionally exceeded the maximum recommended limits for domestic water supply. Total cadmium concentrations exceeded $10 \mu\text{g/L}$ at least once at five of the sites and lead concentrations exceeded $50 \mu\text{g/L}$ at two sites. No relation is apparent between cadmium or lead concentrations and land use.

Stream-bottom sediments at selected sites in Area 34 did not contain significant amounts of trace constituents (table 6.8-2). Comparisons of bottom sediments between sites affected by mining and sites where no coal or mining occurs (sites 39, 66, 89, and 98) show no significant differences in trace-constituent concentrations. Concentrations of iron and manganese in bottom sediments did not differ significantly between mined and unmined sites.

The transport and fate of trace constituents is related to the transport of suspended sediment. The data in Area 34 are not adequate to define these relations. An intensive program involving time and stage sampling would be required to investigate these processes.

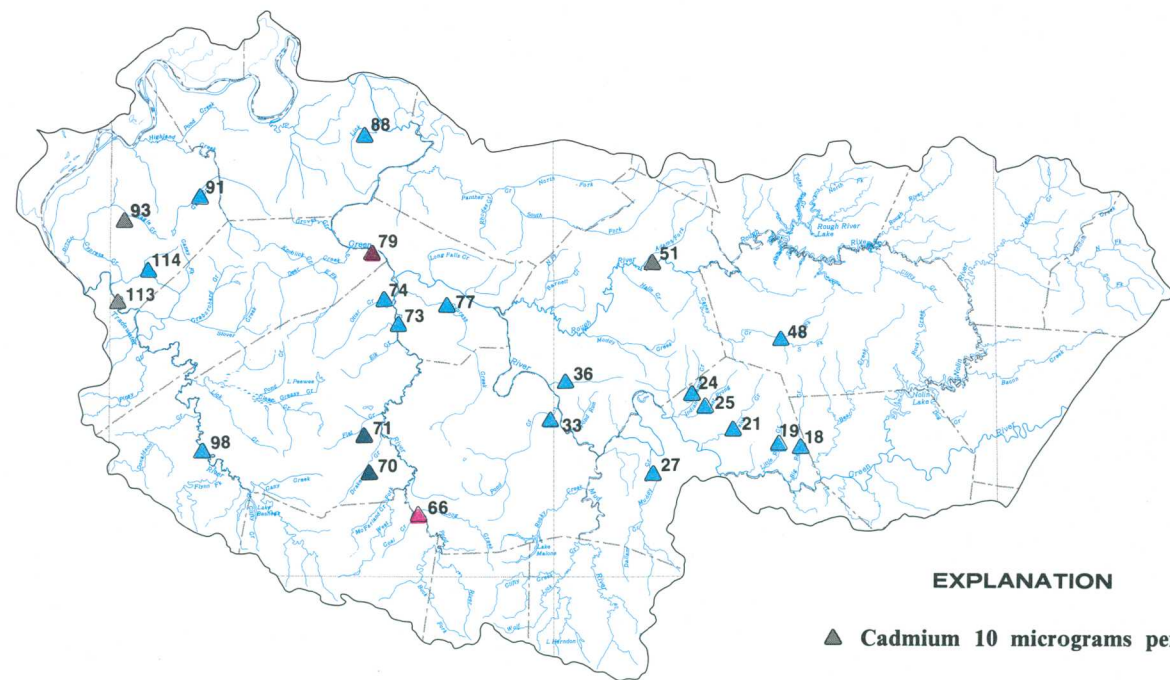


EXPLANATION

- ▲ Analysis in table 6.8-1
- ▲ Analysis in table 6.8-2
- ▲ Analysis in tables 6.8-1 and 6.8-2
- △ Analysis in Section 10.4

83 Site number

See section 10.1 for detailed site description.



EXPLANATION

- ▲ Cadmium 10 micrograms per liter or greater
- ▲ Lead 50 micrograms per liter or greater
- ▲ Mercury 0.5 micrograms per liter or greater

57 Site number

See section 10.1 for detailed site description.

Table 6.8-1 Concentration of selected trace constituents in water, in micrograms per liter.

TOTAL					DISSOLVED				
Site number	Number of samples	Min	Max	Mean	Number of samples	Min	Max	Mean	
ARSENIC	66	10	1	5	2	9	0	1	0.2
	79	23	0	6	1	24	0	2	1
	98	—	—	—	—	—	—	—	—
	113	9	1	11	2	8	0	1	.3
CADMIUM	66	10	0	7	2	9	0	6	2
	79	22	0	42	4	22	0	8	2
	98	—	—	—	—	—	—	—	—
	113	9	0	12	3	8	0	12	3
COBALT	66	9	0	5	1	9	0	0	0
	79	25	0	11	2	25	0	6	1
	98	—	—	—	—	—	—	—	—
	113	8	5	17	10	8	2	12	7
COPPER	66	10	3	14	6	9	0	8	4
	79	25	3	48	11	24	1	18	6
	98	2	0.0	5	2	—	—	—	—
	113	9	2	22	7	8	0	20	6
LEAD	66	10	6	56	16	9	0	42	8
	79	24	3	65	18	24	0	40	6
	98	—	—	—	—	—	—	—	—
	113	9	5	48	17	8	0	11	6
MERCURY	66	10	.4	.5	.5	9	.5	.5	.5
	79	23	.1	.5	.4	24	.1	.5	.4
	98	—	—	—	—	—	—	—	—
	113	9	.5	.5	.5	8	.5	.5	.5
SELENIUM	66	—	—	—	—	—	—	—	—
	79	23	0	1	.8	24	0	1	.8
	98	—	—	—	—	—	—	—	—
	113	—	—	—	—	—	—	—	—
ZINC	66	10	0	60	28	9	0	20	14
	79	24	20	130	43	24	0	130	22
	98	2	60	470	—	—	—	—	—
	113	9	30	160	82	8	30	90	56

Table 6.8-2 Concentration of selected trace constituents in bottom sediments, in micrograms per gram.

Site number	Number of samples	Min	Max	Mean or value	Number of samples	Min	Max	Mean or value	Number of samples	Min	Max	Mean or value	Number of samples	Min	Max	Mean or value
39	—	—	—	—	1	—	—	10	1	—	—	20	1	—	—	10
57	1	—	—	1	1	—	—	10	1	—	—	10	1	—	—	30
66	9	2	11	7	9	10	10	10	9	10	20	11	9	10	40	16
84	1	—	—	0	1	—	—	10	1	—	—	20	1	—	—	20
89	1	—	—	3	1	—	—	10	1	—	—	10	1	—	—	10
98	1	—	—	0	1	—	—	10	1	—	—	80	1	—	—	60
113	8	9	31	14	8	10	10	10	8	10	20	11	8	10	60	21
39	1	—	—	10	1	—	—	12000	1	—	—	10	1	—	—	1200
57	1	—	—	10	1	—	—	17000	1	—	—	10	1	—	—	690
66	9	10	110	21	—	—	—	—	9	10	10	10	—	—	—	—
84	1	—	—	20	1	—	—	21000	1	—	—	20	1	—	—	800
89	1	—	—	20	1	—	—	18000	1	—	—	20	1	—	—	1100
98	1	—	—	30	1	—	—	8600	1	—	—	50	1	—	—	2700
113	8	10	20	12	—	—	—	—	8	10	75	18	—	—	—	—
39	—	—	—	—	—	—	—	—	1	—	—	10	—	—	—	—
57	1	—	—	0	1	—	—	0	1	—	—	40	—	—	—	—
66	9	0	2.1	.4	—	—	—	—	9	10	60	29	—	—	—	—
84	1	—	—	0	1	—	—	0	1	—	—	60	—	—	—	—
89	1	—	—	0	1	—	—	0	1	—	—	50	—	—	—	—
98	1	—	—	0	1	—	—	0	1	—	—	220	—	—	—	—
113	8	0	.8	.3	—	—	—	—	8	40	160	98	—	—	—	—

Figure 6.8-1 Trace constituents sampling sites.

7.0 GROUND WATER

7.1 Occurrence, Movement, and Availability

Ground Water is Present in Consolidated and Unconsolidated Sediments

Ground water generally occurs in sandstone in the bedrock of upland areas and in the alluvial sand and gravel in the valley of the Ohio River. In the eastern part of Area 34, ground water occurs in solutional openings in limestone.

Water that enters the aquifers in Area 34 comes mostly from precipitation which falls directly on the land and in part finds its way to the water table (fig. 7.1-1). Some ground water is recharged by influent seepage from streams that flow across outcrop areas. Ground water exists in two different environments: the consolidated bedrock and the unconsolidated sand and gravel of the Ohio River and its tributaries.

In medium-grained poorly cemented sandstones, such as the Caseyville at places, the yield of wells may be derived largely from intergranular openings (pores), although water from fractures may increase the yield. In sandstones that are fine grained, shaly, or well cemented, intergranular openings may yield very little water directly to wells. In these rocks, most successful wells obtain water from fractures. Generally these openings are comparatively large and numerous at shallow depth and are smaller and more widely spaced at greater depth.

In limestones, fractures may be enlarged by solution and may yield large amounts of water to wells or springs. In the unconsolidated sand and gravel deposits of the Ohio River, the yield of wells is derived entirely from intergranular openings.

Ground water movement in the consolidated rocks is poorly understood but appears to be local as no regional aquifers are known with the possible exception of some of the pre-Pennsylvanian limestones in the eastern part of Area 34.

The availability of ground water in the Pennsylvanian bedrock depends chiefly on the character, thickness, and depth of the aquifers penetrated and to a limited extent on the topographic situation of the

well. Most of the bedrock aquifers in Area 34 are sandstones. They vary in thickness and composition and may thin and disappear in very short distances. The aquifers may be friable and highly permeable, or may contain such large amounts of shale or cementing material that they yield only small amounts of water. In the Pennsylvanian deposits of Area 34, the thickness and character of geologic units may change greatly over short distances. A given unit may be a thick sandstone at one locality, whereas at another point a few miles away it may consist chiefly of shale. Thus, the availability of water in any geologic unit may range widely. The depth to the aquifer largely determines the cost of drilling the well and may influence the quality of water obtained, inasmuch as saline water is present at depth. The depth to the aquifer also may influence the amount of water obtained if the water occurs in fractures, which generally become smaller with increasing depth. Topography seems to have little effect on the availability of ground water in the Western Coal Field region, except for shallow-water bodies penetrated by dug wells and some shallow drilled wells. Shallow wells on hills are apt to go dry, but most of the drilled wells penetrate below the zone of water-table fluctuation. A statistical summary of well characteristics and well locations is shown in table 7.1-1. These data on 567 drilled wells tapping Pennsylvanian rocks in the area can be used to estimate well characteristics at a particular site to aid in determining the location of a ground-water monitoring well, or other similar uses.

Data for this discussion are taken with little change from Maxwell and Devaul (1962, p. 15, 16, and 22).

