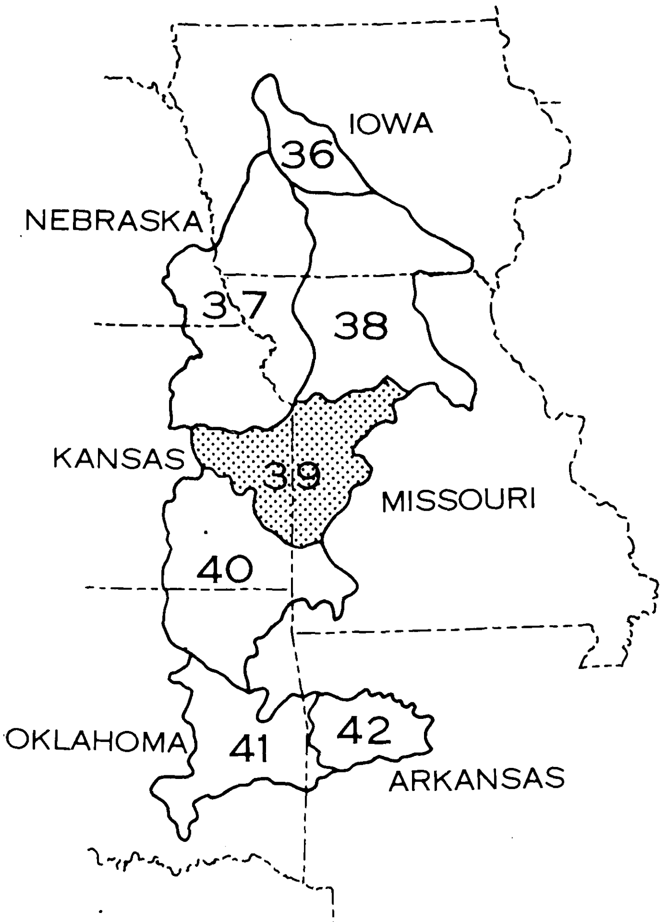
# HYDROLOGY OF AREA 39, WESTERN REGION, INTERIOR COAL PROVINCE KANSAS AND MISSOURI




- MISSOURI RIVER
- SOUTH GRAND RIVER
- LITTLE OSAGE RIVER
- MARAIS DES CYGNES RIVER

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 83-851

ERRATUM

Hydrology of Area 39, Western Region, Interior Coal Province Kansas and Missouri, by H.E. Bevans, John Skelton, J.F. Kenny, and J.V. Davis

U.S. Geological Survey Water-Resources Investigations, Open-File Report 83-851

Page 28 (Table 5.3-1 Summary of flood-frequency equations) should read as follows:

Table 5.3-1. Summary of flood-frequency equations

[Q = flood peak, in cubic feet per second, for t-year recurrence interval; A = drainage area, in square miles; S = slope, in feet per mile, between points 10 and 85 percent of the distance along the main stream channel from the site to the basin divide; $P_2$ = 24-hour rainfall amount, in inches, for 2-year recurrence interval (Hershfield, 1961), determined at the centroid of the basin. Equations only apply to unregulated natural streams]

| Recurrence interval, t, in years | C | x | y | Standard error, in percent |
|---|---|---|---|---|
| Kansas streams: $Q_t = C_t A^{x_t} P_2^{y_t}$ (from Jordan and Irza, 1975) | | | | |
| 2 | 0.707 | 0.548 | 4.752 | 42.5 |
| 5 | 3.98 | .530 | 4.021 | 41.5 |
| 10 | 9.92 | .525 | 3.591 | 43.0 |
| 25 | 25.6 | .524 | 3.127 | 48.0 |
| 50 | 47.6 | .523 | 2.821 | 53.0 |
| 100 | 83.8 | .524 | 2.529 | 58.0 |
| Missouri streams: $Q_t = C_t A^{x_t A^{-0.02}} S_t^{y}$ (from Hauth, 1974) | | | | |
| 2 | 53.5 | 0.851 | 0.356 | 38.6 |
| 5 | 64.0 | .886 | .450 | 34.7 |
| 10 | 67.6 | .905 | .500 | 34.5 |
| 25 | 73.7 | .924 | .542 | 35.0 |
| 50 | 79.8 | .926 | .560 | 33.3 |
| 100 | 85.1 | .934 | .576 | 33.3 |

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U.S. GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 83-851

LAWRENCE, KANSAS
JULY, 1984

**UNITED STATES DEPARTMENT OF THE INTERIOR**

WILLIAM P. CLARK, *SECRETARY*

**GEOLOGICAL SURVEY**

Dallas L. Peck, *Director*

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CONTENTS

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

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

| Multiply | By | To obtain |
|---|---|---|
| inches (in) | 25.4 | millimeters (mm) |
| inches per hour (in/h) | 25.4<br>2.54 | millimeters per hour (mm/h)<br>centimeters per hour (cm/h) |
| feet (ft) | 0.3048 | meters (m) |
| feet per mile (ft/mi) | 0.1894 | meters per kilometer (m/km) |
| miles (mi) | 1.609 | kilometers (km) |
| square miles ($mi^2$) | 2.590 | square kilometers ($km^2$) |
| gallons per minute (gal/min) | 0.06309 | liters per second (L/s) |
| million gallons per day (Mgal/d) | 0.04381<br>3,785 | cubic meters per second ($m^3/s$)<br>cubic meters per day ($m^3/d$) |
| cubic feet per second ($ft^3/s$) | 0.02832 | cubic meters per second ($m^3/s$) |
| cubic feet per second per square mile [$(ft^3/s)/mi^2$] | 0.01093 | cubic meters per second per square kilometer [$(m^3/s)/km^2$] |
| tons | 0.9072 | metric tons (t) |
| tons per square mile per year [$(ton/mi^2)/yr$] | 0.3503 | metric tons per square kilometer per year [$(t/km^2)/a$] |
| gallons (gal) | 3.785 | liters (L) |
| gallons per minute per foot [(gal/min)/ft] | 0.207 | liters per second per meter [(L/s)/m] |
| British thermal units per pound (Btu/lb) | 2.326 | kilojoules per kilogram (kJ/kg) |
| micromhos per centimeter at 25° Celsius ($\mu$mhos/cm) | 1 | microsiemens per centimeter at 25° Celsius ($\mu$S/m) |
| acres | 0.4047 | square hectometers ($hm^2$) |
| acre-feet (acre-ft) | 1,233 | cubic meters ($m^3$) |

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

# HYDROLOGY OF AREA 39, WESTERN REGION, INTERIOR COAL PROVINCE KANSAS AND MISSOURI

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## Abstract

The nationwide need for hydrologic information characterizing conditions in mined and potentially mined areas has become critical with the enactment of the Surface Mining Control and Reclamation Act of 1977. This report is for Area 39 in eastern Kansas and western Missouri, which is one of 7 hydrologic reporting areas in the Western Region of the Interior Coal Province. The report, consisting of a brief text accompanied by a map, graph, table, or other illustration, portrays the general geographic, geologic, and hydrologic environment of the area.

Area 39 has an area of about 10,500 square miles and includes all or parts of 13 Kansas counties and 14 Missouri counties. Major streams draining the area are the Marais des Cygnes (Osage), South Grand, Little Osage, Blackwater, Blue, and Little Blue Rivers, which are tributaries of the Missouri River.

The land surface is a rolling plain with altitudes ranging from about 800 feet in the east to 1,500 feet in the west. The area is underlain mostly by shale, limestone, and sandstone of Pennsylvanian age, with rocks of Permian age present in the extreme western part and rocks of Mississippian and Ordovician age cropping out in the east. Alluvial deposits of Quaternary age are located along the major streams, reaching a maximum depth of 140 feet in the Missouri River valley. Loess deposits occur discontinuously throughout the area at depths of from 2 to 30 feet, being thickest in the northeast part of the area adjacent to the Missouri River valley.

Mean annual rainfall in Area 39 ranges from 34 inches in the west to greater than 40 inches in the east. Agriculture and forests are the predominate land uses. Streams, ponds, and reservoirs provide about 94 percent of the water used in the area. Ground-water supplies are limited except in the Missouri and Marais des Cygnes (Osage) River valleys where wells in unconsolidated deposits may yield from 100 to 2,000 gallons per minute, and in the southeast part of the area where wells in consolidated aquifers of Ordovician age yield up to 600 gallons per minute of good quality water. Most of the water used in the area is for cooling at thermoelectric power plants, followed by withdrawals for public supplies, industrial use, and rural domestic/irrigation supplies.

Strippable coal reserves are present in Pennsylvanian rocks throughout many parts of the area. These coals are generally thin and have relatively high sulfur contents and heat values. Coal has been mined by both surface and underground methods in the area for more than a century; however, strip mining has been the only method used to recover coal since the 1930's. Coal-mining activity has increased sharply since the 1960's; this mining is subject to State and Federal reclamation laws.

Erosion, sedimentation, water-quality degradation, decline in ground-water levels, and diversion of surface drainage are typical problems associated with surface coal mining. Data on streamflow, water quality, and water levels can be useful in considering the effects of these problems. Data are available for 55 continuous-record streamflow-gaging stations, 3 continous-record reservoir-stage stations, 14 partial-record crest-stage stations, 25 partial-record low-flow stations, and 76 water-quality stations. Water-quality data are available for 42 stations on streams draining coal-mined areas, 21 stations on streams draining unmined areas, and 13 miscellaneous sites. Sediment data are available for 45 stations. Ground-water quality data are available for 359 wells in Area 39; water-level data are available for many of these wells.

Hydrologic data for Area 39 are stored in computer files accessible through the National Water Data Exchange (NAWDEX). Additional information is available from the references given in this report.

# 1.0 INTRODUCTION
## *1.1 Objective*

# Report Summarizes Available Hydrologic Information

*Existing hydrologic conditions and sources of information are presented to aid leasing decisions, appraisal of environmental impact studies, and mine-permit applications.*

Hydrologic information and analysis are needed to aid in decisions to grant coal-mining permits and for the preparation of the necessary Environmental Assessments and Impact Studies Reports. This need has become even more critical with the enactment of Public Law 95-87, the "Surface Mining Control and Reclamation Act of 1977." This Act requires an appropriate regulatory agency to issue mining permits based on the review of permit applications assessing hydrologic impacts. Information for assessing hydrologic impacts is partly provided by this report, which broadly characterizes the hydrology of Area 39 in Kansas and Missouri, a part of the Western Region, Interior Coal Province (fig. 1.1-1). This report is one of a series that describes coal provinces nationwide.

This report provides general hydrologic information by means of a brief text with accompanying map, chart, graph, or other illustration, for each of a series of water-resources-related topics. Summation of the topical discussions provides a description of the hydrology of the area. The information contained in the report will be useful to federal agencies in the leasing and management of coal lands; to surface-mine owners, operators, and others preparing permit applications; and to regulatory authorities evaluating the adequacy of the applications.

The hydrologic information presented in this report, or available through sources identified in this report, will be useful in describing the hydrology of the "general area" of any proposed mine. This hydrologic information will be supplemented by the lease applicant's specific-site data as well as data from other sources. The purpose of the specific-site data is to provide a detailed appraisal of the hydrology of the area in the vicinity of the mine and the anticipated hydrologic consequences of the mining operation.

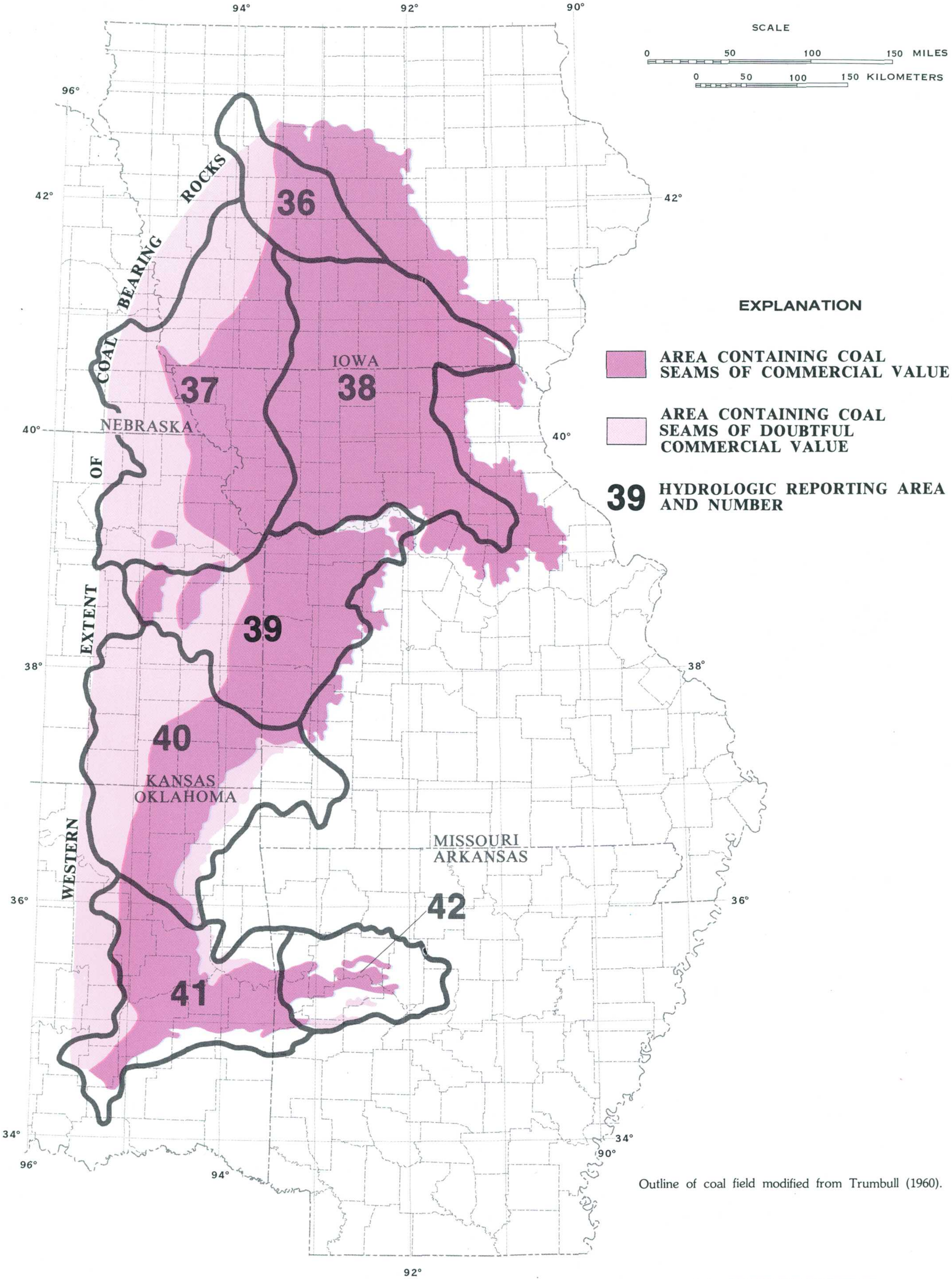



**Figure 1.1-1 Hydrologic reporting areas within Western Region, Interior Coal Province.**

# Area 39 is Located in the Western Interior Coal Province

*This report summarizes the hydrology and water resources of Area 39 in the Western Interior Coal Province in Kansas and Missouri.*

The Western Interior Coal Province is divided into seven reporting areas (report cover), which were defined by hydrologic factors, size, location, and mining activity. Area 39 is located in eastern Kansas and western Missouri as shown in figure 1.2-1.