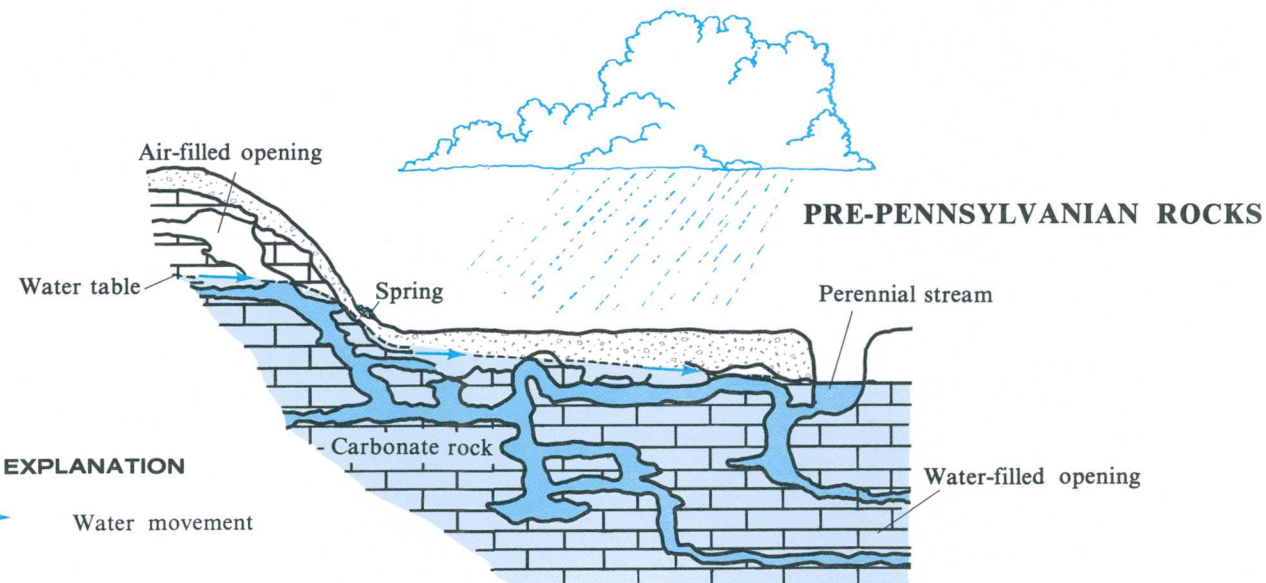
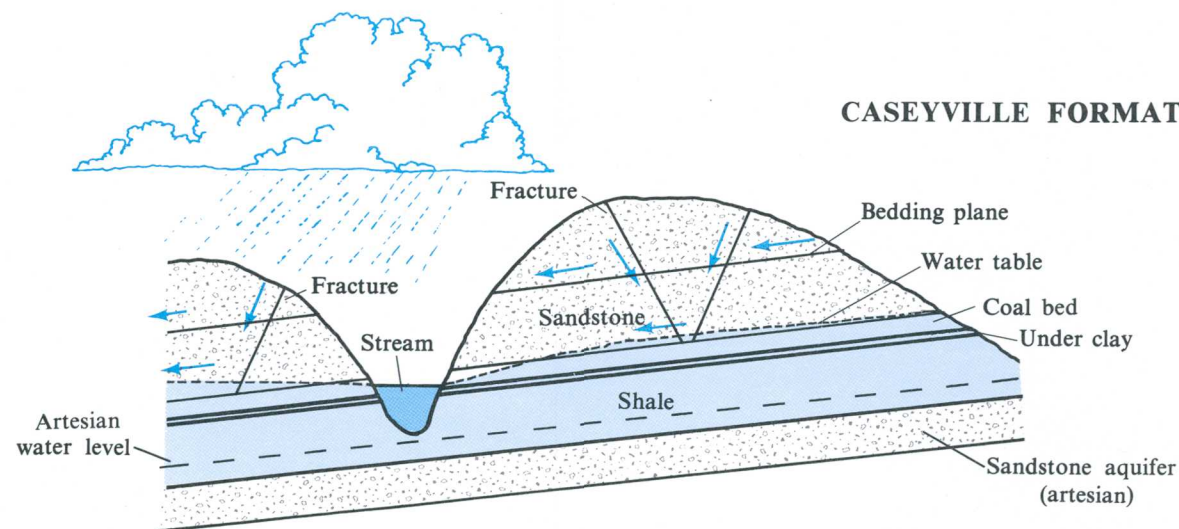
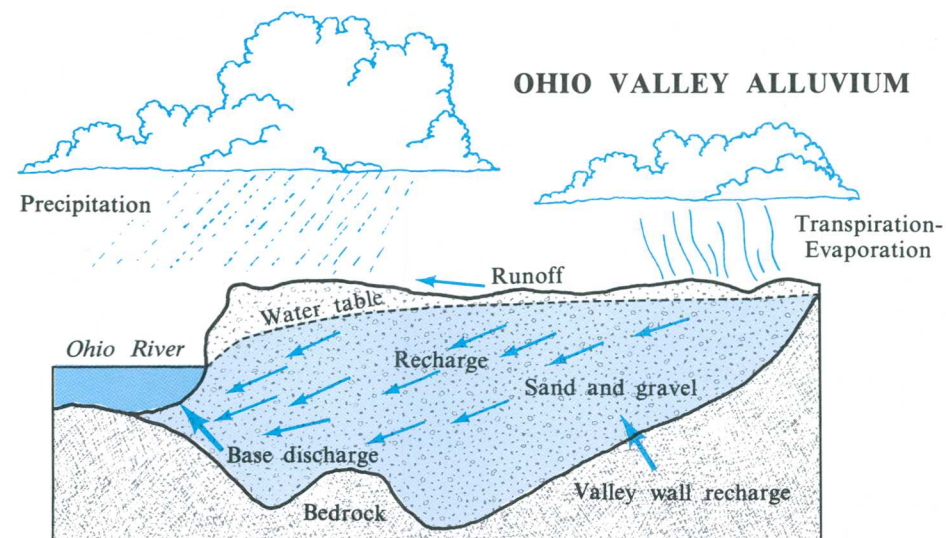


Figure 7.1-1 Water movement in aquifers.

Table 7.1-1 Correlation of data from 567 drilled wells in Pennsylvanian rocks.

Type of well	Water table	78		4	37	27	3	7	9	60	10	-	-	-	-	-	-	-	14	7	52	5	16	62	73	5	-	78	3	75	24	54							
Topographic situation	Artesian	489	86	128	164	38	73	4	145	191	103	22	20	3	221	221	44	3	7	10	14	35	229	52	133	9	0	489	437	52	11	478	30	459	137	352			
	Broad upland		90					2	23	29	26	3	5	2	38	37	13	2	-	3	4	9	47	8	17	2	3	87	85	5	3	87	6	84	15	75			
	Hilltop			165				3	67	63	24	4	4	-	95	62	8	-	1	1	-	2	67	17	70	7	7	158	149	16	3	162	8	157	42	123			
	Hillslope				191			4	82	67	27	5	6	-	116	65	10	-	1	-	3	14	79	15	75	4	6	185	176	15	-	191	6	185	66	125			
	Base of hill					41		4	13	11	9	3	1	-	20	20	1	-	5	3	2	3	11	4	13	0	-	41	33	8	2	39	5	36	15	26			
	Valley bottom						80	-	20	31	17	7	4	1	26	41	12	1	-	3	5	7	39	15	10	1	-	80	67	13	3	77	8	72	23	57			
	Depth in feet	0-25							13							13	-	-	-	-	1	-	-	1	1	10	-	0	13	11	2	-	13	1	12	5	8		
25-75									205						189	16	-	-	-	-	2	7	55	23	112	6	11	194	187	18	-	205	4	201	71	134			
75-150										201					88	108	5	-	-	2	8	13	97	24	51	6	5	196	184	17	1	200	20	181	57	144			
150-300											103				4	85	14	-	5	-	2	11	67	5	11	2	-	103	93	10	1	102	5	98	19	84			
300-500												22			1	13	8	-	-	3	1	1	13	3	1	-	-	22	19	3	2	20	2	20	4	18			
500-1,000													20		-	3	17	-	2	2	1	3	9	3	-	-	-	20	15	5	5	15	-	20	4	16			
1,000+														3	-	-	-	3	-	2	-	-	1	-	-	-	-	3	1	2	2	1	1	2	1	2			
Distance from outcrop area in miles	0-1														295					2	1	8	10	92	31	143	8	13	282	274	21	-	295	11	284	94	201		
	1-5															225				3	5	3	17	126	25	41	5	3	222	196	29	4	221	20	205	60	165		
	5-15																44			2	2	3	8	24	3	1	1	-	44	39	5	5	39	1	43	6	38		
	15+																	3	-	2	-	-	1	-	-	-	-	3	1	2	2	1	1	2	1	2			
Yield in gallons per minute	100+																		7										7	7	-	-	7	-	7	2	5		
	50-100																			10									-	10	8	2	2	8	2	8	2	8	
	25-50+																				14								-	14	13	1	1	13	3	11	2	12	
	0-25+																					35							0	35	34	1	1	34	3	32	4	31	
	Domestic power pump																						243						4	239	224	19	6	237	13	230	55	188	
Dependability Reported	Domestic hand pump																												0	59	48	11	-	59	2	57	22	37	
	Bailer or bucket																												8	177	67	18	-	185	10	175	67	118	
	Inadequate																												14	4	10	9	5	1	13	-	14	7	7
	Goes dry																												16		14	2	-	16	1	15	2	14	
Quality	Never dry																													551	496	55	11	540	32	519	159	392	
	Suitable for domestic use																													510		-	510	25	485	120	390		
	Unsuitable for domestic use																													57	11	46	8	49	41	16			
	Reported salty																														11		2	9	4	7			
	Reported not salty																															556	31	525	157	399			
	Odor of H ₂ S																																33		12	21			
	No odor of H ₂ S																																	534	149	385			
	Reported iron objectionable																																		161				
	Reported iron not objectionable																																			406			

Modified from Maxwell and Devaul, 1962

Explanation of data for above table

Any two items of well data may be correlated by locating the number in the square formed by the intersection of the column and row of the two items.

Each such number is the number of wells in which the two items occur simultaneously. Example: 2 wells are 150 to 300 feet deep and are inadequate; or, of 103 wells that are 150 to 300 feet deep, 2 are inadequate; or of 14 wells that are inadequate, 2 are 150 to 300 feet deep.

The sum of all numbers in each large rectangle enclosed by heavy lines is equal to the number of wells in consideration. The sum of each column of numbers in rectangles enclosed by heavy lines is in the square at the base of each column. The sum of each row of numbers in rectangles enclosed by heavy lines is in the square to the left of each row.

7.0 GROUND WATER

7.1 Occurrence, Movement, Recharge, and Discharge

7.0 GROUND WATER--Continued

7.2 Water Levels

Ground-Water Levels Rise and Lower Seasonally

Ground-water levels rise in winter and decline in summer in response to changes of water in storage in aquifers. Evapotranspiration strongly influences recharge.

Water levels in wells are an indication of the amount of ground water in storage. During years with normal precipitation, ground-water levels rise and fall in a seasonal cycle. The highest water levels are in spring before the growing season and the lowest are in fall before killing frost.

Ground-water levels, typical of wells tapping Pennsylvanian rocks in Area 34, are shown in figure 7.2-1. Although the seasonal fluctuation is about 10 feet, the long-term fluctuation is toward a stable average water level with no upward or downward trend. The seasonal rise and fall of the ground-water level in this well for a shorter, later period of time are shown in figure 7.2-2 at an expanded scale.

Ground-water levels in the Ohio River alluvium have a similar seasonal fluctuation (fig. 7.2-3); however, river stage also has an effect on the ground-water levels. Above average precipitation in the 1970's has caused a valley-wide upward trend in ground-water levels.

Ground-water levels in areas of pre-Pennsylvanian limestone change similar to those in the Pennsylvanian rocks (fig. 7.2-4), but changes are more rapid because the water can move faster in solutional openings than it can in the water-bearing fractures and intergranular openings of the Pennsylvanian rocks.