Area 39 includes all or part of 13 Kansas counties and 14 Missouri counties with an area of about 10,500 square miles; about 60 percent of the area is in Missouri. The area is in the central part of the Western Interior Coal Province which includes parts of six states, and is in the Osage Plains section of the Central Lowlands physiographic province (Fenneman, 1946). The land surface is a rolling plain with altitudes ranging from about 800 feet in the east to 1,500 feet in the west.

Major streams draining Area 39 are the Marais des Cygnes (Osage), South Grand, Little Osage, Blackwater, Blue, and Little Blue Rivers, which are tributaries of the Missouri River. The Marais des Cygnes (Osage) and its tributaries drain almost 100 percent of the area in Kansas and about 70 percent of the area in Missouri. The remainder of the study area is drained by the Blackwater, Blue, and Little Blue Rivers and a few small streams that flow directly into the Missouri River.

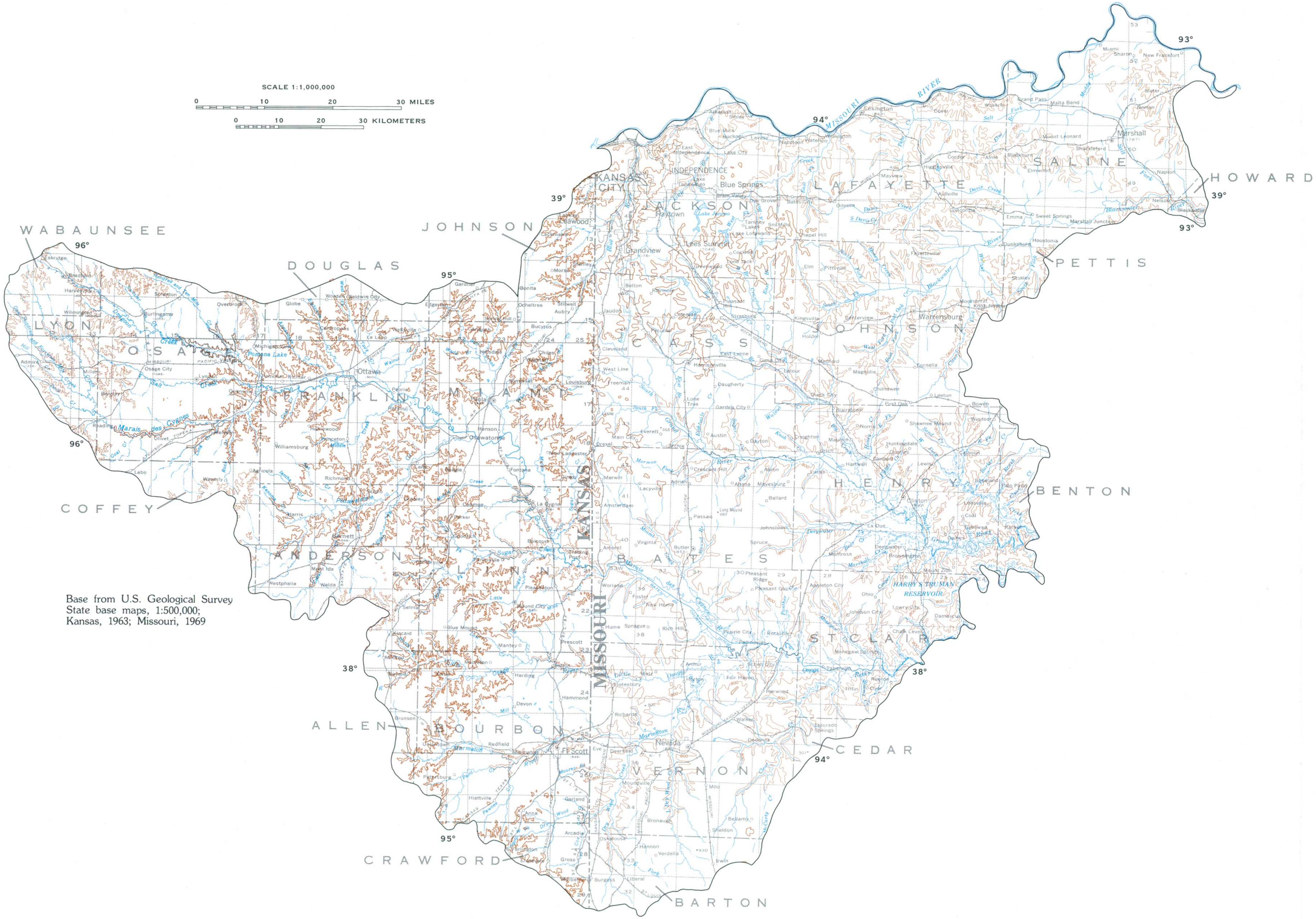



**Figure 1.2-1 Location of Area 39 in Kansas and Missouri.**

# The Hydrologic Environment Can Be Adversely Altered by Surface Coal Mining

*Erosion, sedimentation, water-quality degradation, decline in ground-water levels, and alteration of streamflow characteristics are typical problems associated with surface coal mining.*

Hydrologic problems associated with surface coal mining are a result of environmental disturbance. Removal of vegetation, excavation, and deposition of large volumes of unconsolidated spoil materials cause significant changes to the environment. The magnitude of the effects of these changes depends on several physical and chemical factors. The more important factors include mining and reclamation methods, topography, geology, mineralogy of the overburden, climate, rate and volume of water movement, the distance from stream to mine site, and the time elapsed since mining began.

The process of erosion and sedimentation is greatly accelerated by surface mining (fig. 1.3-1). Detrimental effects include decreased transport capacity of streams; decreased storage capacity of lakes and ponds; decreased or destroyed aquatic habitat; increased turbidity that detracts from the recreational use of water and decreases photosynthetic activity; and transport of pollutants, such as nutrients, pesticides, and trace elements that are adsorbed to the sediment.

Coal mining activities, by disturbing the natural geologic setting as shown in figure 1.3-2, expose sulfide minerals, primarily pyrite and marcasite, to air and water providing favorable conditions for acid production. Drainage from mined areas can have pH values less than 5.0, and large concentrations of sulfate, dissolved solids, iron, lead, and zinc. The acidic water reacts with other minerals, increasing concentrations of trace metals, such as aluminum and manganese. Adverse effects of coal-mine drainage may include decrease of aquatic life, increased corrosiveness of water, limitations on use of water for domestic and industrial purposes, and decrease of aesthetic value and recreational use (fig. 1.3-3). The effects of coal-mine drainage on the ecology of streams are documented by Parsons (1968).

A temporary decline in ground-water levels can occur in and near surface-mining areas when mining extends below the water table. After mining, the spoil material fills with water and an equilibrium water level is again attained. The spoil material may have a greater permeability than the original undisturbed material because of cracks and larger openings in the spoil resulting from irregular placement of soil and blocks of shale, with smaller quantities of sandstone and limestone, and sand and gravel. Ground water in and near the spoils may be more mineralized than in original undisturbed material because of exposure of sulfide minerals to air and water.

Surface mining commonly causes alterations in stream drainage patterns (fig. 1.3-4). These changes in drainage patterns and in surface and sub-surface hydrologic properties can alter high- and low-streamflow characteristics.

Adverse effects of surface mining are most apparent at and near the mine site. The receiving stream for surface and seepage drainage at the mine site usually is most affected. Effects caused by suspended sediment, dissolved mineral concentrations, and pH usually will decrease in severity downstream from the mine due to settling-out of the sediment and increased buffering and dilution capacity of the stream.

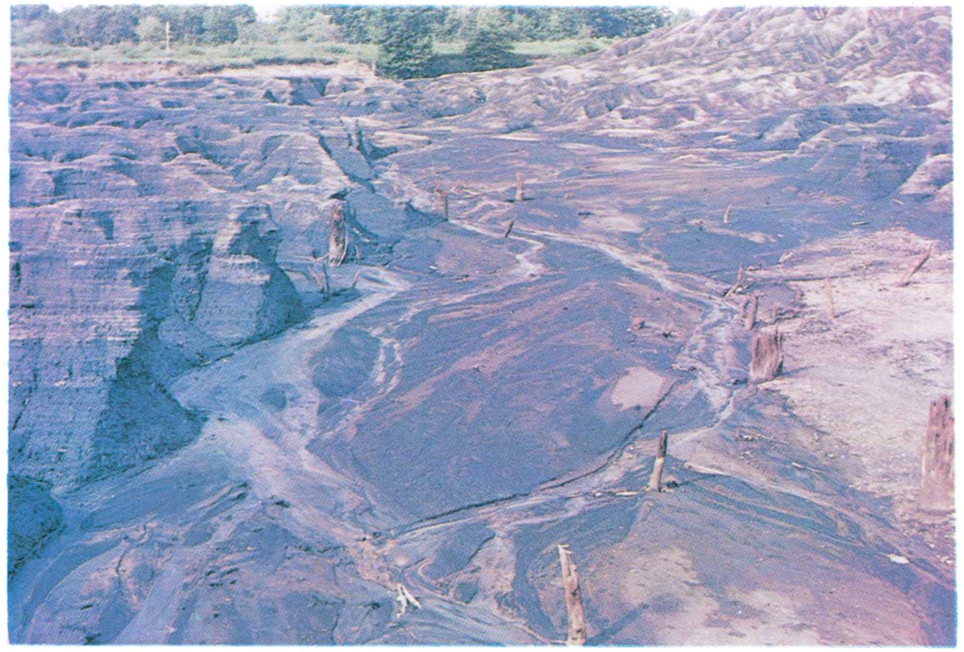


Figure 1.3-1 Erosion and sedimentation are accelerated at an abandoned mine.

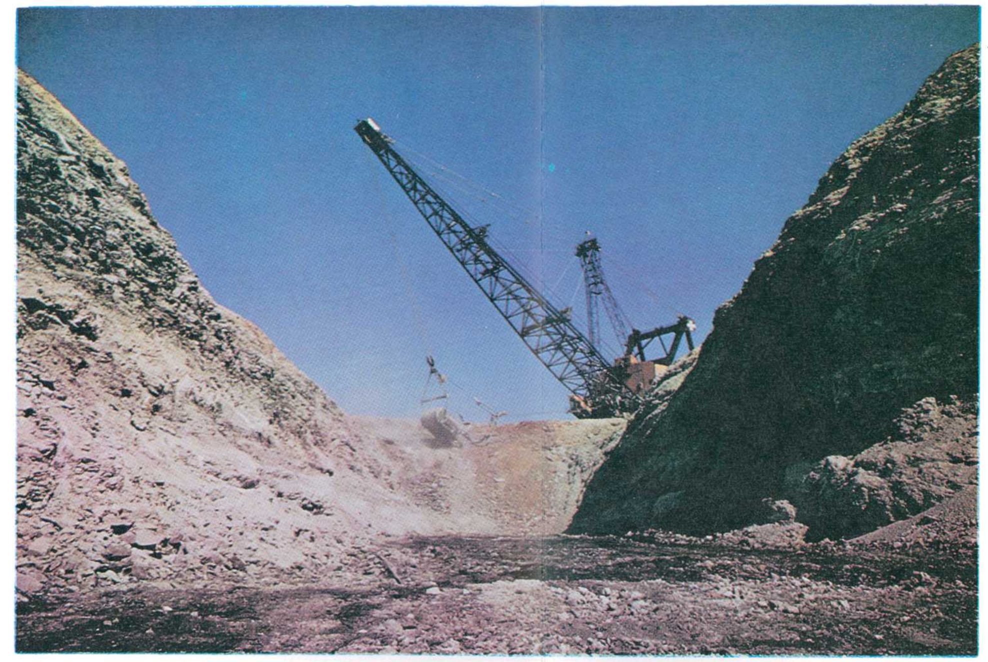


Figure 1.3-2 Active surface mining disturbs the natural geologic setting.