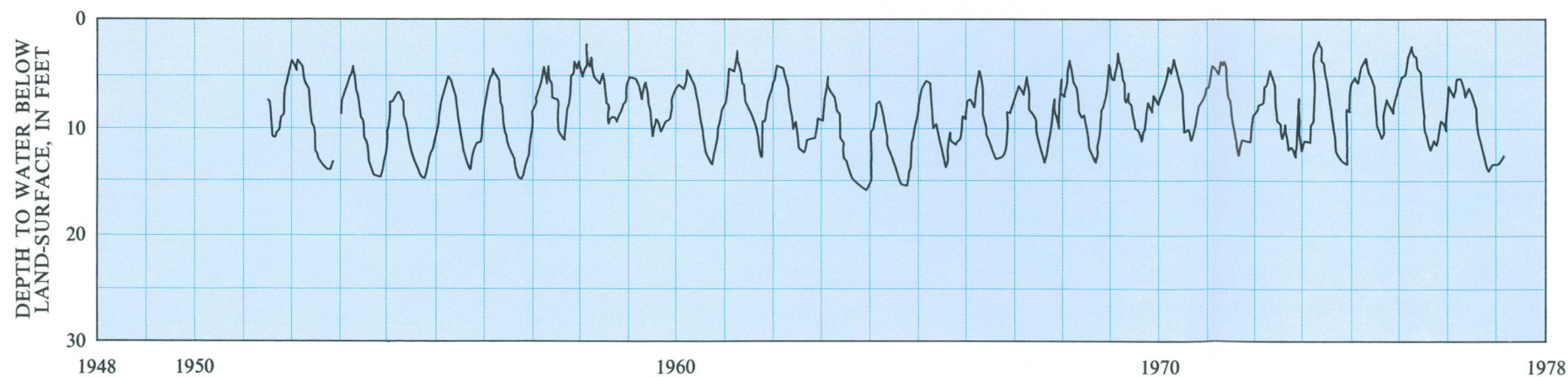


Figure 7.2-1 Long-term trend of water levels in a well 59-feet deep, in Union County, Kentucky.

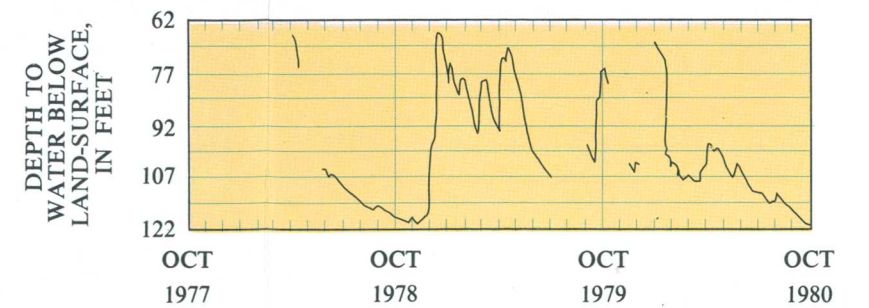


Figure 7.2-4 Rapidly fluctuating water levels in a well 232 feet deep in Hart County, Kentucky.

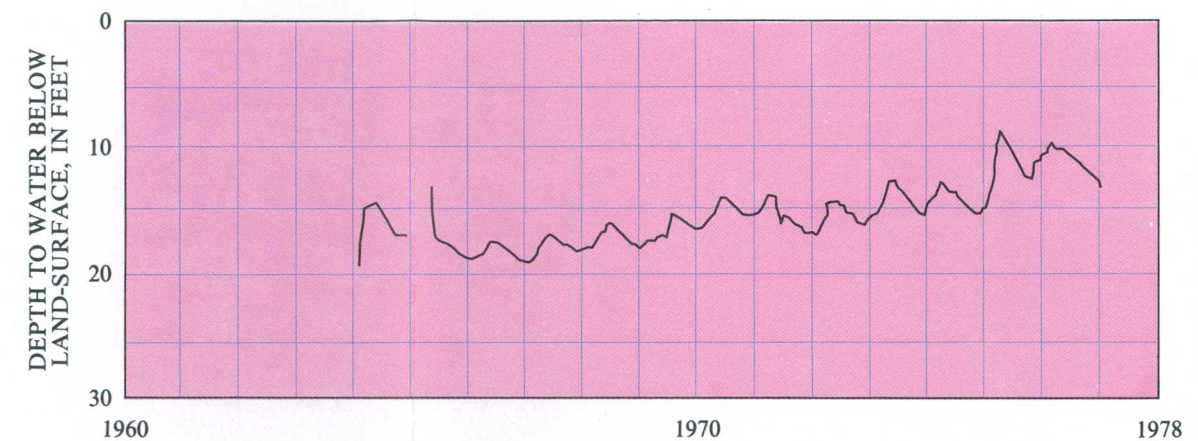


Figure 7.2-3 Long-term trend of water levels in a well 114-feet deep near Owensboro, Kentucky.

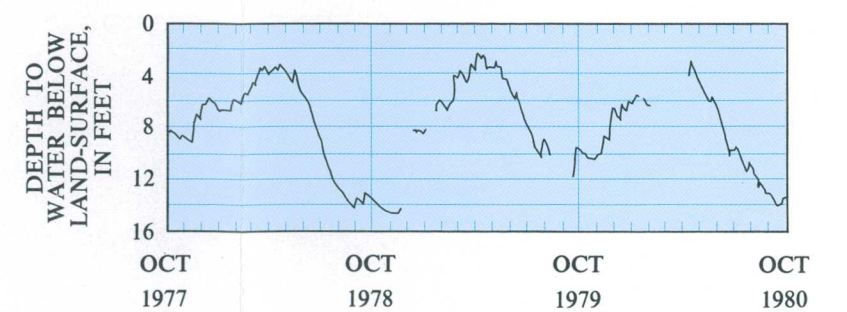


Figure 7.2-2 Typical seasonal fluctuations of ground water in wells in Area 34.

7.0 GROUND WATER--Continued

7.3 Yields

Yields to Wells Vary Greatly

Yields to wells can vary from inadequate for domestic use to as much as 4,000 gallons per minute.

In the Pennsylvanian bedrock of Area 34, the number and degree of interconnection of openings vary greatly and well yields tend to be highly variable. Yields of as much as 250 gal/min have been reported from some of the more massive sandstone aquifers, although the average yield is much less. Many aquifers seldom yield more than 20 gal/min to a well and, in some cases, the amount of water obtained is insufficient for domestic use. Because the geology changes rapidly both laterally and vertically, the use of data from nearby wells to predict yields at a specific site sometimes can be futile.

Larger amounts of water are available from sand and gravel of the Ohio River alluvium where single wells can yield from a few hundred to as much as 1,000 gal/min. Collector type wells have yielded 3,000 to 4,000 gal/min. Much smaller yields are obtained from the alluvium along tributary streams, where sand and gravel deposits are thinner.

In some cases aquifers can be so isolated by bounding faults and facies changes that no water is available to recharge the aquifer; therefore, pumpage actually mines water. This results in rapidly declining water levels as shown in an observation well 380 feet from a well pumping 100 gal/min at the town of Mortons Gap (fig. 7.3-1). Under such conditions a well that initially is adequate in the short term can eventually become inadequate for its intended use because of little or no recharge to the aquifer (Davis and others, 1974, p. 20-22).

Yields of wells from pre-Pennsylvanian limestones are generally sufficient for domestic use. The amount of water available depends on the size of solutional opening penetrated by the wells and yields of wells can vary from essentially zero to several hundred gallons per minute.



BASE FROM U.S. GEOLOGICAL SURVEY
STATE BASE MAPS, 1:500,000: KENTUCKY
AND INDIANA, 1973; ILLINOIS, 1972

EXPLANATION

Coal-bearing rocks

Well and number

See section 10.3 for detailed site description



Figure 7.3-1 Hydrograph of water level in an observation well in Mortons Gap, Hopkins County, showing drawdown and mining of ground-water.

8.0 QUALITY OF GROUND WATER

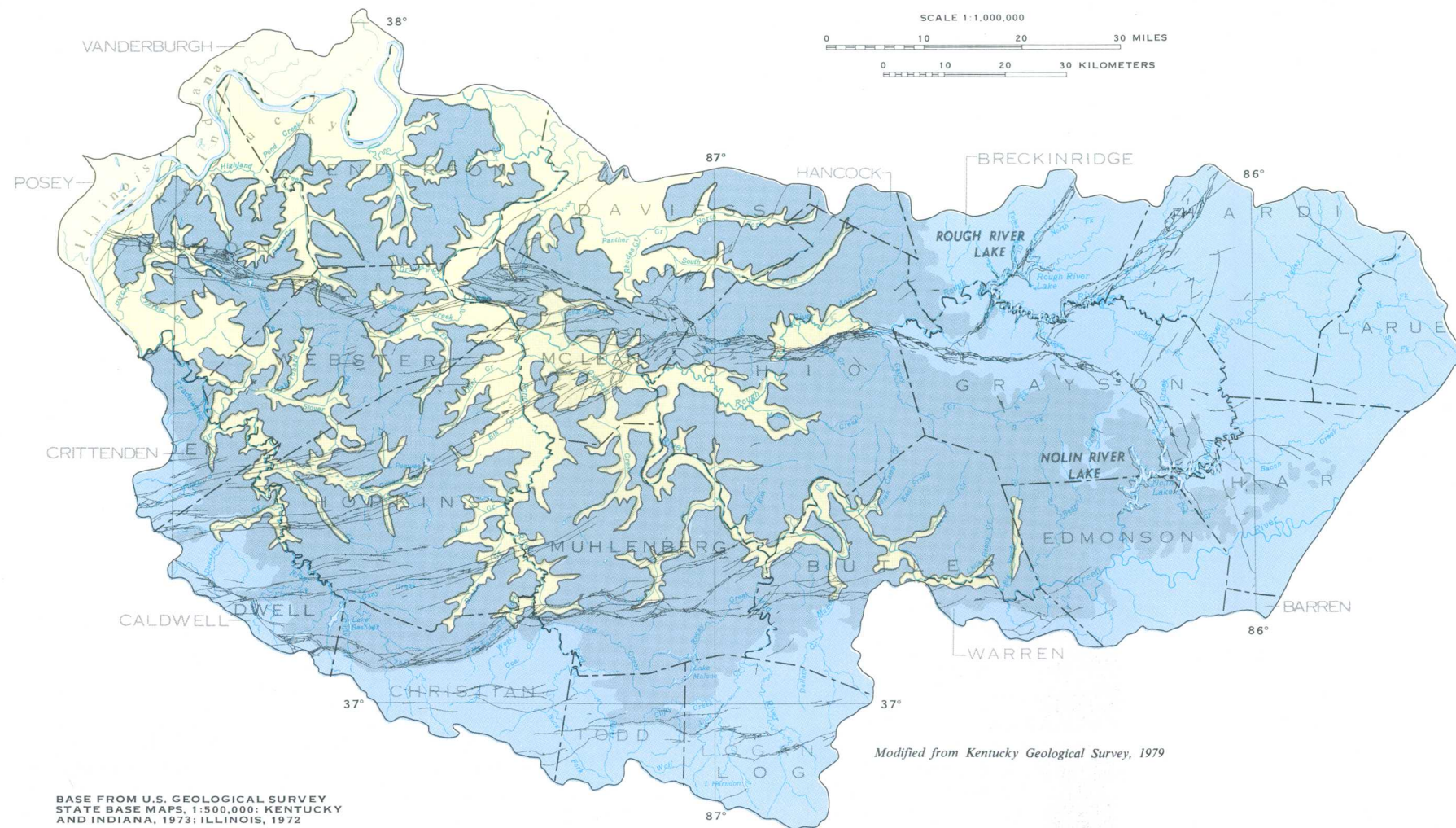
Ground-Water Quality is Characterized by Randomness and Variability

Ground water from the shallow bedrock aquifers generally is soft to moderately hard, but may contain undesirable amounts of iron. Water quality can change drastically in short distances, both laterally and vertically.

The water in the shallow Pennsylvanian bedrock aquifers of Area 34 generally is of the calcium bicarbonate or sodium bicarbonate type. At greater depths, calcium bicarbonate water becomes less common, and the water usually is more highly mineralized and is of the sodium bicarbonate or sodium chloride type. Almost all the sodium chloride water is too highly mineralized for domestic use. Saline water has been found at depths as shallow as 100 feet, but, conversely, fresh water has been obtained from depths approaching 1,000 feet (Davis and others, 1974). Fresh water may underlie salt water in some areas. Water quality may vary drastically over relatively small horizontal and vertical distances. Generally, total water quality is characterized by variability and randomness, with no discernable areal patterns. Individual analyses of water from wells and springs in Area 34 and elsewhere in Kentucky are published in Faust and others (1980).

Water from the alluvium is generally of the calcium bicarbonate type and is generally harder and contains more iron than water from the bedrock. Water from most wells and springs in pre-Pennsylvanian rocks is hard and of the calcium bicarbonate type.