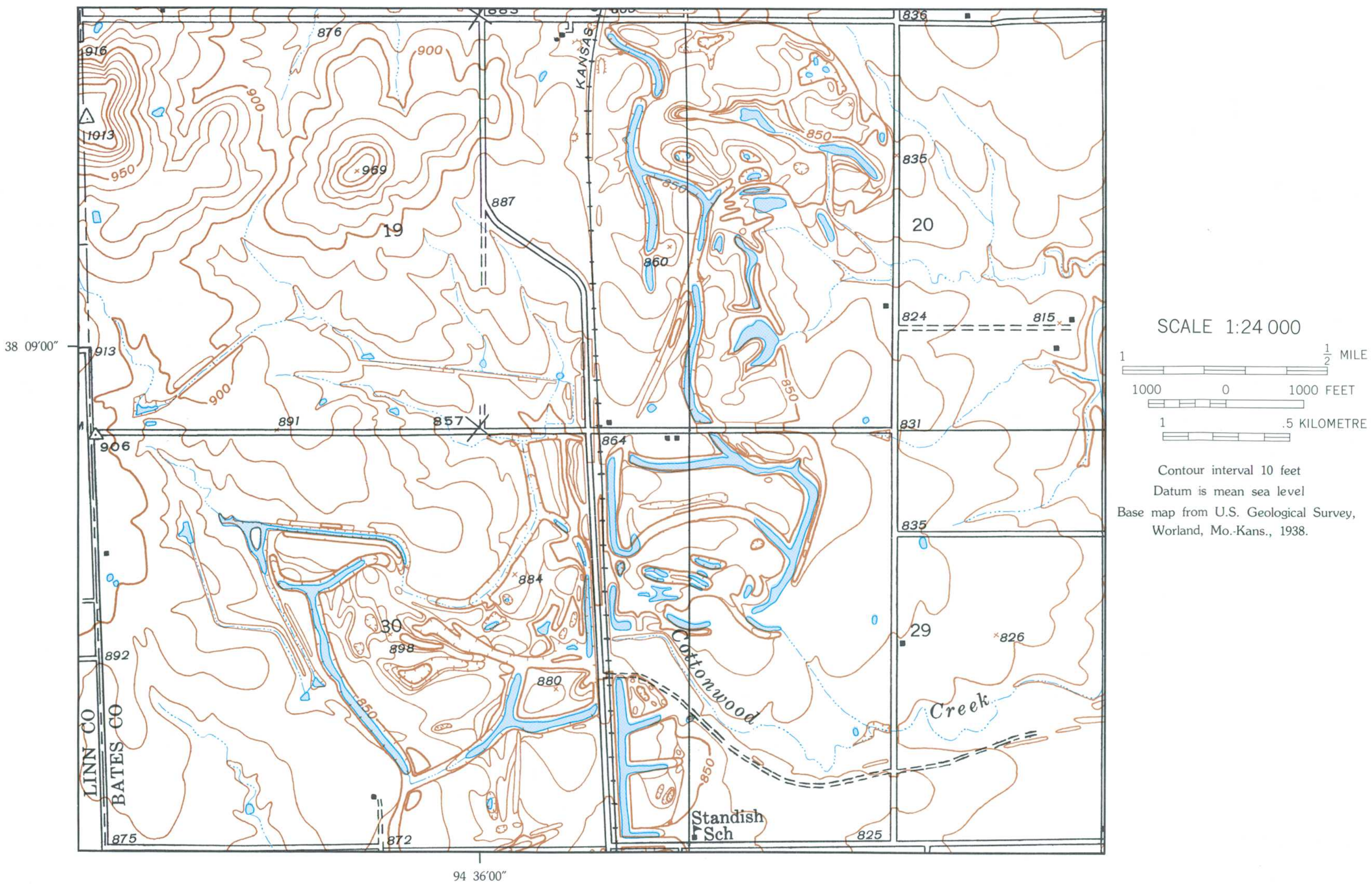



Figure 1.3-4 Topographic map showing alteration of drainage patterns in surface-mined area.

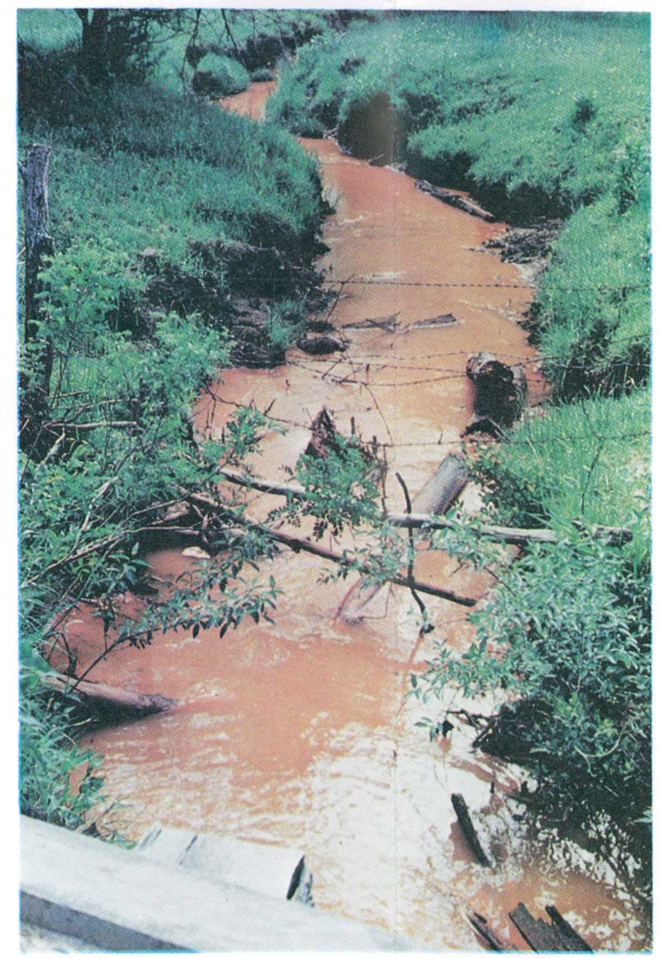


Figure 1.3-3 Adverse effects of coal-mine drainage on a receiving stream.

# Bedrock is Composed Primarily of Shales, Limestones, and Sandstones of Pennsylvanian Age

*Progressively older rocks of Permian, Pennsylvanian, Mississippian, and Ordovician age are exposed from west to east; these rocks are overlain locally by alluvium and loess.*

A generalized geologic map of Area 39 is shown in figure 2.1-1. Bedrock consists of progressively older bands of Permian, Pennsylvanian, Mississippian, and Ordovician rocks that crop out from west to east. These rocks dip to the west and northwest at about 25 feet per mile as a result of a dominant regional structural feature known as the Ozark uplift. Pre-Mississippian uplifts of this broad dome and post-Mississippian subsidence in eastern Kansas and adjacent areas created the Forest City Basin, in which Area 39 lies. Description of other structural features of this basin are discussed by McCracken, 1971. Essentially all of the area lies in the physiographic region known as the Osage Plains and is characterized by rolling plains of low relief, carved on sedimentary rocks of Pennsylvanian age. Numerous small faults have been mapped in the area, most of which have displacements of less than 50 feet.

Rocks of Permian age are present in Area 39 only where they crop out in Wabaunsee, Lyon, and Osage Counties, Kansas. These rocks are predominately shale and limestone units.

Bedrock in most of the area consists of rocks of Pennsylvanian age, which are primarily alternating beds of shale, limestone, and sandstone. Strippable coals in Kansas and Missouri are present in some shales of Pennsylvanian age, particularly in the Marmaton and Cherokee Groups. In Kansas, additional coal reserves occur in the Douglas and Wabaunsee Groups (see section 3.1). Aggregate thickness of the Pennsylvanian rocks in Area 39 averages about 1000 feet (Seevers, 1969). Thickness of these rocks generally increases from east to west, though it is modified by structural features (Zeller, 1968). The nonuniform resistance of the shale and limestone rock layers to erosion has created irregular east-facing ridges known as cuestas, which interrupt the otherwise rolling terrain.

Rocks of Missippian age crop out along the eastern edge of the area and are absent where the older Ordovician rocks crop out. Elsewhere these rocks lie at depths ranging from a few feet to about 1700 feet (Merriam, 1963). The Mississippian System in Area 39 is about 400 feet thick and is composed mostly of carbonate rocks and chert.

Rocks of Ordovician age crop out only in the east-central part of the area and are composed primarily of cherty dolomite, limestone, and sandstone. Ordovician rocks are present in the subsurface throughout the rest of Area 39.

Quaternary deposits of the Holocene and Pleistocene Series, which overlie the bedrock in many parts of the area, are important because they provide dependable supplies of water and form productive soils. These deposits include alluvium, loess, and glacial till, materials that were deposited by distinctly different means, and in specific areas. Alluvial deposits consist of unconsolidated sand, gravel, silt, and clay that were transported by streams. In the Missouri River valley, these deposits may reach a maximum thickness of 140 feet, but average 85 to 95 feet (Emmett and Jeffery, 1970). In other major stream valleys, thickness of alluvial deposits may reach 50 feet; it is generally less than 20 feet along the smaller tributary streams. Loess deposits consist of wind-blown silt and are present discontinuously throughout the area. Thickness of loess ranges from 2 feet in the southern part of the area to 30 feet in the northeast part of the area adjacent to the Missouri River valley (Howe and Koenig, 1961). Glacial till, composed of materials transported by glaciers and deposited by melting ice, is very sparse south of the Missouri River. The approximate southern limit of glaciation, shown in figure 2.1-1, is an indication of the southern extent of scattered deposits of glacial till.

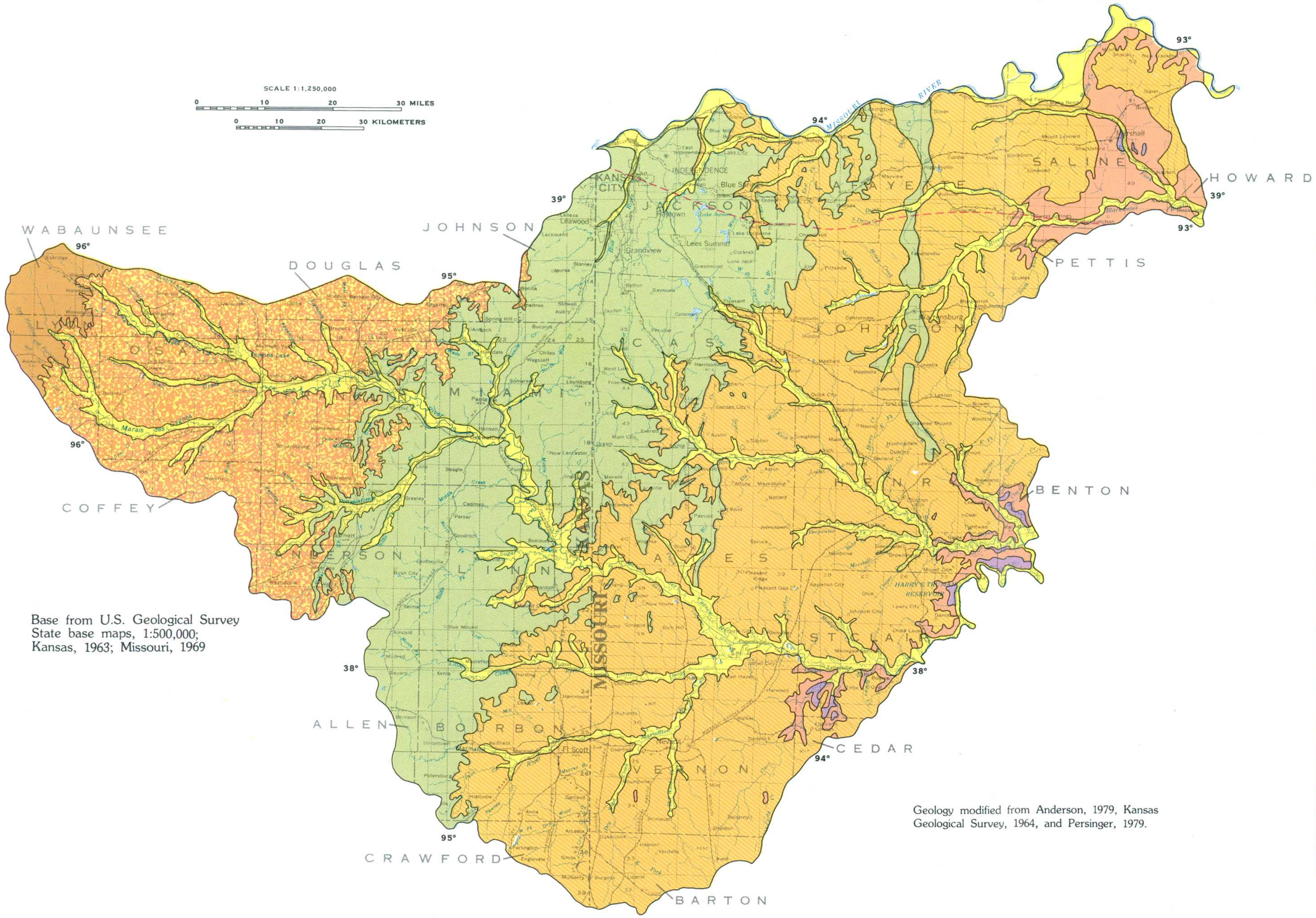



**Figure 2.1-1 Generalized geology.**

## EXPLANATION

| | | |
|---|---|---|
| | **QUATERNARY SYSTEM** | |
| **Holocene Deposits** | Alluvium | sand, gravel, silt, clay |
| **Pleistocene Deposits** | Loess (not shown) | wind blown silt |
| | Glacial till (not shown) | clay, sand, gravel, boulders |
| | **PERMIAN SYSTEM** | |
| **Lower Permian Series** | Chase Group<br>Council Grove Group<br>Admire Group | limestone, shale |
| | **PENNSYLVANIAN SYSTEM** | |
| **Virgilian Series** | Wabaunsee Group<br>Shawnee Group<br>Douglas Group | shale, sandstone, thin limestone |
| **Missourian Series** | Lansing Group<br>Kansas City Group<br>Pleasanton Group | shaly limestone and sandstone |
| **Desmoinsean Series** | Marmaton Group<br>Cherokee Group | shale, sandstone, limestone, coal, clay |
| | **MISSISSIPPIAN SYSTEM** | |
| | undifferentiated | limestone, shale, sandstone |
| | **ORDOVICIAN SYSTEM** | |
| | undifferentiated | limestone, dolomite, chert, shale |

Approximate southern limit of glaciation

# Soil Characteristics Vary with Geology and Physiography

*The four major types of soils present in the area were formed from alluvium in bottomlands; loess and glacial till on uplands; limestone, sandstone, and shale on nearly level to gently sloping prairies; and cherty limestone and dolomite in steep Ozark regions.*

Distribution of soil types varies with geologic and physiographic features. Soil characteristics are determined by the physical and mineral composition of the parent materials, relief of the land, climate, plant and animal life in and on the soil, and length of time that soil formation processes have acted on the soil material. In Area 39 these factors allow distinction of soils into four major groups: alluvial, loess, prairie, and Ozark soils (figure 2.2-1). For general purposes, soils are grouped into soil associations consisting of one or more major soil series and at least one minor soil series. Twenty-two representative soil associations are shown in figure 2.2-1. Because these soil associations are those recognized by the individual counties or States in which they were mapped, nomenclature often differs from one area to another; no attempt has been made to reconcile these differences.

Alluvial soils are present on broad, nearly level to gently sloping bottomlands along the Missouri River and its tributaries and in narrower floodplains of other major streams in the area. These soils were formed from deep silty, loamy, and clayey alluvium in the Missouri River valley, loess-covered areas, and prairies; they are derived from loamy, sandy, or cherty alluvium in narrow bottomland areas in the Ozarks.

Loess soils are located on rolling to hilly topography in the northern part of the area in Johnson County, Kansas, and along the Missouri River in Missouri. These soils were formed from thick loess deposits along river bluffs and from thinner loess deposits and glacial till on broad uplands. They are very productive, fertile soils.

Prairie soils cover most of the area. These soils were formed from limestone, sandstone, and shale on nearly level to gently sloping uplands, stream terraces, and floodplains. Soils developed from sandstone and limestone tend to be loamy and are shallow on ridges; soils developed from shale are usually deep, claypan soils.

Ozark soils are present only on the extreme eastern edge of the area, on narrow, cherty limestone ridges and steep side slopes of narrow valleys. Ozark soils formed either in residuum from cherty limestone or dolomite, from thin loess mantles on ridges, or from alluvium.

Soil-engineering properties significant to mining and reclamation operations include depth to bedrock, slope, permeability, available water capacity, soil reaction, and erosion potential. Suitability ratings of soil used as a plant growth medium in the reclamation of drastically disturbed lands are published by the U.S. Department of the Interior (1977).

Most soils in Area 39 are moderately deep to deep, with depth to bedrock approaching 5 feet for some soils. Shallow soils are present on ridges in prairie and Ozark areas. Slopes range from virtually zero for some of the alluvial soils to 60 percent for some soils on Ozark uplands.

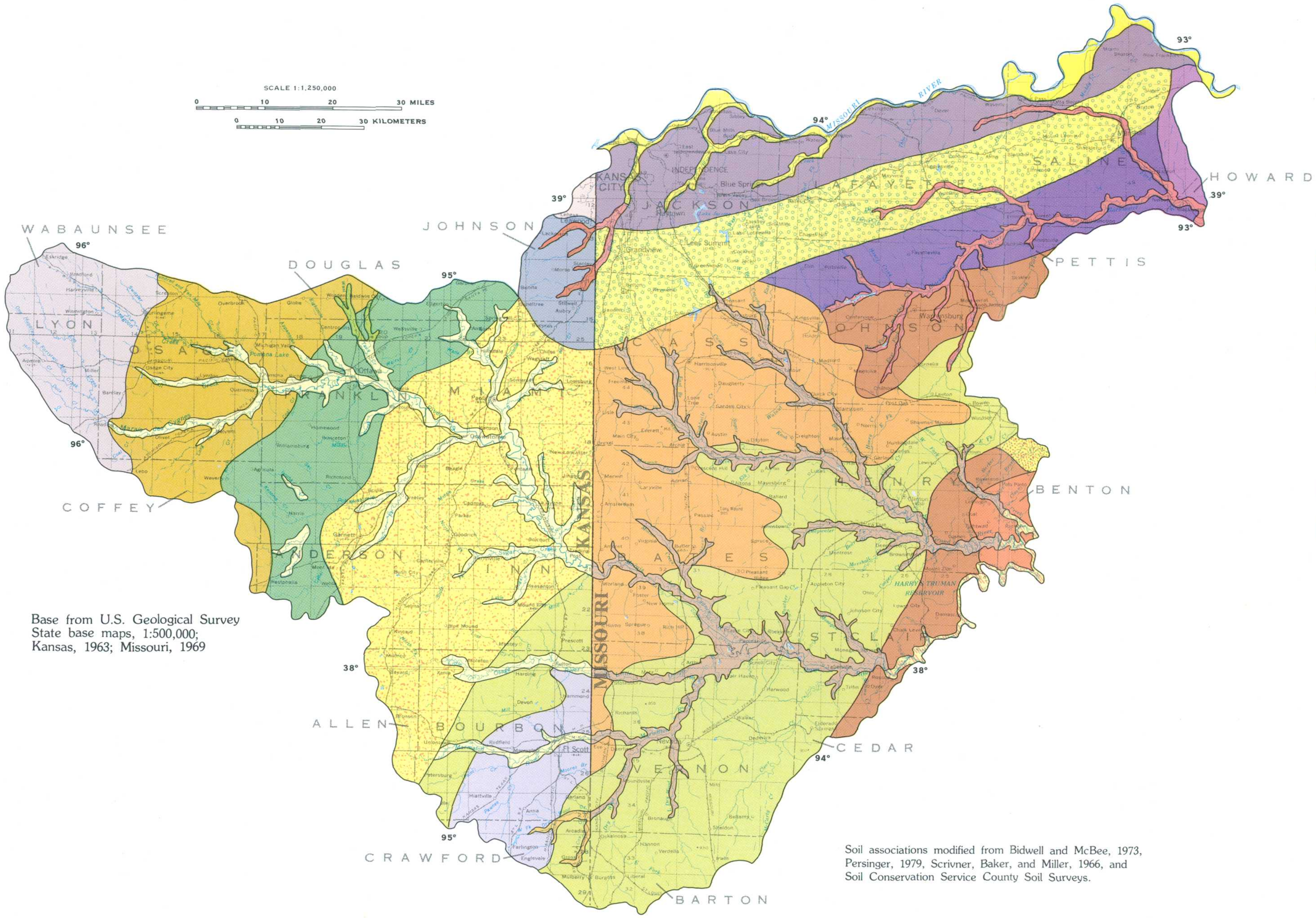
Soil permeability is defined as the rate of vertical transmission of water in saturated soil under unit pressure head. Permeabilities of soils in Area 39 range from very slow (less than 0.06 inch per hour) to moderately rapid (2.0 to 6.0 inches per hour). In general, permeabilities are lowest in soils developed from shale, clay shale, loess, and alluvium, and are moderate in soils developed from sandstone and limestone.

Available water capacity is defined as the difference between the moisture content of soil after gravity drainage is complete (field capacity) and the moisture content at the wilting point of most plants. In Area 39, available water capacity is greatest in the river valleys and some loess-covered areas, where deep, silty soils hold much water that plants can extract. Available water capacity is moderate in soils that are greater than 40 percent clay, and is least in shallow or stony soils. Available water capacity also is low in some clay soils, which hold water so tightly that plants are unable to extract it.

Soil reaction, the acidity or alkalinity of the soil expressed in pH units, ranges from strongly acid to mildly alkaline (pH 5.0 to 7.5). Those soils formed from sandstone and shale tend to be strongly acidic to neutral (pH 5.0 to 7.0). Those soils formed on material weathered from shale with interbedded limestone may be slightly acid to mildly alkaline (pH 6.0 to 7.5) due to release of calcium carbonate from the limestone. Soil reactions in alluvial soils vary with the composition of the material from which they were derived.

Erosion potential is affected by such factors as permeability rates, soil texture and stability, soil depth, slope, and vegetative cover. Most soils in Area 39 have moderate erosion potential, although a few are susceptible to wind and water erosion if proper control measures are not taken. Clayey soils under native vegetation or carefully managed cropland and pasture undergo very little erosion. Loess soils, soils on steep slopes, or soils that have been denuded are more likely to be eroded.

Discussion of these and other important soil properties, as well as more detailed maps and descriptions of individual soil series and associations, are available in publications of the U.S. Department of Agriculture, Soil Conservation Service. For further information, contact the Soil Conservation Service offices in Salina, Kansas, and Columbia, Missouri.




Base from U.S. Geological Survey State base maps, 1:500,000; Kansas, 1963; Missouri, 1969

Soil associations modified from Bidwell and McBee, 1973, Persinger, 1979, Scrivner, Baker, and Miller, 1966, and Soil Conservation Service County Soil Surveys.

**Figure 2.2-1 Soil associations.**

## EXPLANATION

### SOILS OF KANSAS

**ALLUVIAL SOILS**

- Kennebec-Chase
- Wabash-Kennebec-Reading
- Verdigris-Osage-Lanton
- Hepler-Radley

**LOESS SOILS**

- Sharpsburg-Lagoda-Knox
- Grundy-Pawnee

**PRAIRIE SOILS**

- Catoosa-Clareson-Summit
- Parsons-Dennis-Bates
- Catoosa-Kenoma-Zaar
- Kenoma-Woodson-Dennis
- Summit-Kenoma-Lula
- Ladysmith-Labette-Tully

### SOILS OF MISSOURI

**ALLUVIAL SOILS**

- Haynie-Leta-Waldron
- Kennebec-Nodaway-Colo-Zook
- Hepler-Radley-Verdigris-Osage
- Hartville-Ashton-Cedargap-Nolin

**LOESS SOILS**

- Marshall-Knox
- Sharpsburg-Grundy-Lagoda-Pershing
- Grundy-Pershing
- Menfro-Winfield-Weldon

**PRAIRIE SOILS**

- Summit-Newtonia-Parsons-Dennis
- Parsons-Dennis-Bates
- Bolivar-Mandeville

**OZARK SOILS**

- Gerald-Craig-Eldon and Newtonia-Baxter
- Clarksville-Fullerton-Talbot

# Most of Area 39 is Agricultural Land

*Land-use and land-cover maps and resource evaluation using remote-sensing techniques provide detailed information for many applications.*

Land use varies with the geology, soils distribution, climate, and topography of an area. Land use by county in Area 39 is shown in figure 2.3-1. Agricultural land used for growing crops comprises the greatest percentage of land throughout the area. Pasture and rangeland, covered with native grasses and used for grazing, is more prevalent in the western part of the area, in Kansas; forest land is more common in the eastern part, in Missouri. Areas covered by water, wetlands, urban and industrial land, and barren land constitute a relatively minor percentage of the total area and are designated "other".

Additional land-use information is available as a result of the increasing accessibility of aerial photography and other remote-sensing imagery. Detailed land-use and land-cover maps have been prepared by the U.S. Geological Survey from Landsat imagery. These maps are published at a scale of 1:250,000 and show two levels of classification (Anderson and others, 1976) using a minimum mapping unit of 4 hectares (about 10 acres). Land-use and land-cover maps are available for all parts of Area 39; information on ordering these maps may be obtained from:

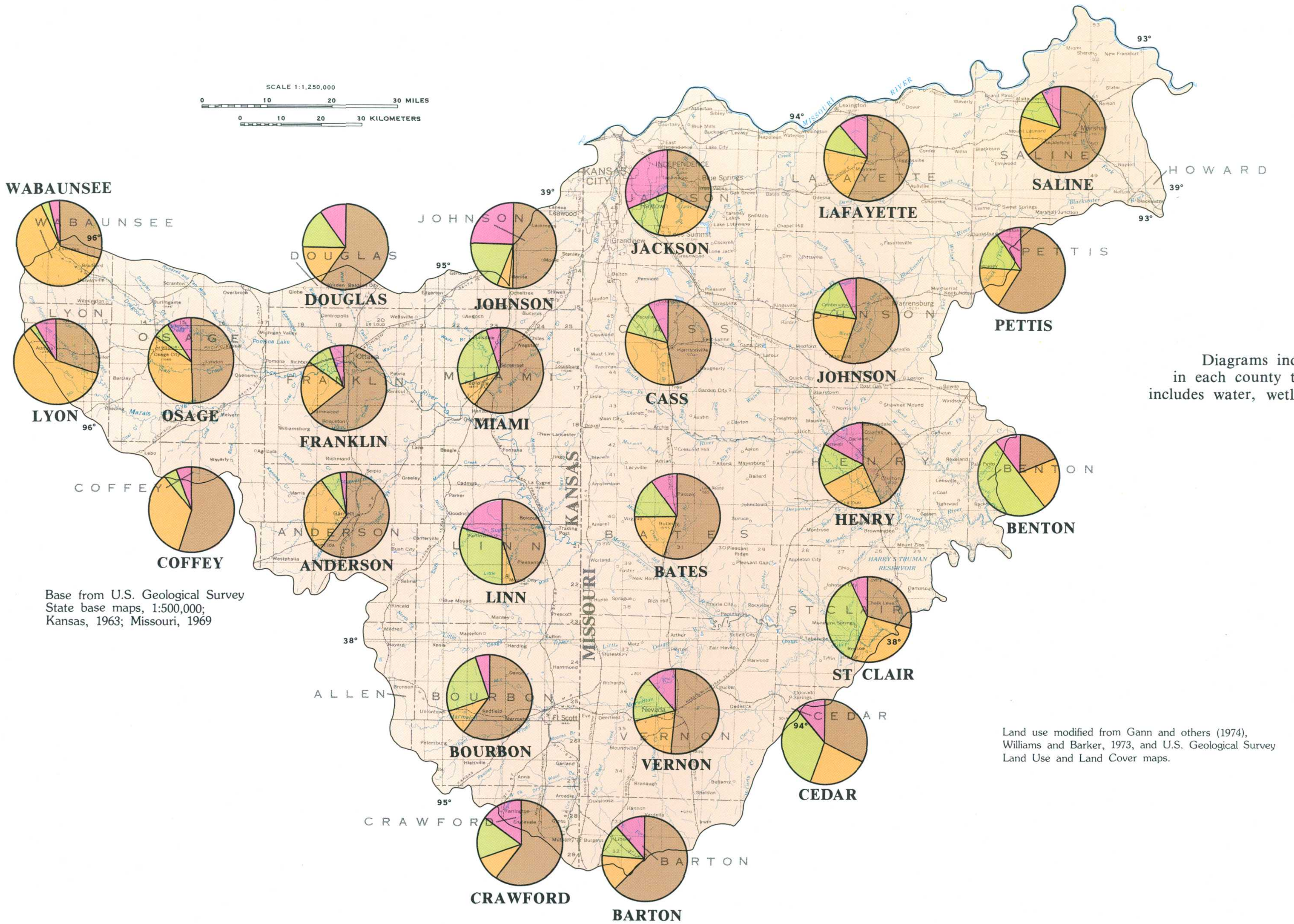
Mid-Continent Mapping Center (NCIC-M)
U.S. Geological Survey
1400 Independence Road
Rolla, Missouri 65401
Phone: (314) 341-0851

Kansas land-use patterns also are delineated on a map at a scale of 1:1,000,000 (Williams and Barker, 1973). The Kansas Applied Remote Sensing (KARS) Program, located in the University of Kansas Space Technology Center, provides assistance to local, regional, State, and Federal agencies in the design, interpretation, and application of remote-sensing data systems. Major areas of KARS Program Research and applications are:

- Land-use and land-cover inventory, change detection and mapping
- Irrigated-lands inventories
- Water-resources management
- Wildlife-habitat evaluation
- Strip-mined-lands assessment
- Crop- and rangeland-resource inventory and evaluation
- Integrated natural-resources inventories
- Geographic-information-system design, construction, and application
- Thematic mapping
- Technology transfer and remote-sensing education

For additional information contact:

Kansas Applied Remote Sensing (KARS) Program
University of Kansas
Space Technology Center
2291 Irving Hill Road
Lawrence, Kansas 66045
Phone (913) 864-4775




Base from U.S. Geological Survey
State base maps, 1:500,000;
Kansas, 1963; Missouri, 1969

Land use modified from Gann and others (1974), Williams and Barker, 1973, and U.S. Geological Survey Land Use and Land Cover maps.