Available minimum, maximum, mean, and median values for the concentration of common chemical constituents in ground water from wells and springs in Area 34 are shown in figure 8.0-1. Because of the broad range of some constituents, the median value is more typical or representative of natural ground water than the mean or the extreme values. Waters with specific conductance values greater than 10,000 $\mu\text{mhos/cm}$ were considered to be unsuitable for domestic use and were not used in compiling the water quality tables in figure 8.0-1.



- EXPLANATION**
- Alluvium
 - Pennsylvanian rocks
 - Pre-Pennsylvanian rocks
 - Fault

Figure 8.0-1 Chemical composition of ground water.

Concentrations in milligrams per liter unless otherwise specified					
Constituent	Range	Mean	Median	Number of samples	
ALLUVIUM	Iron (Fe)	0 - 31	2.9	1.3	215
	Calcium (Ca)	18 - 220	74	73	98
	Magnesium (Mg)	3.5 - 73	24	24	98
	Sodium (Na)	3.8 - 220	19	8.9	91
	Potassium (K)	0.2 - 7.4	1.4	1.0	92
	Bicarbonate (HCO ₃)	20 - 690	278	288	195
	Sulfate (SO ₄)	0 - 273	39	24	219
	Chloride (Cl)	1.0 - 405	23	9	220
	Dissolved solids (residue at 180°C)	165 - 1,130	340	323	92
	Specific conductance (micromhos per centimeter at 25°C)	121 - 2,120	580	546	220
	Hardness as calcium carbonate (CaCO ₃)	4 - 850	270	268	220
	pH (units)	5.7 - 8.8	-	7.3	174
Constituent	Range	Mean	Median	Number of samples	
PENNSYLVANIAN	Iron (Fe)	0 - 48	2.2	0.3	288
	Calcium (Ca)	0.5 - 556	50	18	158
	Magnesium (Mg)	0 - 462	28	8.7	158
	Sodium (Na)	4 - 2,398	207	147	145
	Potassium (K)	0.1 - 33	2.6	1.7	145
	Bicarbonate (HCO ₃)	0 - 1,595	426	388	301
	Sulfate (SO ₄)	0 - 3,550	155	28	296
	Chloride (Cl)	2 - 3,209	73	21	310
	Dissolved solids (residue at 180°C)	82 - 5,980	823	519	141
	Specific conductance (micromhos per centimeter at 25°C)	59 - 9,460	1,113	850	311
	Hardness as calcium carbonate (CaCO ₃)	2 - 2,910	222	100	296
	pH (units)	2.7 - 9.3	-	7.5	206
Constituent	Range	Mean	Median	Number of samples	
PRE-PENNSYLVANIAN	Iron (Fe)	0 - 630	1.7	0.09	661
	Calcium (Ca)	3.6 - 680	81	54	217
	Magnesium (Mg)	0.2 - 321	24	7.2	217
	Sodium (Na)	0.6 - 1,698	48	3.5	208
	Potassium (K)	0.2 - 27	1.9	1.0	198
	Bicarbonate (HCO ₃)	0 - 1,140	184	166	758
	Sulfate (SO ₄)	0 - 3,531	106	10	761
	Chloride (Cl)	0 - 2,600	28	5	807
	Dissolved solids (residue at 180°C)	28 - 5,850	450	228	321
	Specific conductance (micromhos per centimeter at 25°C)	250 - 9,040	524	325	829
	Hardness as calcium carbonate (CaCO ₃)	1 - 2,780	243	161	761
	pH (units)	1.9 - 9.4	-	7.4	728

9.0 WATER-DATA SOURCES

9.1 Introduction

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.

9.0 WATER-DATA SOURCES--Continued
9.2 National Water-Data Exchange--NAWDEX

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

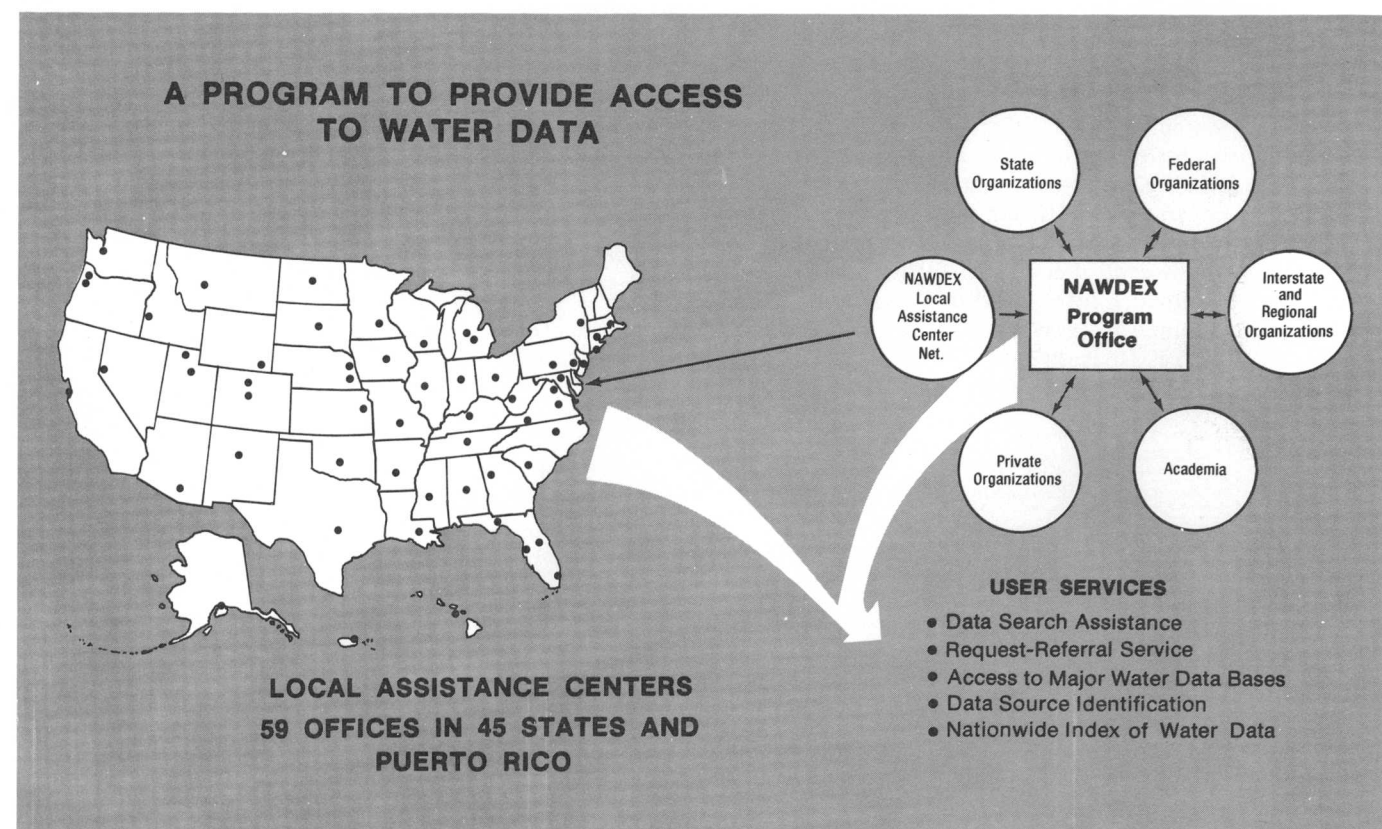


Figure 9.2-1 Access to water data.

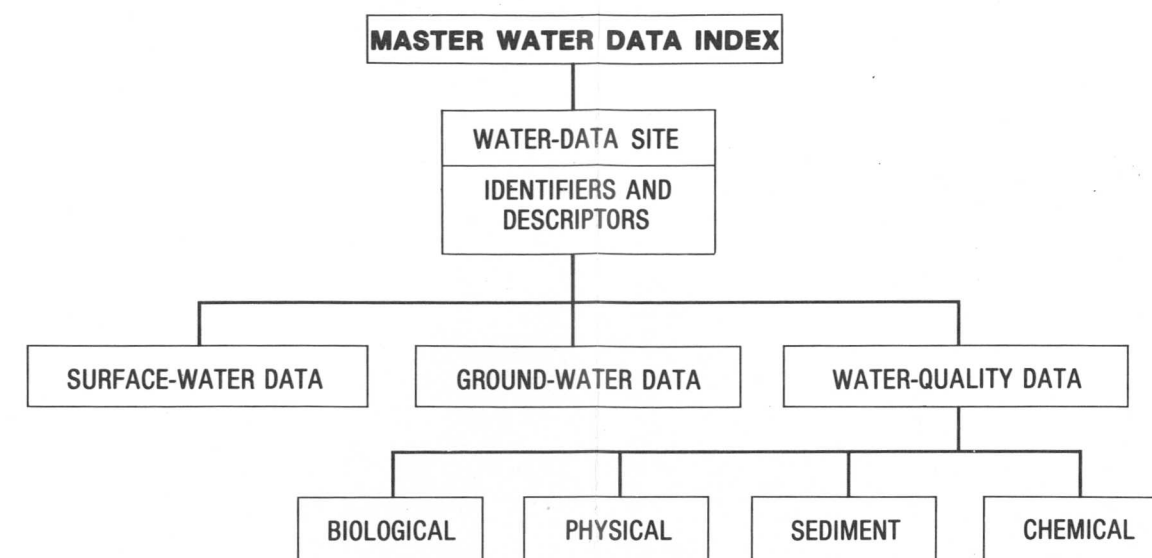


Figure 9.2-2 Master water-data index.

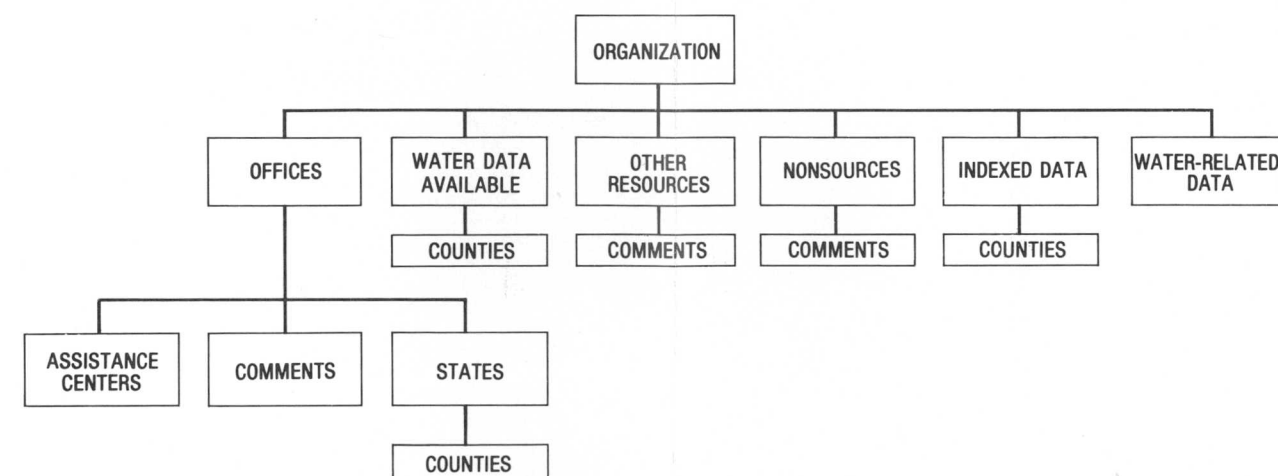


Figure 9.2-3 Water-data sources directory.

9.0 WATER-DATA SOURCES--Continued
9.3 WATSTORE

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 determina-

tions 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.