## EXPLANATION

Diagrams indicate approximate percentage of total area in each county that has indicated land use. "Other" category includes water, wetlands, urban and industrial areas, and barren land.

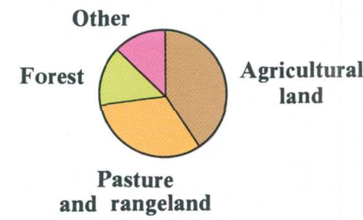



**Figure 2.3-1 Land use.**

# Ninety-Four Percent of the Water Used in Area 39 is From Surface-Water Sources

*Most of the water used (83 percent) is for cooling at thermoelectric powerplants.*

The reported surface- and ground-water use for Area 39 during 1980 (Missouri) and 1981 (Kansas) was about 1,442 million gallons per day (Mgal/d). About 1,358 Mgal/d (94 percent) was from surface-water sources and 84 Mgal/d (6 percent) from ground water. Surface-water sources include streams, ponds, and reservoirs. Water-use data for each county are shown in table 2.4-1.

The greatest volume of water (1,198 Mgal/d) was used for cooling in generating electricity. Withdrawals for public supplies (137 Mgal/d) accounted for most of the other use. Industrial, rural domestic, and irrigation use only amounted to about 7 percent of the water withdrawn.

Water use by source and category is shown in figure 2.4-1. The data are collected and compiled for each state on a continuing basis and are available from district offices of the U.S. Geological Survey.

Most surface water in the area has been classified by State regulatory agencies to protect livestock and wildlife watering, aquatic life, noncontact recreation, and crop irrigation. Most reaches of the major rivers also are classified to protect primary contact water use and the use of surface water as a source of potable water. Detailed information on use classification of streams in Kansas and Missouri is available from the Kansas Department of Health and Environment (1978) and the Missouri Department of Natural Resources (1981).

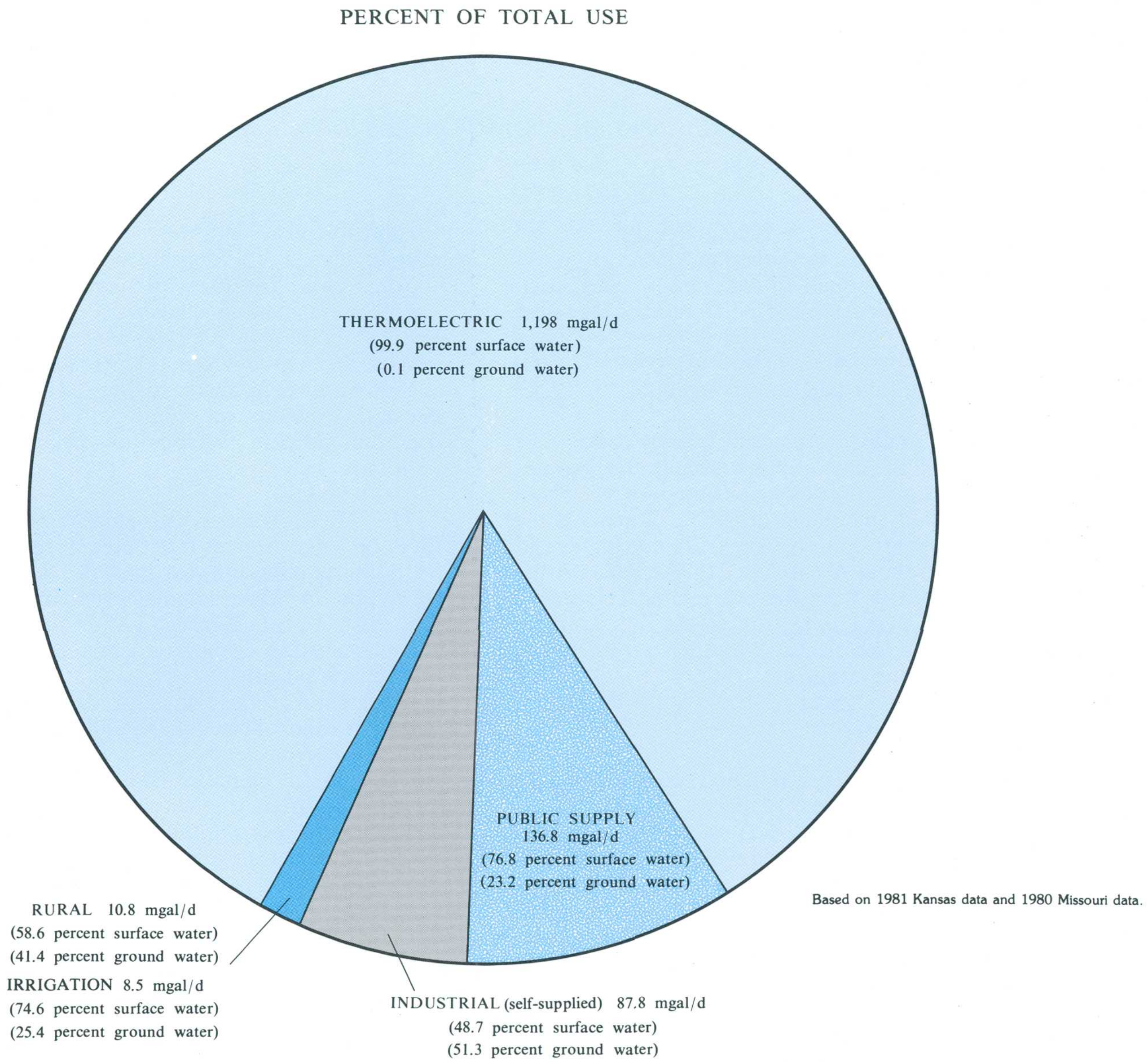



**Figure 2.4-1 Total reported water use, in million gallons per day (mgal/d), and percentage of surface water and ground water used in each category.**

**Table 2.4-1 Reported water use, in million gallons per day.**

[GW = ground water, SW = surface water, data prorated to include only the parts of counties within Area 39]

| | Public supply[a] | | Rural (self-supplied)[b] | | Irrigation | | Thermoelectric[b] | | Industrial (self-supplied) | |
|---|---|---|---|---|---|---|---|---|---|---|
| County | GW | SW | GW | SW | GW | SW | GW | SW | GW | SW |
| KANSAS (1981 Data) | | | | | | | | | | |
| Allen | - | 0.13 | | | - | 0.03 | | | 0.001 | 1.61 |
| Anderson | 0.28 | .03 | | | - | .36 | | | - | - |
| Bourbon | - | 2.45 | | | - | .23 | | | .04 | - |
| Coffey | .08 | .53 | | | - | .09 | | | - | 19.0 |
| Crawford | .61 | - | | | - | .42 | | | - | - |
| Douglas | 1.94 | 4.10 | | | 0.42 | .004 | | | 10.8 | 3.11 |
| Franklin | .15 | 1.68 | | | - | .09 | | | - | - |
| Johnson | 2.67 | 2.08 | | | .004 | .66 | | | 17.4 | .29 |
| Linn | - | .24 | | | - | .0005 | | | - | - |
| Lyon | .07 | 6.50 | | | - | .05 | | | - | - |
| Miami | .02 | .45 | | | - | - | | | - | - |
| Osage | .15 | 1.21 | | | - | .004 | | | .0002 | - |
| Wabaunsee | .33 | - | | | .04 | .01 | | | .10 | - |
| Subtotal | 6.30 | 19.4 | | | 0.46 | 1.95 | | | 28.3 | 24.0 |
| MISSOURI (1980 Data)[c] | | | | | | | | | | |
| Barton | 0.17 | 0.10 | 0.04 | 0.09 | 0.10 | 0.47 | - | - | 0.02 | 0.01 |
| Bates | .50 | 1.23 | .31 | .81 | - | .20 | - | - | 1.62 | 1.08 |
| Benton | .04 | - | .07 | .07 | .01 | .0008 | - | - | .01 | .008 |
| Cass | .04 | 3.74 | .92 | .99 | - | 1.89 | - | 0.18 | .47 | .32 |
| Henry | .65 | .69 | .68 | .88 | - | .074 | - | 378 | .19 | .13 |
| Jackson | 15.9 | 77.6 | .11 | .24 | .34 | - | 1.22 | 790 | 8.72 | 5.81 |
| Johnson | 2.45 | .28 | .34 | .86 | .04 | .28 | - | - | .33 | .22 |
| Lafayette | .43 | 2.04 | .65 | 1.01 | - | .39 | - | - | .29 | .19 |
| Pettis | .04 | .32 | .09 | .08 | .009 | .01 | - | - | .04 | .02 |
| Saline | 3.51 | - | .61 | .67 | .23 | .04 | - | 29.0 | 1.65 | 3.49 |
| St. Clair | .12 | .007 | .35 | .41 | - | .08 | - | - | .06 | .04 |
| Vernon | 1.67 | - | .31 | .22 | .98 | .98 | - | - | 3.34 | 7.49 |
| Subtotal | 25.5 | 86.0 | 4.48 | 6.33 | 1.71 | 4.41 | 1.22 | 1,197 | 16.7 | 18.8 |
| Totals | 31.8 | 105 | 4.48 | 6.33 | 2.17 | 6.36 | 1.22 | 1,197 | 45.0 | 42.5 |

[a] Includes municipal supplies, public water supply districts, subdivisions, mobile-home parks, institutions, and miscellaneous facilities.
[b] No data available for Kansas
[c] Area of Cedar and Cooper Counties included in Coal Area 39 is insignificant and was not included.

# Area 39 Characterized by Humid, Continental Climate

*Average annual rainfall ranges from 34 inches in the west to greater than 40 inches in the east.*

The climate of Area 39 is continental in type and is affected primarily by alternate masses of warm moist air from the Gulf of Mexico and cold, comparatively dry air from the polar regions. Weather patterns consequently are characterized by large variations in precipitation and temperature. Extremes and sudden changes are common.

Average annual temperature averages about 56° Fahrenheit in the area. July is usually the warmest month with an average daily maximum of 91° F and an average daily minimum of 69° F; January is the coldest month with an average daily maximum and minimum of about 40° F and 21° F. The growing season, or period from the last killing frost in the spring to the first killing frost in the fall, averages about 185 days (see Kansas Water Resources Board, 1958). Prevailing winds are from the south during the growing season, and from the north during the winter.

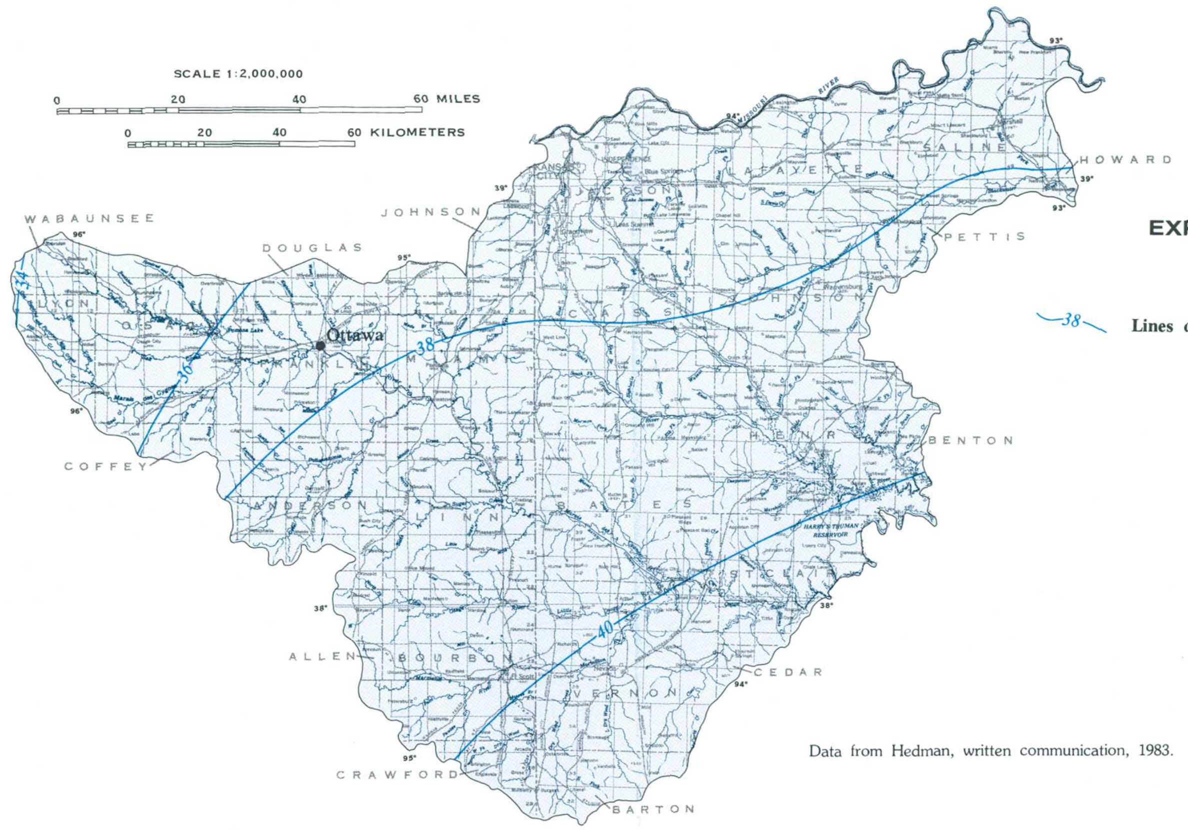
Average annual precipitation ranges from 34 inches in the western part of the area to greater than 40 inches in the east (fig. 2.5-1). About 70 percent of this precipitation falls during the growing season months of April to October, commonly in intense thunderstorms of short duration or longer storms of great areal extent. Periods of little or no precipitation can occur at any time of year. Precipitation is less intense during the winter months. Annual snowfall averages about 16 inches (U.S. Department of Interior, Geological Survey, 1970) and the ground generally is snow-covered for a total of less than 30 days each year.

Climatological data for Ottawa, Kansas, are shown in figure 2.5-2. Monthly mean temperatures at Ottawa, Kansas for 1941-70 range from a low of 30.5° F in January to a high of 78.8° F in July. Monthly mean precipitation during this period ranged from a minimum of 1.3 inches in February to a maximum of 5.76 inches in June. High temperatures during the summer months often coincide with periods of deficient precipitation, causing drought conditions.

The rate of evaporation increases from east to west in the area. Annual free water surface evaporation, or the amount of water that will evaporate from a thin film of water having no appreciable heat storage, is shown in figure 2.5-3. Determination of free water surface evaporation is useful because it approximates potential evaporation from adequately watered natural surfaces such as vegetation and soil (Farnsworth and others, 1982).

Other useful climatic data include probability analysis of rainfall frequency and intensity. Contours of the 24-hour rainfall that would be exceeded once in 10 years for the region are shown in figure 2.5-4.

Climatological data are collected for a number of stations in the area by the National Oceanic and Atmospheric Administration. Data are published monthly for each State in "Climatological Data" and "Hourly Precipitation" and include records of temperature, precipitation, snowfall, evaporation, wind velocity, relative humidity, and soil temperature.




EXPLANATION

38 Lines of equal precipitation, in inches.

**Figure 2.5-1 Mean annual precipitation 1951-80.**

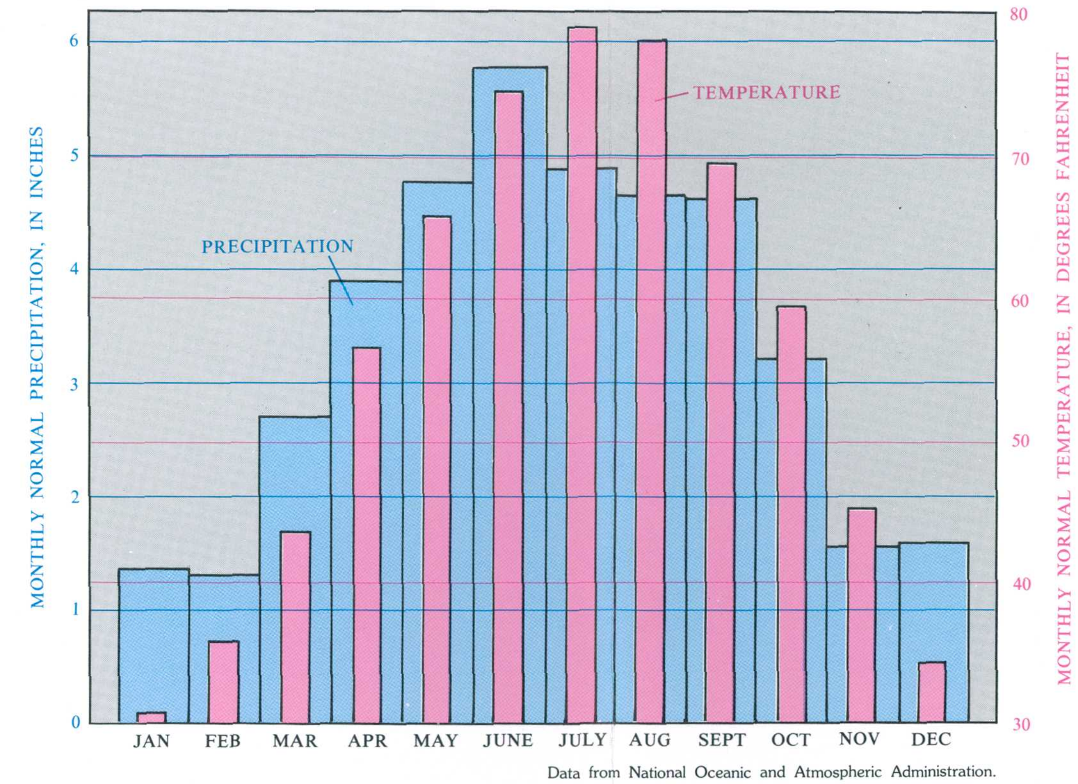
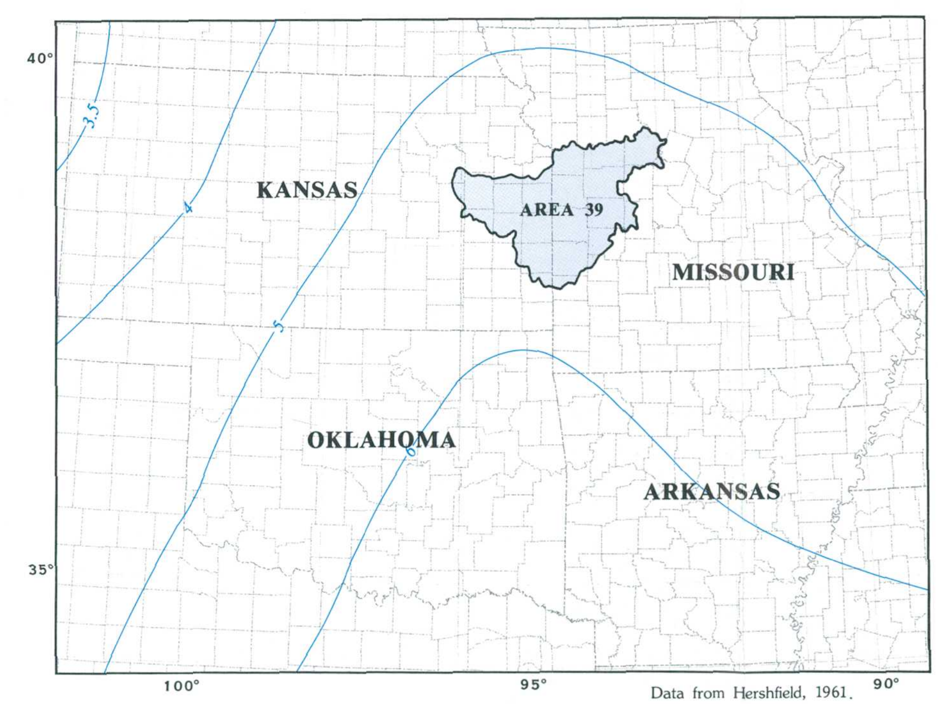



**Figure 2.5-2 Monthly mean precipitation and temperature, measured at Ottawa, Kansas, 1941-70.**


EXPLANATION

42 Lines of equal evaporation, in inches.

**Figure 2.5-3 Annual free water surface evaporation, 1956-70.**




EXPLANATION

5 10-year, 24-hour rainfall, in inches.

**Figure 2.5-4 Rainfall frequency.**

# Coal Reserves in 19 Counties Total 1.75 Billion Tons

*Bituminous coals of Pennsylvanian age occur in seams from 1 to 4 feet thick and have relatively high sulfur contents and heat values.*

Coal deposits are present in Pennsylvanian rocks throughout most of Area 39. The prevailing dip of these coal-bearing rocks is to the northwest; consequently depth to the coal increases in the direction of the dip. The coal seams are predominately flat-lying and relatively free of faulting (Mining Informational Services, 1982).

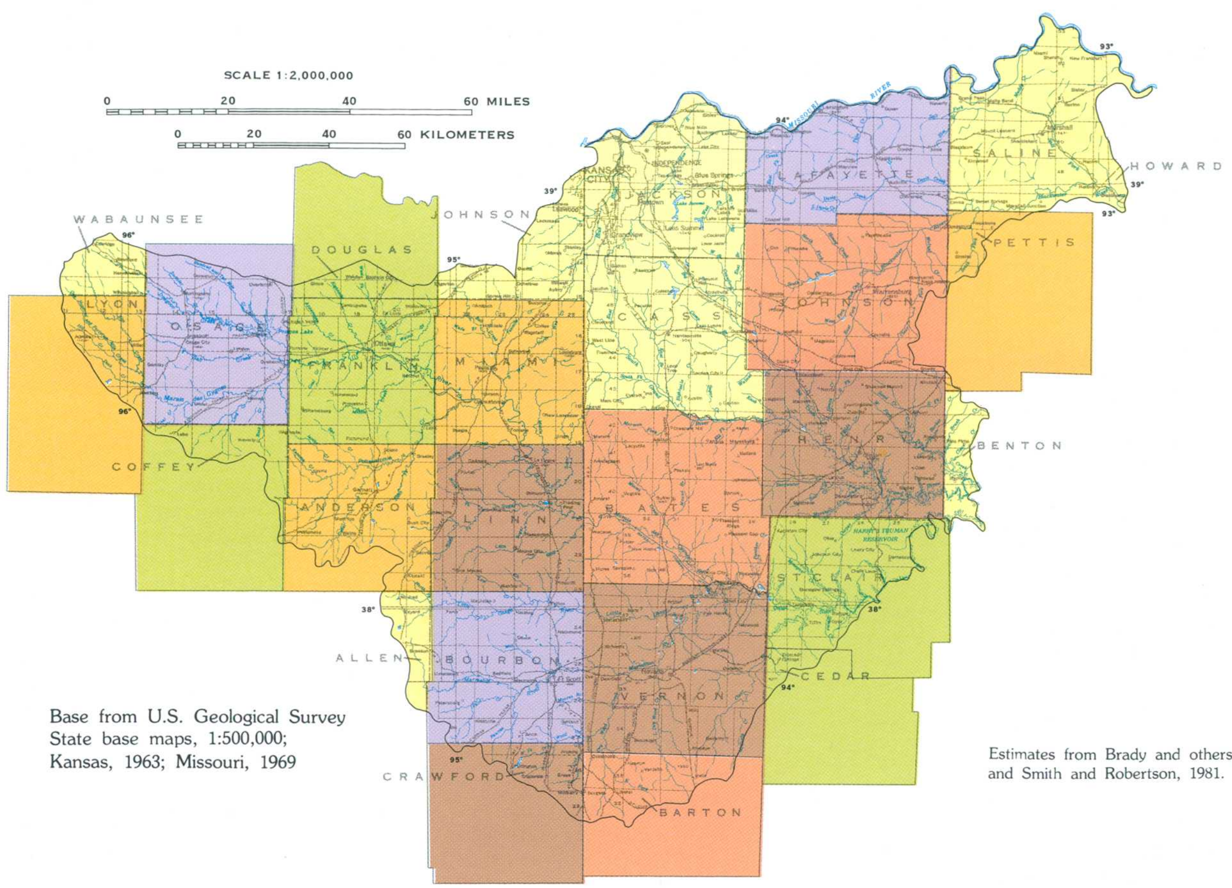
Remaining identified coal reserves, as determined by Brady and others (1976) and Robertson and Smith (1981), are indicated in figure 3.1-1. These are coals that can be mined with current (1983) technology and under current economic conditions. For Area 39, where virtually all coal is and will continue to be produced by strip-mining methods, an overburden to coal thickness ratio of 30:1 or less was used as the criteria for evaluating remaining reserves.

Identified coal reserves include those reserves in three reliability classes (measured, indicated, and inferred) as agreed upon by the U.S. Bureau of Mines and the U.S. Geological Survey (Averitt, 1975). Estimates of measured reserves are determined from closely spaced (no greater than ½ mile apart) observation points showing the thickness and extent of the coal seams. Estimates of indicated reserves are based on observation points up to 1½ miles apart, from which the thickness and extent of the coal seams are projected using geologic evidence. Estimates of inferred reserves are based on observation points averaging about 2 miles apart, and on an assumed continuity of coal seams into areas surrounding those containing measured and indicated reserves. The greatest amounts of strippable reserves are located in Crawford and Linn Counties, Kansas, and Henry and Vernon Counties, Missouri.

Potentially strippable coals in Kansas and Missouri occur in the Wabaunsee and Douglas Groups of the Virgilian Series and in the Marmaton and Cherokee Groups of the Desmoinesian Series. Coal seams that currently cannot be mined economically in Area 39 due to increasing depth to coal with increasing distance from the outcrop, large amounts of limestone overburden, thinness or discontinuity of the seam, or undesirable sulfur content are not considered reserves in this report. Coals that represent strippable reserves are shown stratigraphically in figure 3.1-2. In general these coals are thin, ranging from 1 to 4 feet in thickness.

Coals in Kansas and Missouri are high volatile bituminous in rank. Heat values are generally high, averaging about 12,300 British thermal units per pound (Btu/lb.) for Kansas coals and 11,000 Btu/lb. for Missouri coals. The sulfur contents of coals in Area 39, on an as-received basis, range from 3 to 10 percent, and average about 4.5 percent. Most of the sulfur occurs as the iron sulfide mineral, pyrite. [See Brady and Dutcher (1974), Mining Informational Services (1982), and Smith and Robertson (1981)].

Detailed information on chemical and physical properties of coals in Area 39 can be obtained from the references listed in section 11.0. Stratigraphic, petrographic, and chemical information on coal-bearing rocks nationwide is stored in a U.S. Geological Survey data base known as the National Coal Resources Data System (NCRDS). Contact the U.S. Geological Survey, MS 956, Reston, VA 22092 for accessing procedures.