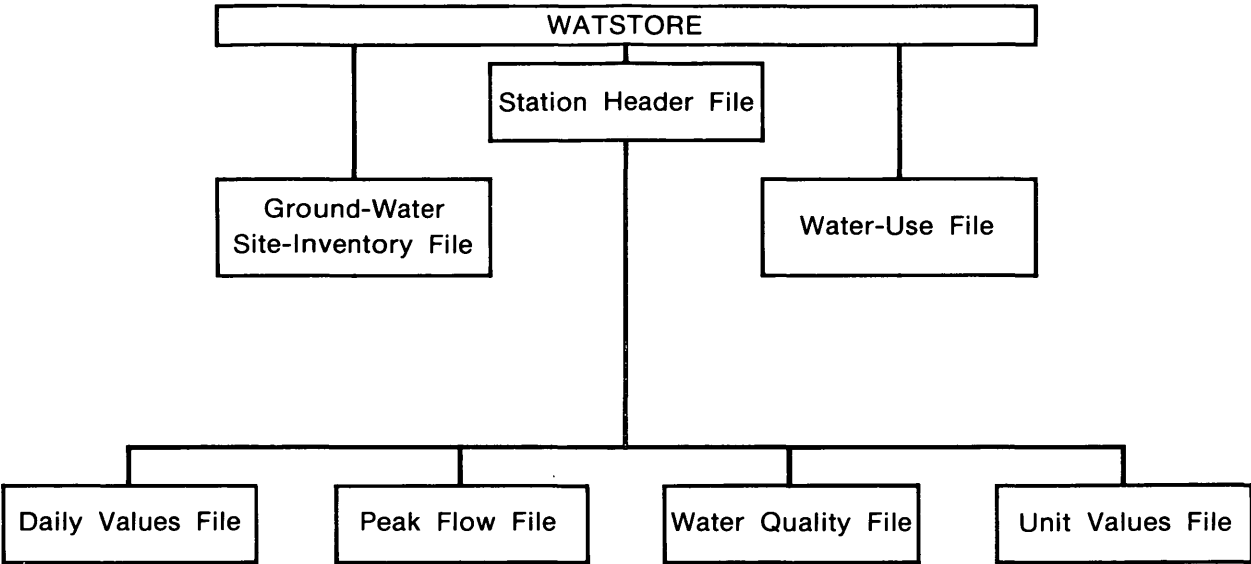


Figure 9.3-1 Index file stored data.

9.0 WATER-DATA SOURCES--Continued

9.4 Index to Water-Data Activities in Coal Provinces

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

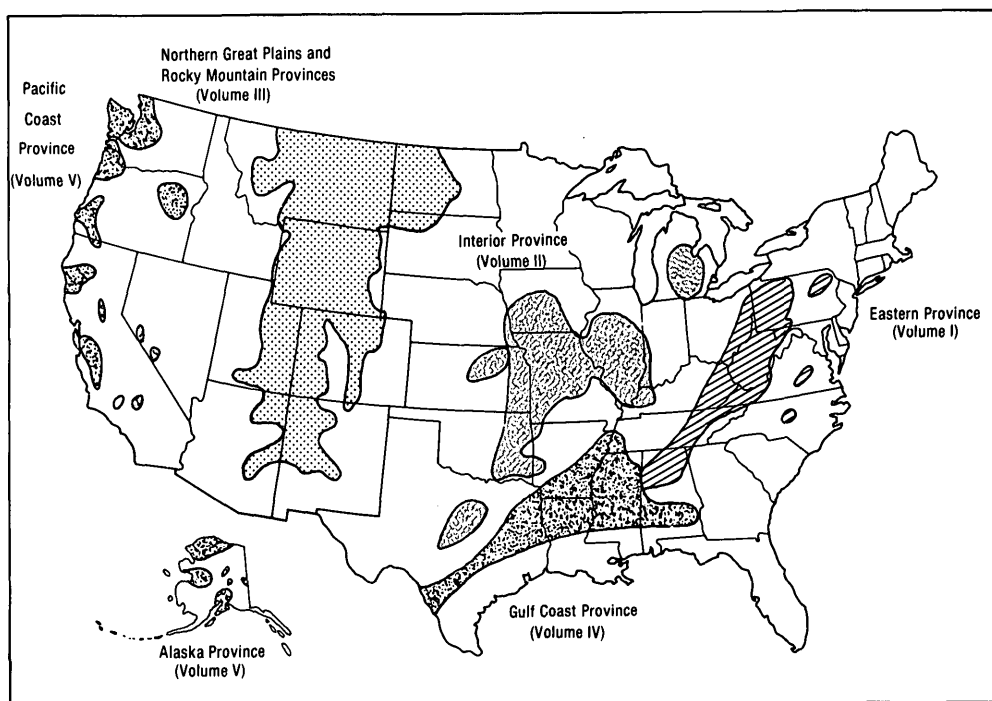


Figure 9.4-1 Index volumes and related provinces.

10.0 SUPPLEMENTAL INFORMATION FOR AREA 34

10.1 Active Surface-Water Sites

Active surface-water sites.

CHEM- ICAL AC- TIVE STA- TUS	SITE NUMBER	STATION NUMBER	STATION NAME AND LOCATION	DRAINAGE AREA	LATI- TUDE	LONGI- TUDE	SW BEGIN YEAR	SW END YEAR	COM- PL- ETE FLOW	QM BEGIN YEAR	QM END YEAR	BIO. AC- TIVE STA- TUS	PHY. AC- TIVE STA- TUS	SED. AC- TIVE STA- TUS
N	1	03309500	MCDUGAL CREEK NEAR HODGENVILLE, KENTUCKY	5.34	373237	0854019	1953	1971	D				Y	
N	2	03310000	NORTH FORK NOLIN RIVER AT HODGENVILLE, KENTUCKY	36.4	373433	0854425	1940		D	1970	1972		Y	
N	3	03310078	SOUTH FORK NOLIN RIVER AT MATHERS MILL, KENTUCKY	49.6	373235	0854607	1974					N		
N	4	03310270	VALLEY CREEK NEAR GLENDALE, KENTUCKY	90.1	373641	0855550	1972			1960	1975		Y	
N	5	03310300	NOLIN RIVER AT WHITE MILLS, KENTUCKY	357	373303	0860243	1959		I	1970			Y	N
N	6	03310380	BACON CREEK AT HIGHWAY 31W AT BONNIEVILLE, KENTUCKY	53.5	372230	0855409	1974						Y	
N	7	03310385	BACON CREEK TRIBUTARY NEAR UPTON, KENTUCKY	0.56	372615	0855301	1974						Y	
N	8	03310400	BACON CREEK NEAR PRICE- VILLE, KENTUCKY	85.4	372131	0855953	1959		I	1970			Y	N
Y	9	03310550	ROCK CREEK NEAR CLARKSON, KENTUCKY		372602	0860928				1979			Y	Y
N	10	03310880	BRIER CREEK TRIBUTARY NEAR OLLIE, KENTUCKY	0.31	371741	0861149	1975						Y	
N	11	03310900	NOLIN LAKE NEAR KYROCK, KENTUCKY	703	371642	0861451	1963		I				Y	
N	12	03311000	NOLIN RIVER AT KYROCK, KENTUCKY	703	371627	0861503	1929		I	1948	1979		Y	
N	13	03311500	GREEN RIVER AT LOCK 6, AT BROWNSVILLE, KENTUCKY	2762	371225	0861540	1924		I	1978	1979		Y	
N	14	03311600	BEAVERDAM CREEK AT RHODA, KENTUCKY	10.9	370918	0861335	1961		I	1965	1978		Y	
N	15	03312000	BEAR CREEK NEAR LEITCH- FIELD, KENTUCKY	30.8	372536	0861645	1949		D				Y	
Y	16	03312040	BEAR CREEK NEAR BEE SPRINGS, KENTUCKY		371725	0861935				1979			Y	Y
Y	17	03312070	SUNFISH CREEK NEAR BEE SPRINGS, KENTUCKY		371723	0862236				1979			Y	Y

Active surface-water sites -- continued.

CHEM- ICAL AC- TIVE STA- TUS	SITE NUMBER	STATION NUMBER	STATION NAME AND LOCATION	DRAINAGE AREA	LATI- TUDE	LONGI- TUDE	SW BEGIN YEAR	SW END YEAR	COM- PL- ETE FLOW	QW BEGIN YEAR	QW END YEAR	BIO. AC- TIVE STA- TUS	PHY. AC- TIVE STA- TUS	SED. AC- TIVE STA- TUS
Y	18	03312120	BIG REEDY CREEK NEAR ROUNDHILL, KENTUCKY		371418	0862623				1979			Y	Y
Y	19	03312130	LITTLE REEDY CREEK NEAR ROUNDHILL, KENTUCKY		371445	0862918				1979			Y	Y
N	20	03315500	GREEN RIVER AT LOCK 4 AT WOODBURY, KENTUCKY	5403	371056	0863748	1917		I	1957	1965		Y	
Y	21	03315510	WELCH CREEK NEAR ABERDEEN, KENTUCKY		371542	0863544				1979			Y	Y
N	22	03315515	WELCH CREEK NEAR MORGAN- TOWN, KENTUCKY	59.5	371347	0863949	1974						Y	
Y	23	03315520	GREEN RIVER AT ABERDEEN, KENTUCKY	5488	371436	0864122	1960			1958			Y	Y
Y	24	03315590	INDIAN CAMP CREEK NEAR MORGANTOWN, KENTUCKY		371811	0864139				1979			Y	Y
Y	25	03315600	EAST PRONG INDIAN CAMP CREEK NEAR MORGANTOWN, KENTUCKY		371725	0864023				1979			Y	Y
N	26	03315610	INDIAN CAMP CREEK NEAR ABERDEEN, KENTUCKY		371708	0864306	1974						Y	
Y	27	03315810	MUDDY CREEK AT DUNBAR, KENTUCKY	94.3	371101	0864624	1953	1974		1960			Y	Y
Y	28	03315830	PANTHER CREEK NEAR ROCHESTER, KENTUCKY		371319	0865124				1979			Y	Y
N	29	03316000	MUD RIVER NEAR LEWISBURG, KENTUCKY	90.5	370015	0865426	1938		D	1960	1972		Y	
Y	30	03316275	MUD RIVER NEAR HUNTSVILLE, KENTUCKY	268	370724	0865402	1974			1979			Y	Y
Y	31	03316300	ROCKY CREEK NEAR PENROD, KENTUCKY		370757	0865383				1979			Y	Y
	32	03316500	GREEN RIVER AT PARADISE, KENTUCKY	6182	371553	0865843	1939		I	1978	1979		Y	
Y	33	03316640	POND CREEK NEAR MARTWICK, KENTUCKY	125	371801	0870016	1972			1972			Y	Y
Y	34	03316645	GREEN RIVER AT ROCKPORT, KENTUCKY	6323	372008	0870010	1940			1979			Y	Y
N	35	03316655	LEWIS CREEK TRIBUTARY NEAR MCHENRY, KENTUCKY	0.96	372110	0865356	1975			1976	1978		Y	
Y	36	03316660	LEWIS CREEK AT ROCKPORT, KENTUCKY		372051	0865902	1979			1979			Y	Y
N	37	03316815	ROUGH RIVER AT VERTREES, KENTUCKY	43.5	374139	0860752	1974						Y	
N	38	03316865	ROUGH RIVER NEAR CONSTANTINE, KENTUCKY		373808	0861209	1974						Y	
Y	39	03316885	MEETING CREEK NEAR BIG CLIFTY, KENTUCKY		373434	0861259	1979			1979			Y	Y
N	40	03317500	NORTH FORK ROUGH RIVER NEAR WESTVIEW, KENTUCKY	42.0	374132	0862329	1954		D	1970	1972		Y	
N	41	03317965	LONG LICK CREEK TRIBUTARY NEAR AXTEL, KENTUCKY	0.38	373846	0862957	1974						Y	
	42	03318005	ROUGH RIVER LAKE NEAR FALLS OF ROUGH, KENTUCKY	454	373712	0862958	1959		I				Y	
	43	03318010	ROUGH RIVER NEAR FALLS OF ROUGH AT DAM	454	373719	0863015	1962	1961					Y	
Y	44	03318300	ROCK LICK CREEK NEAR FALLS OF ROUGH, KENTUCKY		373750	0863332				1979			Y	Y
Y	45	03318500	ROUGH RIVER AT FALLS OF ROUGH, KENTUCKY	504	373520	0863305	1939		I	1950			Y	Y
N	46	03318505	PLEASANT RUN TRIBUTARY NEAR FALLS OF ROUGH, KENTUCKY	0.22	373449	0863049	1974						Y	
Y	47	03318600	SHORT CREEK NEAR FALLS OF ROUGH, KENTUCKY		373128	0863128				1979			Y	Y
Y	48	03318700	SOUTH FORK CANEY CREEK AT CANEYVILLE, KENTUCKY		372526	0862858				1979			Y	Y
Y	49	03318800	CANEY CREEK NEAR HORSE BRANCH, KENTUCKY	124	372750	0863920	1956		I	1970			Y	Y
N	50	03319000	ROUGH RIVER NEAR DUNDEE KENTUCKY	757	373251	0864318	1939		I				Y	N
Y	51	03319500	ROUGH RIVER AT DUNDEE, KENTUCKY	815	373346	0864616				1979			Y	Y
Y	52	03319510	ADAMS FORK NEAR FORDSVILLE, KENTUCKY		373742	0864148				1979			Y	Y
N	53	03319520	WEST FORK ADAMS FORK TRIBUTARY NEAR FORDSVILLE, KENTUCKY	0.26	374113	0864133	1975						Y	
Y	54	03319530	WEST FORK ADAMS FORK NEAR FORDSVILLE, KENTUCKY		373744	0864339				1979			Y	Y
N	55	03319540	ADAMS FORK NEAR DUNDEE, KENTUCKY	48.9	373456	0864524	1974						Y	
Y	56	03319570	HALLS CREEK NEAR DUNDEE, KENTUCKY		373158	0864921				1979			Y	Y
Y	57	03319615	MUDDY CREEK NEAR BEAVER DAM, KENTUCKY		372513	0865055				1979			Y	Y
Y	58	03319620	THREELICK CREEK NEAR BEAVER DAM, KENTUCKY		372502	0865103				1979			Y	Y
Y	59	03319700	BARNETT CREEK NEAR HARTFORD, KENTUCKY		373212	0865834	1979			1979			Y	Y