Base from U.S. Geological Survey State base maps, 1:500,000; Kansas, 1963; Missouri, 1969

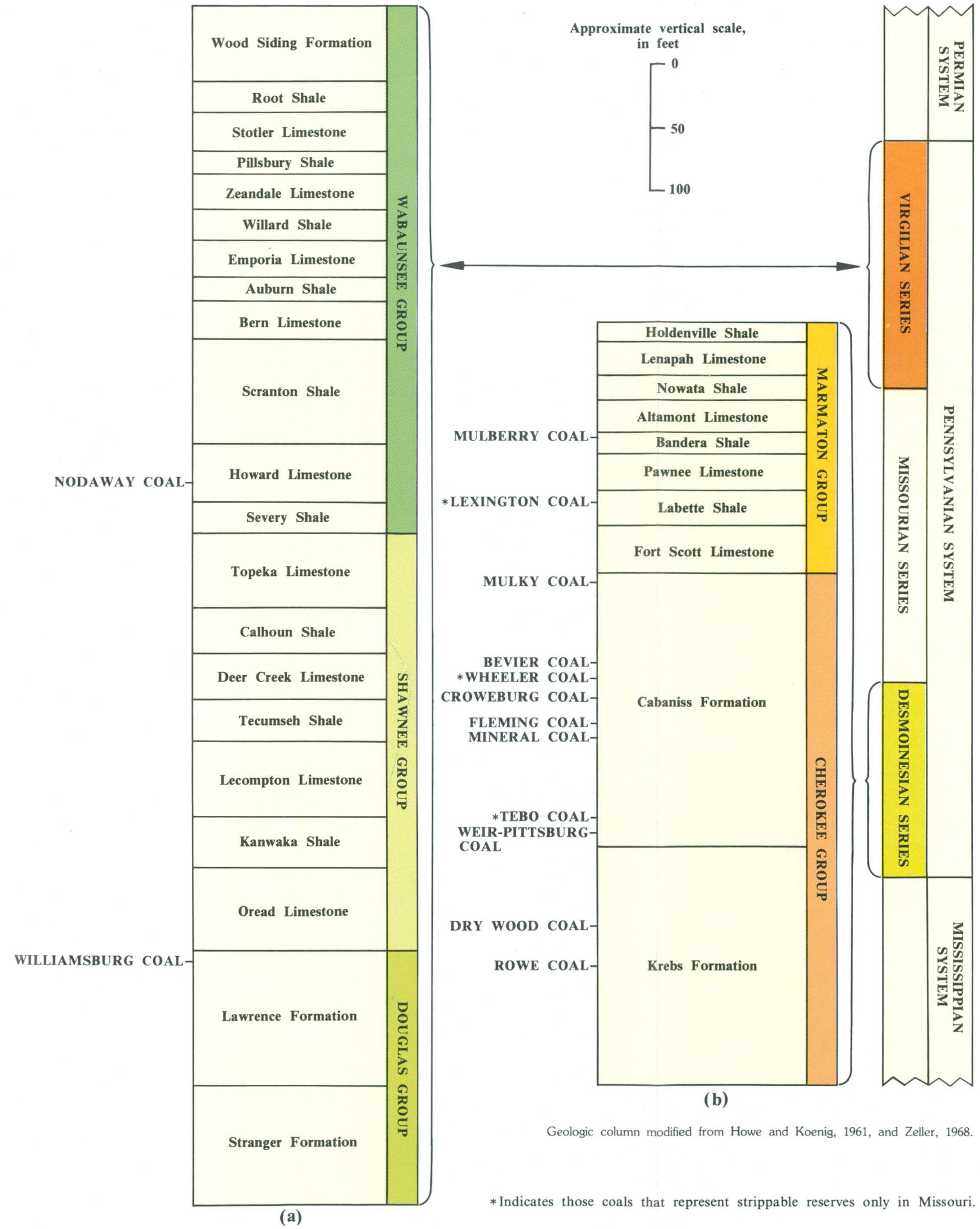
Estimates from Brady and others, 1976, and Smith and Robertson, 1981.

**EXPLANATION**

REMAINING STRIPPABLE COAL RESERVES, IN MILLIONS OF TONS

- 0
- 0-5
- 5-50
- 50-100
- 100-200
- 200-300

**Figure 3.1-1 Remaining identified coal reserves in Area 39 counties.**




Geologic column modified from Howe and Koenig, 1961, and Zeller, 1968.

*Indicates those coals that represent strippable reserves only in Missouri.

**Figure 3.1-2 Generalized geologic column showing stratigraphic position of strippable reserves of coal (a) in Virgilian Series in Kansas, and (b) in Desmoinesian Series in Kansas and Missouri.**

# Approximately 520 Million Tons of Coal Have Been Mined by Surface and Underground Methods in Area 39

*All coal currently is produced from strip mines, located in three Kansas counties and four Missouri counties. Although these mines are subject to reclamation laws, about 85,000 acres of land remain disturbed from previous coal operations.*

Coal has been mined in the area for more than a century. Techniques for recovering this mineral resource have included underground mining through shafts, drifts, and slopes; and surface mining. Coal production by all mining methods through 1980 in the area is indicated in figure 3.2-1. The greatest amounts of coal have been mined near outcrop areas where the overburden was thin (permitting surface mining) and in areas where the coal seams were thickest (permitting underground mining). Almost 90 percent of the past coal production has occurred in 5 counties: Crawford County in Kansas, and Barton, Bates, Henry, and Lafayette Counties in Missouri. Coals mined have been primarily from the Cherokee Group, notably the Weir-Pittsburg, Tebo, Mineral, and Bevier seams (Section 3.1).

Historical trends in coal production for Kansas and Missouri are illustrated in figure 3.2-2. Early production of coal was almost entirely from underground mines; however, since 1925 in Missouri and 1931 in Kansas strip mining has accounted for more than half of all coal mined, and in recent years has comprised essentially all of the coal produced in the area (Mining Informational Services, 1982). Peaks in coal production were reached during the years just prior to 1920 and during the World War II years. Significant increases in coal mining activity since the 1960's have occurred due to the increased demand for fossil fuels and the development of more efficient equipment for strip mining the remaining thin coal seams. Coal production in Missouri alone increased from 3.7 million tons in 1967 to 6.8 million tons in 1976 (Vaill and Barks, 1980).

Recent coal production in Missouri has exceeded that in Kansas for geographic, economic, and political reasons. Because of the northwest dip of the Pennsylvanian strata (Section 3.1) the overburden that must be removed to reach the thin coal seams is generally thicker in Kansas than in Missouri, causing prohibitively high stripping ratios (thickness of overburden to thickness of coal). The cost of mining and land reclamation are also higher with increasing depth of overburden. Reclamation laws and enforcement may differ from one State to another. Demand for high-sulfur coal mined in Kansas and Missouri varies with supply of coal from other States and with the number of oil- and gas- fired plants that are converting to coal.

More than half of the recent coal mining in Kansas and Missouri has been conducted in Area 39. Over 20 million tons of coal were produced from Bourbon, Crawford, and Linn Counties in Kansas and Barton, Bates, Henry, and Vernon Counties in Missouri from 1976 to 1980 inclusive. Average annual tonnages mined for those years were 877,000 tons for the three counties in Kansas and 3,435,000 tons for the four counties in Missouri (Mining Informational Services, 1978-1982). In the Kansas part of Area 39, where stripping ratios are among the highest in the nation, five mines are currently (1983) in operation. The largest of these mines is in Linn County, where the Mulberry coal is being extracted. Multiple-seam mining is common in Bourbon and Crawford Counties, where the Mulky, Bevier, Croweburg, Fleming, and Mineral coals are mined. The Rowe and Drywood seams are mined in parts of Barton and Vernon Counties, although most coal production in the Missouri part of Area 39 is from the Weir-Pittsburg, Tebo, Mineral, Croweburg, and Mulky seams in Vernon and Henry Counties. Tandem mining of stratigraphically close coals is common. The Mulberry coal is currently mined in Bates County, at the mine that extends into adjacent Linn County, Kansas.

At large strip mines in Kansas and Missouri, electric shovels and draglines with bucket capacities of from 30 to 110 cubic yards are used for overburden removal. For smaller operations or in areas of shallow overburden, bulldozers and large tractor-scrapers are often utilized.

The primary use of coals mined in Area 39 is for electric power generation. While these bituminous coals produce more heat than equal volumes of subbituminous coals or lignite mined from thicker seams in the western United States, their high sulfur contents necessitate the additional cost of pollution-control equipment to meet air-quality regulations for sulfur dioxide emissions.

Added expense in coal mining after 1968 was incurred with the passage of State laws requiring reclamation of surface-mined lands. During the following decade these State laws were strengthened, and the more comprehensive Federal Surface Mining Control and Reclamation Act of 1977 was enacted. This legislation has initiated protection of land and water resources, but may limit the amount of coal that can be strip mined economically.

Although lands mined since the passage of these laws are subject to reclamation, much land in Area 39 remains disturbed due to pre-law mining, proximity to mining operations, and/or surface effects of underground mining. The acreages of unreclaimed land resulting from coal mining in 16 counties in Area 39 are indicated in figure 3.2-3. No acreages of disturbed land were reported for Lyon County, Kansas, or for Jackson and Lafayette Counties, Missouri, where negligible amounts of land disturbed by old underground or small surface mining operations remain unreclaimed. Of a total of about 85,000 acres of disturbed land in counties reporting acreages, reclamation is required by law on only about 7,200 acres, or 8.5 percent.