10.0 SUPPLEMENTAL INFORMATION FOR AREA 34--Continued
10.1 Active Surface-Water Sites--Continued

Active surface-water sites -- continued.

CHEM- ICAL AC- TIVE STA- TUS	SITE NUMBER	STATION NUMBER	STATION NAME AND LOCATION	DRAINAGE AREA	LATI- TUDE	LONGI- TUDE	SW BEGIN YEAR	SW END YEAR	COM- PL- ETE FLOW	OW BEGIN YEAR	OW END YEAR	BIO. AC- TIVE STA- TUS	PHY. AC- TIVE STA- TUS	SED. AC- TIVE STA- TUS
Y	60	03319750	NORTH FORK BARNETT CREEK NEAR HARTFORD, KENTUCKY		373223	0870039				1979		Y	Y	Y
Y	61	03319925	BUCK CREEK NEAR LIVERMORE, KENTUCKY		373031	0870827				1979		Y	Y	Y
Y	62	03320000	GREEN RIVER AT LOCK 2, AT CALHOUN, KENTUCKY	7564	373202	0871550	1930		I	1949		Y	Y	Y
Y	63	03320075	LONG FALLS CREEK NEAR RUMSEY, KENTUCKY		373253	0871639				1979		Y	Y	Y
N	64	03320080	LONG FALLS CREEK NEAR CALHOUN, KENTUCKY	38.0	373350	0871633	1974	1979				Y	Y	N
Y	65	03320400	LONG CREEK NEAR KIRKMAN'S- VILLE, KENTUCKY		370616	0871334				1979		Y	Y	Y
Y	66	03320500	POND RIVER NEAR APEX, KENTUCKY	194	370720	0871910	1940		I	1961		Y	Y	Y
Y	67	03320700	WEST FORK POND RIVER NEAR APEX, KENTUCKY		370740	0872217				1979		Y	Y	Y
Y	68	03320740	MCFARLAN CREEK NEAR WHITE PLAINS, KENTUCKY		370725	0872332				1979		Y	Y	Y
N	69	03320770	WEST FORK POND RIVER NEAR WHITE PLAINS, KENTUCKY	81.0	370925	0872135	1974					Y	Y	
Y	70	03321035	DRAKES CREEK NEAR WHITE PLAINS, KENTUCKY	52.5	371157	0872453	1974			1979		Y	Y	Y
Y	71	03321050	FLAT CREEK NEAR MADISONVILLE, KENTUCKY		371511	0872650				1979		Y	Y	Y
N	72	03321100	POND RIVER NEAR SACRAMENTO, KENTUCKY	523	372341	0871819	1954			1959	1973	Y	Y	
Y	73	03321120	POND RIVER NEAR VANDETTA, KENTUCKY		372630	0872110				1979		Y	Y	Y
Y	74	03321150	OTTER CREEK NEAR HANSON, KENTUCKY		372913	0872248				1979		Y	Y	Y
Y	75	03321170	CYPRESS CREEK NEAR CENTRAL CITY, KENTUCKY		371810	0871150				1979		Y	Y	Y
Y	76	03321180	LITTLE CYPRESS CREEK NEAR CENTRAL CITY, KENTUCKY		371743	0870828				1979		Y	Y	Y
Y	77	03321210	CYPRESS CREEK NEAR CALHOUN, KENTUCKY	142	372920	0871710	1979		I	1979		Y	Y	Y

Active surface-water sites -- continued.

CHEM- ICAL AC- TIVE STA- TUS	SITE NUMBER	STATION NUMBER	STATION NAME AND LOCATION	DRAINAGE AREA	LATI- TUDE	LONGI- TUDE	SW BEGIN YEAR	SW END YEAR	COM- PL- ETE FLOW	QW BEGIN YEAR	QW END YEAR	BIO. AC- TIVE STA- TUS	PHY. AC- TIVE STA- TUS	SED. AC- TIVE STA- TUS
N	78	03321215	CYPRESS CREEK NEAR RUMSEY, KENTUCKY	149	373032	0871900	1972	1976	D	1973	1975		Y	
Y	79	03321230	GREEN RIVER NEAR BEECH GROVE, KENTUCKY	8452	373521	0872416				1974		Y	Y	Y
N	80	03321275	EAST FORK DEER CREEK TRIBUTARY NEAR ONTON, KENTUCKY	0.95	373129	0872831	1975			1976	1980		Y	
N	81	03321290	DEER CREEK NEAR SEBREE, KENTUCKY	122	373421	0873109	1972			1974	1975		Y	
Y	82	03321350	SOUTH FORK PANTHER CREEK NEAR WHITESVILLE, KENTUCKY	58.2	373708	0865315	1968		I	1970			Y	Y
Y	83	03321400	NORTH FORK PANTHER CREEK NEAR MASONVILLE, KENTUCKY		374219	0870303				1979			Y	Y
Y	84	03321430	PANTHER CREEK NEAR OWENS- BORO, KENTUCKY		374249	0871246	1979		I	1979			Y	Y
N	85	03321450	PANTHER CREEK NEAR CURDS- VILLE, KENTUCKY	344	374331	0871649	1972			1973	1976		Y	
Y	86	03321455	KNOBLICK CREEK NEAR CURDSVILLE, KENTUCKY		374243	0872000	1979			1979			Y	Y
N	87	03321465	RHODES CREEK TRIBUTARY NEAR OWENSBORO, KENTUCKY	0.29	374711	0871222	1974						Y	
Y	88	03321485	LICK CREEK NEAR BLUFF CITY, KENTUCKY		374243	0872634				1979			Y	Y
Y	89	03322180	CANOE CREEK NEAR HENDERSON, KENTUCKY	56.0	374711	0873530	1975			1979			Y	Y
Y	90	03322360	BEAVERDAM CREEK NEAR CORYDON, KENTUCKY	14.3	374214	0874152	1972		I	1979			Y	Y
Y	91	03322370	CASEY CREEK NEAR WAVERLY, KENTUCKY		374007	0874707				1979			Y	Y
	92	03322420	OHIO RIVER AT UNIONTOWN DAM, KENTUCKY	108000	374800	0875900	1977		I				Y	
Y	93	03382570	EAGLE CREEK NEAR MORGANFIELD, KENTUCKY		373916	0875800				1979			Y	Y
Y	94	03382600	TRADEWATER RIVER AT POOLS MILL BRIDGE NEAR DAWSON SPRINGS, KENTUCKY	60.4	370430	0873446	1975			1966			Y	Y
Y	95	03382650	CASTLEBERRY CREEK NEAR DAWSON SPRINGS, KENTUCKY		370521	0873513				1979			Y	Y
N	96	03382685	TRADEWATER RIVER AT MURPHY FORK NEAR DAWSON SPRINGS, KENTUCKY	94.3	370849	0873900	1972			1966	1975		Y	
N	97	03382975	WARD CREEK AT LEWISTON, KENTUCKY	0.91	370834	0874825	1974						Y	
Y	98	03383000	TRADEWATER RIVER AT OLNEY, KENTUCKY	255	371326	0874653	1940		I	1948			Y	Y
N	99	03383605	WEST FORK DONALDSON CREEK NEAR FREDONIA, KENTUCKY	2.52	371508	0875925	1974			1975	1980		Y	
Y	100	03383650	DONALDSON CREEK NEAR FRYER, KENTUCKY		371535	0875420				1979			Y	Y
Y	101	03383755	CLEAR CREEK AT HIGHWAY 70 BRIDGE NEAR RICHLAND, KENTUCKY	17.0	371746	0873418	1975			1966			Y	Y
N	102	03383900	CLEAR CREEK AT WATSON BRIDGE NEAR COILTOWN, KENTUCKY	78.8	371855	0873923	1975						Y	
	103	03384000	ROSE CREEK AT NEBO, KENTUCKY	2.10	372258	0873759	1951		D				Y	
Y	104	03384035	LICK CREEK NEAR RABBIT RIDGE, KENTUCKY		371815	0872458				1979			Y	Y
N	105	03384050	CLEAR CREEK AT BRIDGE ON STATE HIGHWAY 293 NEAR PROVIDENCE, KENTUCKY	197	372033	0874800	1975			1966	1967		Y	
N	106	03384100	TRADEWATER RIVER NEAR PROVIDENCE, KENTUCKY	605	372348	0875042	1953			1965	1972		Y	
Y	107	03384103	TRADEWATER RIVER NEAR BLACK- FORK, KENTUCKY		372356	0875417				1979			Y	Y
N	108	03384110	PINEY CREEK AT MOUTH NEAR BLACKFORD, KENTUCKY	60.8	372409	0875507	1975			1965	1965		Y	
Y	109	03384106	PINEY CREEK NEAR SHADY GROVE, KENTUCKY		372131	0875528				1979			Y	Y
Y	110	03384150	CRAB ORCHARD CREEK NEAR CLAY, KENTUCKY		372744	0874646				1965			Y	Y
N	111	03384154	CRABORCHARD CREEK AT CLAY, KENTUCKY	86.6	372737	0874922	1966			1969	1972		Y	
Y	112	03384158	CANEY FORK NEAR CLAY, KENTUCKY		373127	0874929				1979			Y	Y
Y	113	03384180	TRADEWATER RIVER NEAR SULLIVAN, KENTUCKY	861	372846	0875713	1975		I	1975			Y	Y
Y	114	03384200	SMITH DITCH NEAR STURGIS, KENTUCKY		373254	0875525				1979			Y	Y
N	115	03384215	CYPRESS CREEK AT STURGIS, KENTUCKY	48.1	373149	0875831	1975						Y	

EXPLANATION

Complete Flow:

Other Activities:

I - Active

Y - Active

D - Discontinued

N - Inactive

Blank - No activity

10.0 SUPPLEMENTAL INFORMATION FOR AREA 34--Continued

10.2 Inactive Surface-Water Sites

Inactive surface-water sites.

CHEM- ICAL AC- TIVE STA- TUS	SITE NUMBER	STATION NUMBER	STATION NAME AND LOCATION	DRAINAGE AREA	LATI- TUDE	LONGI- TUDE	SW BEGIN YEAR	SW END YEAR	COM- PL- ETE FLOW	QW BEGIN YEAR	QW END YEAR	BIO. AC- TIVE STA- TUS	PHY. AC- TIVE STA- TUS	SED. AC- TIVE STA- TUS
N	116	03309000	GREEN RIVER AT MAMMOTH CAVE, KENTUCKY	1983	371043	0860646	1938	1950	D	1958	1974	N	N	
N	117	03309100	WET PRONG BUFFALO CREEK NEAR MAMMOTH CAVE, KENTUCKY	2.26	371347	0861024	1962	1974		1962	1974	N	N	N
N	118	03309600	MCDUGAL CREEK AT HODGENVILLE, KENTUCKY		373429	0854338				1970	1970	N	N	
N	119	03310030	NORTH FORK NOLIN RIVER NEAR EAGLE MILLS, KENTUCKY		373332	0854718				1970	1972	N	N	
N	120	03310100	NOLIN RIVER AT EAGLE MILLS, KENTUCKY		373355	0855011				1970	1972	N	N	
N	121	03310117	MIDDLE CREEK ABOVE NEELY BRANCH NEAR TONIEVILLE, KY		373850	0854535				1971	1971	N	N	
N	122	03310120	MIDDLE CREEK NEAR TONIE- VILLE, KENTUCKY		373726	0854800				1970	1972	N	N	
N	123	03310130	MIDDLE CREEK AT EAGLE MILLS, KENTUCKY		373422	0854926				1971	1972	N	N	
N	124	03310160	NOLIN RIVER NEAR GLENDALE, KENTUCKY	185	373503	0855459	1972	1975		1971	1975	N	N	
N	125	03310210	VALLEY CREEK AT ELIZABETH- TOWN, KENTUCKY		374049	0855234				1970	1973	N	N	
N	126	03310225	VALLEY CREEK AT GAITHERS, KENTUCKY		373940	0855409				1971	1973	N	N	
N	127	03310250	WEST RHODES CREEK NEAR CECILIA, KENTUCKY		373756	0855532				1970	1972	N	N	
N	128	03310273	NOLIN RIVER NEAR STAR MILLS, KENTUCKY		373553	0855715				1971	1972	N	N	
N	129	03310500	NOLIN RIVER AT WAX, KENTUCKY	600	372043	0860721	1935	1962	D	1949	1961	N	N	N
N	130	03310600	DOG CREEK NEAR MAMOTH CAVE, KENTUCKY	8.12	371647	0860705	1961	1974		1961	1974	N	N	
N	131	03311100	BYLEW CREEK NEAR MAMMOTH CAVE, KENTUCKY	5.16	371540	0861307	1961	1974		1965	1974	N	N	
N	132	03312100	BEAR CREEK NEAR ROUNDHILL, KENTUCKY	137	371456	0862140	1953	1972		1960	1972	N	N	
N	133	03316200	WOLFLOK CREEK NEAR LEWISBURG, KENTUCKY	116	370108	0865733	1953	1972		1970	1972	N	N	

Inactive surface-water sites -- continued.

CHEM- ICAL AC- TIVE STA- TUS	SITE NUMBER	STATION NUMBER	STATION NAME AND LOCATION	DRAINAGE AREA	LATI- TUDE	LONGI- TUDE	SW BEGIN YEAR	SW END YEAR	COM- PL- ETE FLOW	QW BEGIN YEAR	QW END YEAR	BIO. AC - TIVE STA- TUS	PHY. AC- TIVE STA- TUS	SED. AC- TIVE STA- TUS
N	134	03317000	ROUGH RIVER NEAR MADRID, KENTUCKY	225	373531	0861946	1936	1959	D				N	
N	135	03318000	ROUGH RIVER NEAR FALLS OF ROUGH, KENTUCKY	454	373633	0862947	1936	1956	D				N	N
N	136	03318200	ROCK LICK CREEK NEAR GLEN DEAN, KENTUCKY	20.1	373924	0863343	1955	1971	D				N	N
N	137	03319600	ROUGH RIVER AT HARTFORD, KENTUCKY		372710	0865438			1966	1972			N	
N	138	03319885	GREEN RIVER AT LIVERMORE, KENTUCKY	7510	372908	0870811	1939			1948	1975		N	
N	139	03321000	POND RIVER NEAR WHITE PLAINS, KENTUCKY	346	371337	0872057	1927	1940	D				N	
N	140	03321370	SOUTH FORK PANTHER CREEK NEAR MASONVILLE, KENTUCKY	109	373843	0870039	1954	1972					N	
N	141	03321410	NORTH FORK PANTHER CREEK NEAR MASONVILLE, KENTUCKY	88.3	374205	0870354	1954	1972		1970	1971		N	
N	142	03321500	GREEN RIVER AT LOCK AND DAM 1 AT SPOTTSVILLE, KENTUCKY	9181	375130	0872435	1928	1931	D	1955	1962		N	
N	143	03322350	HIGHLAND CREEK NEAR WAVERLY, KENTUCKY	62.3	374122	0874508	1975	1977					N	
N	144	03322400	HIGHLAND CREEK NEAR UNIONTOWN, KENTUCKY	166	374551	0874957	1953	1977		1970	1972		N	
N	145	03382680	TRADEWATER RIVER AT COLLINS BRIDGE NEAR DAWSON SPRINGS, KENTUCKY		370700	0873720				1965	1967		N	
N	146	03382720	BUFFALO CREEK NEAR DAWSON SPRINGS, KENTUCKY	12.7	370829	0873654				1965	1967		N	
N	147	03382725	BUFFALO CREEK AT HAMBY FORK NEAR DAWSON SPRINGS, KENTUCKY		370852	0873813				1965	1965		N	
N	148	03382835	COPPERAS CREEK AT HIGHWAY BRIDGE NEAR ILSLEY, KENTUCKY		371208	0873726				1966	1967		N	
N	149	03382845	COPPERAS CREEK AT HIGHWAY 62 NEAR ST. CHARLES, KENTUCKY		371108	0873657				1965	1965		N	
N	150	03382855	CANY CREEK AT MOUTH NEAR DAWSON SPRINGS, KENTUCKY		370949	0873947				1965	1967		N	
N	151	03382870	TRADEWATER RIVER AT STATE HIGHWAY 109 AT DAWSON SPRINGS, KENTUCKY		370903	0874029				1966	1967		N	
N	152	03382890	PINY CREEK BELOW LAKE BESHEAR DAM NEAR DAWSON SPRINGS, KENTUCKY		370853	0874055				1966	1967		N	
N	153	03383500	TRADEWATER RIVER NEAR DALTON, KENTUCKY	283	371628	0874748	1927	1940	D	1965	1966		N	
N	154	03383700	DONALDSON CREEK AT BRIDGE ON HIGHWAY 293 NEAR DALTON, KENTUCKY		371703	0874837				1966	1966		N	
N	155	03383710	TRADEWATER RIVER AT STATE HIGHWAY 293 NEAR DALTON, KENTUCKY		371900	0874840				1965	1966		N	
N	156	03383770	RICHLAND CREEK ABOVE TRIBUTARY NUMBER 1 NEAR ILSLEY, KENTUCKY		371334	0873553				1966	1967		N	
N	157	03383775	UNNAMED TRIBUTARY NUMBER 1 TO RICHLAND CREEK NEAR ILSLEY, KENTUCKY		371331	0873553				1966	1967		N	
N	158	03383780	UNNAMED TRIBUTARY NUMBER 1 TO RICHLAND CREEK NEAR ILSLEY, KENTUCKY		371339	0873529				1966	1967		N	
N	159	03383800	RICHLAND CREEK AT RICHLAND, KENTUCKY		371626	0873615				1966	1966		N	
N	160	03383901	UNNAMED TRIBUTARY TO CLEAR CREEK NEAR BEULAH, KENTUCKY		371649	0874111				1966	1966		N	
N	161	03384060	TRADEWATER RIVER AT DAM NEAR PROVIDENCE, KENTUCKY		372242	0874805				1965	1966		N	
N	162	03384070	OWEN CREEK AT MOUTH NEAR PROVIDENCE, KENTUCKY		372244	0874757				1965	1965		N	
N	163	03384072	TRADEWATER RIVER AT BRIDGE BELOW DAM AT PROVIDENCE, KENTUCKY		372251	0874801				1966	1967		N	
N	164	03384133	UNNAMED TRIBUTARY TO SLOVER CREEK NEAR PROVIDENCE, KENTUCKY		372617	0874705				1968	1968		N	
N	165	03384136	SLOVER CREEK NEAR CLAY, KENTUCKY		372652	0874709				1969	1969		N	
N	166	03384138	UNNAMED TRIBUTARY TO SLOVER CREEK NEAR CLAY, KENTUCKY		372628	0874646				1969	1969		N	
N	167	03384140	UNNAMED TRIBUTARY TO SLOVER CREEK NEAR CLAY, KENTUCKY		372652	0874710				1969	1969		N	
N	168	03384145	FREDRICKS DITCH NEAR CLAY, KENTUCKY		372721	0874711				1969	1969		N	
N	169	03384151	CRABORCHARD CREEK NEAR CLAY, KENTUCKY		372717	0874823				1969	1969		N	
N	170	03384152	CRABORCHARD CREEK AT CLAY, KENTUCKY		372738	0874915				1966	1966		N	

EXPLANATION

Complete flow:
I - Active
D - Discontinued
Blank - No activity

Other Activities:
Y - Active
N - Inactive

10.0 SUPPLEMENTAL INFORMATION FOR AREA 34--Continued

10.3 Summary of Ground-Water Level and Quality Observation Wells

Ground-water level and quality observation wells.

SITE NUMBER	IDENTIFICATION NUMBER	COUNTY	FORMATION TAPPED	DEPTH OF WELL	PERIOD OF RECORD	FREQUENCY OR TYPE OF MEASUREMENT	1/ _
1	370733087291201	Christian	Tradewater Formation of Middle Pennsylvanian age	95	1952-	R	
2	370822087393901	Christian	Caseyville Formation of Early Pennsylvanian age	418	1951, 1957-58 1966-	Q	
3	371606087355001	Hopkins	Tradewater Formation of Middle Pennsylvanian age	626	1966-67 1972-	Q	
4	371407087283501	Hopkins	Caseyville Formation of Early Pennsylvanian age	943	1970-	P	
5	371405087283001	Hopkins	Caseyville Formation of Early Pennsylvanian age	1015	1965-67 1969-	Q	
6	371142087364801	Hopkins	Carbondale Formation of Middle Pennsylvanian age	115	1966-	R	
7	371620087363901	Hopkins	Carbondale Formation of Middle Pennsylvanian age	150	1966-	R	
8	372428087372901	Hopkins	Lisman Formation of Late Pennsylvanian age	50	1952-	R	
9	373942087561301	Union	Carbondale Formation of Middle Pennsylvanian age	59	1951-	R	
10	374441087421001	Henderson	Lisman Formation of Late Pennsylvanian age	157	1952-	R	
11	375200087342901	Henderson	Carbondale Formation of Middle Pennsylvanian age	109	1949-	R	
12	375152087311501	Henderson	Carbondale Formation of Middle Pennsylvanian age	142	1950-	R	
13	374918087142201	Daviess	Glacial sand and gravel of Quaternary age	122	1966-67 1969-	Q	
14	374914087141501	Daviess	Glacial sand and gravel of Quaternary age	114	1964-	R	
15	374633087053801	Daviess	Glacial sand and gravel of Quaternary age	104	1974-	Q	
16	374638087054101	Daviess	Glacial sand and gravel of Quaternary age	104	1951-	R	
17	375133086575001	Daviess	Carbondale and Tradewater Formations of Middle Pennsylvanian age	108	1969-	R	
18	372410086523501	Ohio	Caseyville and Tradewater Formations of Early and Late Pennsylvanian age	231	1980-	R	
19	372822086165801	Grayson	Hardinsburg Sandstone of Late Mississippian age	384	1980-	R	
20	370923086041601	Edmonson	Ste. Genevieve Limestone of Late Mississippian age	491	1966-77, 1979-	R	
21	371538085525801	Hart	St. Louis Limestone of Late Mississippian age	203	1980-	R	
22	371556085574901	Hart	Ste. Genevieve Limestone of Late Mississippian age	181	1978-80	R	

1/ R - Recorded

P - Periodic

Q - Water-quality sample, once yearly

Ground-water level and quality observation wells -- continued.

SITE NUMBER	IDENTIFICATION NUMBER	COUNTY	FORMATION TAPPED	DEPTH OF WELL	PERIOD OF RECORD	FREQUENCY OR TYPE OF MEASUREMENT
23	371746085542801	Hart	St. Louis Limestone of Late Mississippian age	232	1978-	R
24	372316085585101	Hart	Ste. Genevieve Limestone of Late Mississippian age	86	1979-	R
25	372301085535601	Hart	St. Louis Limestone of Late Mississippian age	296	1980-	R
26	373141085535001	Hardin	St. Louis Limestone of Late Mississippian age	117	1980-	R
27	373616085570301	Hardin	St. Louis Limestone of Late Mississippian age	106	1971-	R
28	373551085542701	Hardin	St. Louis Limestone of Late Mississippian age	143	1971-	R
29	374151085413201	Larue	Warsaw Limestone of Late Mississippian age	363	1971-	R

1/ R - Recorded

P - Periodic

Q - Water-quality sample, once yearly

Appendix 3.

1. The first thirteen digits of the station numbers are derived from the latitude-longitude locations of the stations, either well or spring. The last two digits are sequence numbers used to differentiate stations that are close to each other and have identical thirteen digit coordinates. For example, the location of station number 370824085573201 is 37°08'24" north latitude; 085°57'32" west longitude. The final 01 is the sequence number.

10.0 SUPPLEMENTAL INFORMATION FOR AREA 34--Continued

10.4 Trace Constituents

Total trace constituents in water, in micrograms per liter.

MAP NUMBER	<u>ARSENIC</u>				<u>CADMIUM</u>				<u>COBALT</u>			
	NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX	NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX	NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX
9	1	0	--	--	1	0	--	--	--	--	--	--
16	1	1	--	--	1	0	--	--	--	--	--	--
17	1	1	--	--	1	0	--	--	--	--	--	--
18	1	0	--	--	1	0	--	--	--	--	--	--
19	1	1	--	--	1	0	--	--	--	--	--	--
21	1	1	--	--	1	1	--	--	--	--	--	--
23	1	1	--	--	1	3	--	--	--	--	--	--
24	1	1	--	--	1	0	--	--	--	--	--	--
25	1	1	--	--	1	0	--	--	--	--	--	--
27	1	0	--	--	1	0	--	--	--	--	--	--
28	1	1	--	--	1	0	--	--	--	--	--	--
31	1	2	--	--	1	0	--	--	--	--	--	--
33	1	1	--	--	1	1	--	--	--	--	--	--
34	1	2	--	--	1	0	--	--	--	--	--	--
36	1	0	--	--	1	1	--	--	--	--	--	--
39	1	2	--	--	1	0	--	--	--	--	--	--
44	1	3	--	--	1	1	--	--	--	--	--	--
45	1	0	--	--	1	0	--	--	--	--	--	--
47	1	0	--	--	1	0	--	--	--	--	--	--
48	1	1	--	--	1	0	--	--	--	--	--	--
51	1	2	--	--	1	14	--	--	--	--	--	--
52	1	1	--	--	1	2	--	--	--	--	--	--
54	1	0	--	--	1	0	--	--	--	--	--	--
56	1	1	--	--	1	0	--	--	--	--	--	--
57	1	0	--	--	1	0	--	--	--	--	--	--
58	1	1	--	--	1	0	--	--	--	--	--	--
59	1	1	--	--	1	2	--	--	--	--	--	--
60	1	0	--	--	1	0	--	--	--	--	--	--
61	1	0	--	--	1	0	--	--	--	--	--	--
62	1	2	--	--	1	1	--	--	--	--	--	--
63	1	0	--	--	1	0	--	--	--	--	--	--
65	1	1	--	--	1	0	--	--	--	--	--	--
66	10	2	1	5	10	2	0	7	9	1	0	5
67	1	1	--	--	1	0	--	--	--	--	--	--
70	1	0	--	--	1	10	--	--	--	--	--	--
71	1	0	--	--	1	22	--	--	--	--	--	--
73	1	1	--	--	1	3	--	--	--	--	--	--
74	1	2	--	--	1	0	--	--	--	--	--	--
75	1	0	--	--	1	2	--	--	--	--	--	--
76	1	0	--	--	1	1	--	--	--	--	--	--
77	1	1	--	--	1	2	--	--	--	--	--	--
79	23	1	0	6	22	4	0	42	25	2	0	11
82	1	1	--	--	1	3	--	--	--	--	--	--
83	1	2	--	--	1	1	--	--	--	--	--	--
84	1	2	--	--	1	3	--	--	--	--	--	--
86	1	1	--	--	1	0	--	--	--	--	--	--
88	1	1	--	--	1	0	--	--	--	--	--	--
89	1	2	--	--	1	0	--	--	--	--	--	--
91	1	9	--	--	0	0	--	--	--	--	--	--
93	--	--	--	--	1	12	--	--	1	0	--	--
98	1	1	--	--	1	2	--	--	--	--	--	--
107	--	--	--	--	1	2	--	--	1	0	--	--
113	9	2	1	--	9	3	0	12	8	10	5	17
114	--	--	--	--	1	4	--	--	1	0	--	--

Total trace constituents in water, in micrograms per liter -- continued.

COPPER					LEAD				MERCURY				SELENIUM				ZINC			
MAP NUMBER	NUMBER OF SAMPLE	MEAN OR VALUE	MIN	MAX	NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX	NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX	NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX	NUMBER OF SAMPLES	MEAN OR VALUE	MIN	MAX
9	1	2	--	--	1	5	--	--	1	.3	00	00	1	0	--	--	1	40	--	--
16	1	1	--	--	1	3	--	--	1	.4	--	--	1	0	--	--	1	10	--	--
17	1	1	--	--	1	4	--	--	1	.3	--	--	1	0	--	--	1	10	--	--
18	1	2	--	--	1	3	--	--	1	.5	--	--	1	0	--	--	1	10	--	--
19	1	2	--	--	1	5	--	--	1	.7	--	--	1	0	--	--	1	20	--	--
21	1	2	--	--	1	11	--	--	1	.5	--	--	1	0	--	--	1	10	--	--
23	1	7	--	--	1	14	--	--	1	.1	--	--	1	0	--	--	1	50	--	--
24	1	1	--	--	1	0	--	--	1	.5	--	--	1	0	--	--	1	0	--	--
25	1	2	--	--	1	5	--	--	1	.7	--	--	1	0	--	--	1	10	--	--
27	1	4	--	--	1	4	--	--	1	.5	--	--	1	0	--	--	1	50	--	--
28	1	2	--	--	1	2	--	--	1	.3	--	--	1	0	--	--	1	20	--	--
31	1	1	--	--	1	1	--	--	1	.2	--	--	1	0	--	--	1	10	--	--
33	1	3	--	--	1	4	--	--	1	.7	--	--	1	0	--	--	1	100	--	--
34	1	3	--	--	1	1	--	--	1	.1	--	--	1	0	--	--	1	20	--	--
36	1	4	--	--	1	1	--	--	1	.5	--	--	1	0	--	--	1	190	--	--
39	1	1	--	--	1	3	--	--	1	.2	--	--	1	0	--	--	1	10	--	--
44	1	2	--	--	1	5	--	--	1	.2	--	--	1	0	--	--	1	20	--	--
45	1	2	--	--	1	1	--	--	1	.2	--	--	1	0	--	--	1	10	--	--
47	1	0	--	--	1	3	--	--	1	.3	--	--	1	0	--	--	1	10	--	--
48	1	1	--	--	1	3	--	--	1	.5	--	--	1	0	--	--	1	10	--	--
51	1	13	--	--	1	20	--	--	1	.1	--	--	1	0	--	--	1	90	--	--
52	1	1	--	--	1	10	--	--	1	.3	--	--	1	0	--	--	1	20	--	--
54	1	2	--	--	1	1	--	--	1	.1	--	--	1	0	--	--	1	0	--	--
56	1	1	--	--	1	1	--	--	1	.2	--	--	1	0	--	--	1	10	--	--
57	1	62	--	--	1	1	--	--	1	.2	--	--	1	4	--	--	1	30	--	--
58	--	--	--	--	--	--	--	--	1	.2	.2	.2	1	0	--	--	1	10	--	--
59	1	3	--	--	1	10	--	--	1	.1	--	--	1	0	--	--	1	20	--	--
60	1	3	--	--	1	2	--	--	1	.1	--	--	1	0	--	--	1	30	--	--
61	1	4	--	--	1	1	--	--	1	.1	--	--	1	0	--	--	1	80	--	--
62	1	3	--	--	1	3	--	--	1	.1	--	--	1	0	--	--	1	10	--	--
63	1	1	--	--	1	2	--	--	1	.1	--	--	1	0	--	--	1	20	--	--
65	1	2	--	--	1	2	--	--	--	.2	--	--	1	0	--	--	1	20	--	--
66	10	6	3	14	10	16	6	56	10	.1	0	.4	1	0	--	--	10	27	0	60
67	1	5	--	--	1	4	--	--	1	1	--	--	1	0	--	--	1	30	--	--
70	1	13	--	--	1	13	--	--	1	.5	--	--	1	0	--	--	1	1700	--	--
71	1	18	--	--	1	16	--	--	1	.7	--	--	1	0	--	--	1	2100	--	--
73	1	11	--	--	1	0	--	--	1	.7	--	--	1	0	--	--	1	60	--	--
74	1	2	--	--	1	3	--	--	1	.5	--	--	1	0	--	--	1	50	--	--
75	1	2	--	--	1	1	--	--	1	.1	--	--	1	0	--	--	1	30	--	--
76	1	2	--	--	1	4	--	--	1	.1	--	--	1	1	--	--	1	40	--	--
77	1	8	--	--	1	7	--	--	1	.9	--	--	1	0	--	--	1	60	--	--
79	25	11	3	48	24	18	3	65	23	.2	0	.5	23	.1	0	1	24	43	10	130
82	1	4	--	--	1	10	--	--	1	.1	--	--	1	0	--	--	1	50	--	--
83	1	5	--	--	1	3	--	--	1	0	--	--	1	0	--	--	1	30	--	--
84	1	5	--	--	1	13	--	--	1	.1	--	--	1	0	--	--	1	40	--	--
86	1	1	--	--	1	0	--	--	1	.1	--	--	1	0	--	--	1	20	--	--
88	1	2	--	--	1	2	--	--	1	1.1	--	--	1	0	--	--	1	30	--	--
89	1	2	--	--	1	4	--	--	1	.1	--	--	1	0	--	--	1	10	--	--
91	1	4	--	--	1	2	--	--	1	.5	--	--	1	0	--	--	1	20	--	--
93	1	8	--	--	1	9	--	--	1	.2	--	--	1	0	--	--	1	20	--	--
98	2	3	0	5	1	6	--	--	1	.9	--	--	1	0	--	--	2	265.0	60.0	470.0
107	1	3	--	--	1	3	--	--	1	.4	--	--	1	0	--	--	1	20	--	--
113	9	7	2	22	9	17	5	48	9	.2	0	.5	1	0	--	--	9	82	30	160
114	1	3	--	--	1	3	--	--	1	.6	--	--	1	0	--	--	1	20	--	--

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