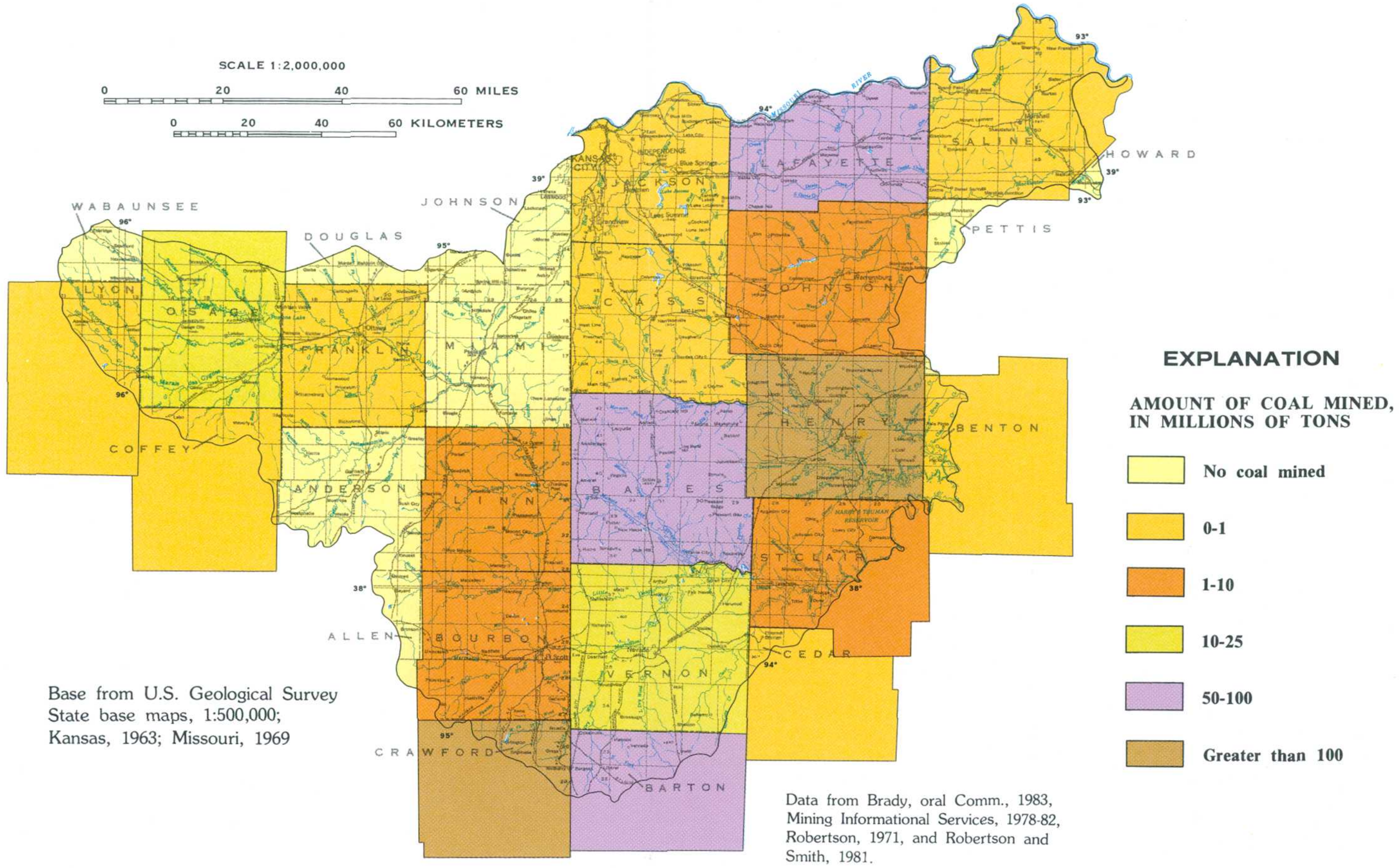



**Figure 3.2-1** Coal production through 1980 in Area 39 counties.

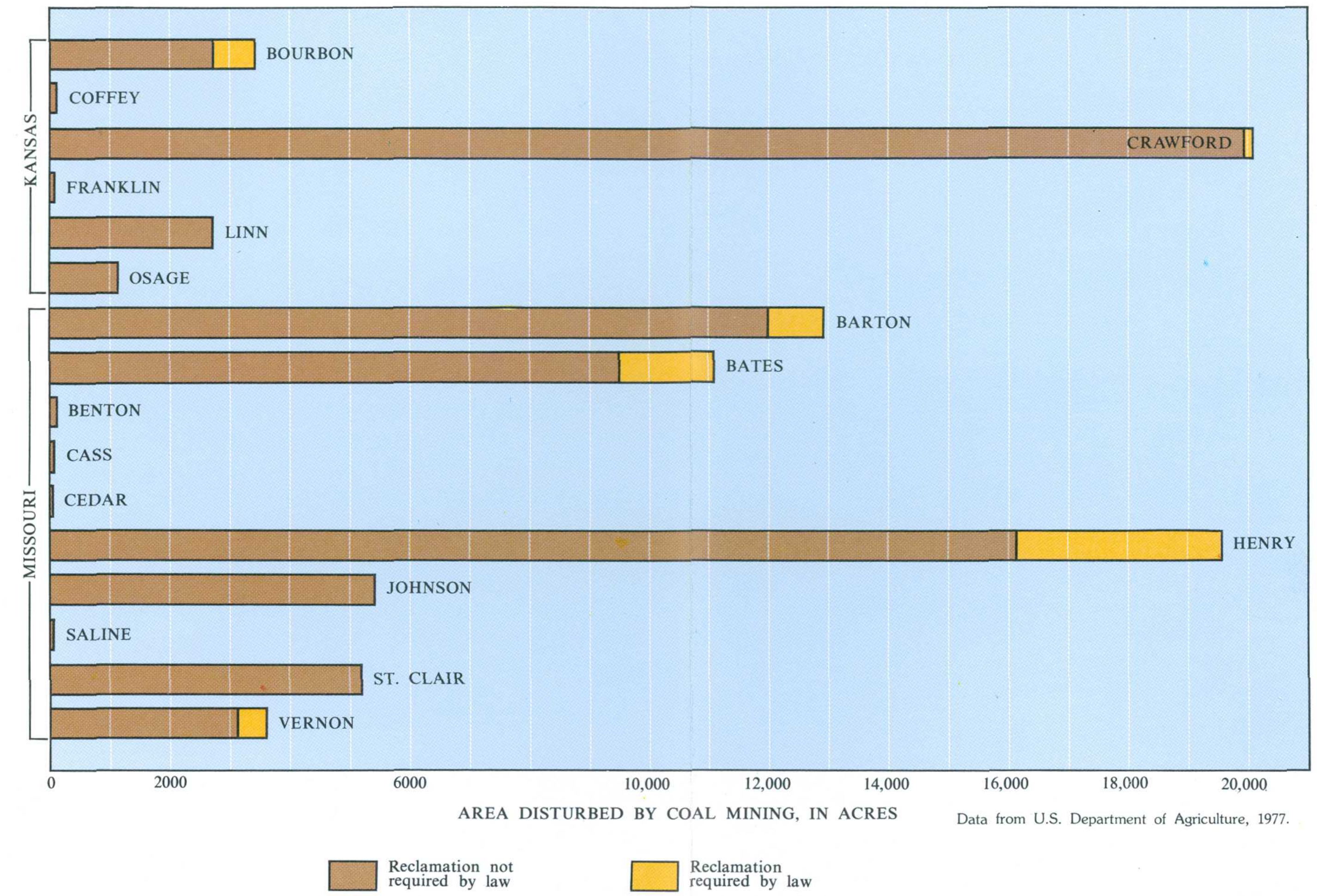



**Figure 3.2-3** Acreages of unreclaimed coal-mined land in Area 39 counties.

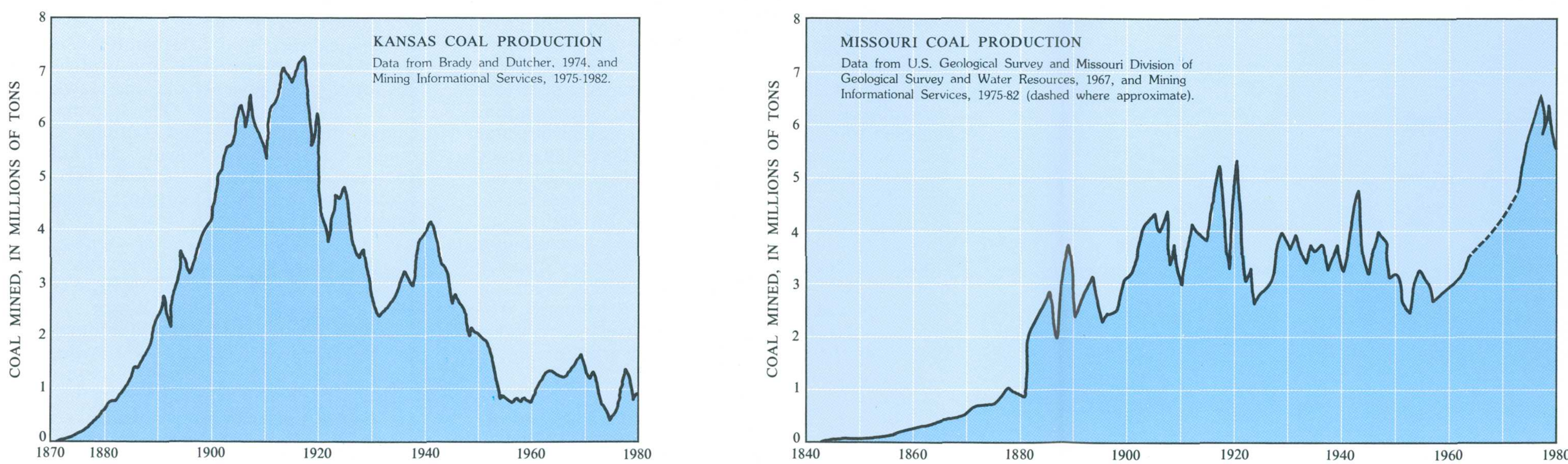



**Figure 3.2-2** Historical trends in coal mining, by state.

## 4.0 SURFACE-WATER DATA NETWORK

# Hydrologic Characteristics of the Major Streams and Their Tributaries are Defined by Data from 139 Surface-Water Stations

*The data network consists of continuous-record streamflow and reservoir-stage stations, partial-record crest-stage and low-flow stations, and stations where water-quality data are available.*

The objective of the surface-water data network is to provide representative streamflow and water-quality information for the area. Location and type of data collected for all active and discontinued stations are shown in figure 4.0-1. Information about the station name and location, period of record, types of data collected, and drainage-area size is provided in Section 10.1.

At present (1983), hydrologic data are available for 139 stations, of which 60 are currently active. The network consists of 55 stations where continuous-record streamflow data are available, 3 continuous-record reservoir-stage stations, 14 partial-record crest-stage stations, 25 partial-record low-flow stations, and 76 stations where water-quality data have been collected. Surface-water quality data are available for 42 stations on streams draining coal-mined areas and 21 stations on streams draining unmined areas; the network includes 45 stations where sediment data are available.

Records of stage, or water-surface elevation above an arbitrary datum, are obtained either from direct readings on a nonrecording gage or from a continuous water-stage recorder. Stage records, when combined with direct measurements of streamflow (discharge) to derive stage-discharge relations, are used to compute discharge for any given stage. For stations with continuous recorders, daily values for streamflow are available; for other stations only limited data are collected. Crest-stage gages register the peak stage occurring between inspections and provide records of peak discharges for determining flood-frequency characteristics. Discharge measurements at partial-record low-flow stations, made during dry periods when streamflow is primarily from ground-water discharge, can be correlated with continuous-discharge records from nearby streams to define low-flow characteristics.

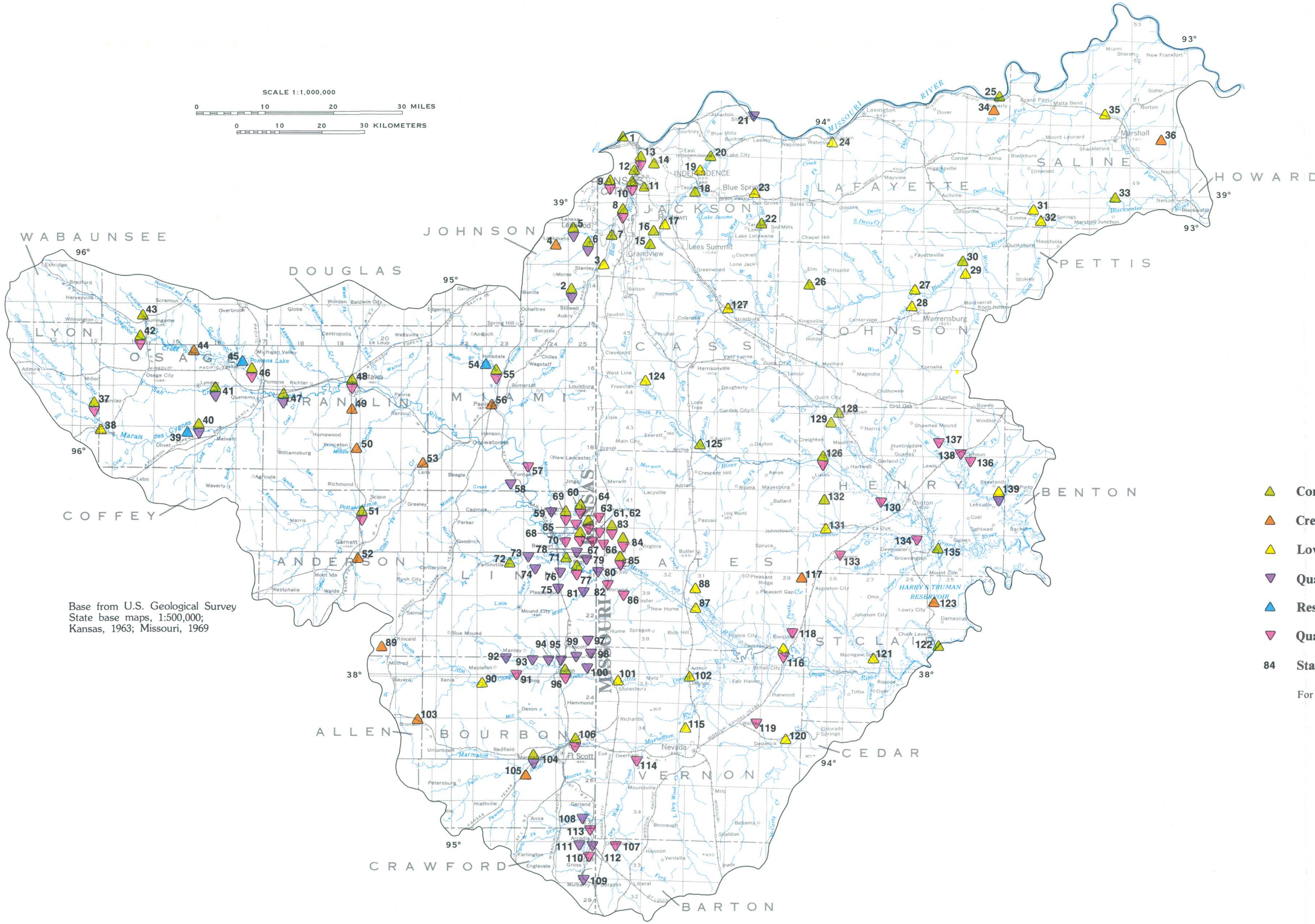
For reservoir stations, capacity tables are prepared relating volume to stage. Application of stage readings to capacity tables gives the volume, from which daily, monthly, and yearly changes can be computed.

Water-quality data commonly are collected at stream-gaging stations in order to provide relationships between streamflow and concentrations or loads of constituents. Several types of data are collected, but not necessarily at each station. Temperature and specific conductance commonly are recorded by means of automatic monitors. Temperature, specific conductance, pH, and dissolved oxygen usually are measured when water-quality samples for chemical analyses are collected.

Sediment data may include determinations of suspended-sediment concentrations as well as particle-size analyses of suspended sediment and bed material. These data are used to establish relations between sediment yields and streamflow, and to predict long-term sediment characteristics of streams. Particle-size data are useful in identifying the character of the sediment in transport and deposited on the stream bed.

The National Stream-Quality Accounting Network (NASQAN) is a national data-collection network operated by the U.S. Geological Survey to depict areal variability in streamflow and water quality on a year-to-year basis and to detect and assess any long-term changes (Ficke and Hawkinson, 1975). Data collected at NASQAN stations include discharge measurements and samples for chemical-quality, suspended-sediment, and phytoplankton analyses. The Area 39 surface-water network includes one NASQAN station, Osage River near Schell City, Mo. (Station 116).

Additional data and information about the surface-water stations are available from computer storage through the National Water Data Exchange (NAWDEX) and are published annually in the U.S. Geological Survey reports "Water-Resources Data for Kansas" and "Water-Resources Data for Missouri." All data are collected by the U.S. Geological Survey in cooperation with various federal, State, and local agencies and can be retrieved through the National Water Data Storage and Retrieval system (WATSTORE) as explained in Section 9.3.




Base from U.S. Geological Survey
State base maps, 1:500,000;
Kansas, 1963; Missouri, 1969

**EXPLANATION**

- Continuous-record streamflow gaging station
- Crest-stage station
- Low-flow station
- Quality-of-water station
- Reservoir station
- Quality-of-water station where sediment data are available

84 Station number

For description of the stations, see Section 10.1

**Figure 4.0-1 Location of stations in the surface-water network.**

# Streamflow Varies Seasonally

*Daily and seasonal variations in precipitation cause considerable differences in monthly and yearly flow patterns and volumes.*

Seasonal variations in streamflow are shown in figure 5.1-1 by a sample hydrograph for the 1981 water year. Lowest flows occur during periods of little or no precipitation, usually in the late summer when evapotranspiration rates are high, or in the late winter. The highest flows of the year occur in spring and early summer. Flow variability from month to month is illustrated in figure 5.1-2. Flows during the 1981 water year generally were less than the long-time average monthly flows from October through April and greater thereafter, and the peak flow of the year was considerably less than the all-time maximum. Average annual flows at streamflow-gaging stations where continuous record was sufficient to establish an average annual flow rate are shown in table 5.1-1. Average annual flows of ungaged streams in Area 39 (except the Missouri River) can be estimated by using the equation,

$$Q_a = 0.80\, A^{0.95}$$

where average annual streamflow ($Q_a$) is in cubic feet per second, and drainage area (A) is in square miles. The standard error of estimate of the equation is about 10 percent. The equation is based on data from 26 long-time continuous-record streamflow-gaging stations with drainage areas ranging from 1.1 to 8,220 square miles. The relationship between drainage area and mean annual flow is shown graphically in figure 5.1-3.

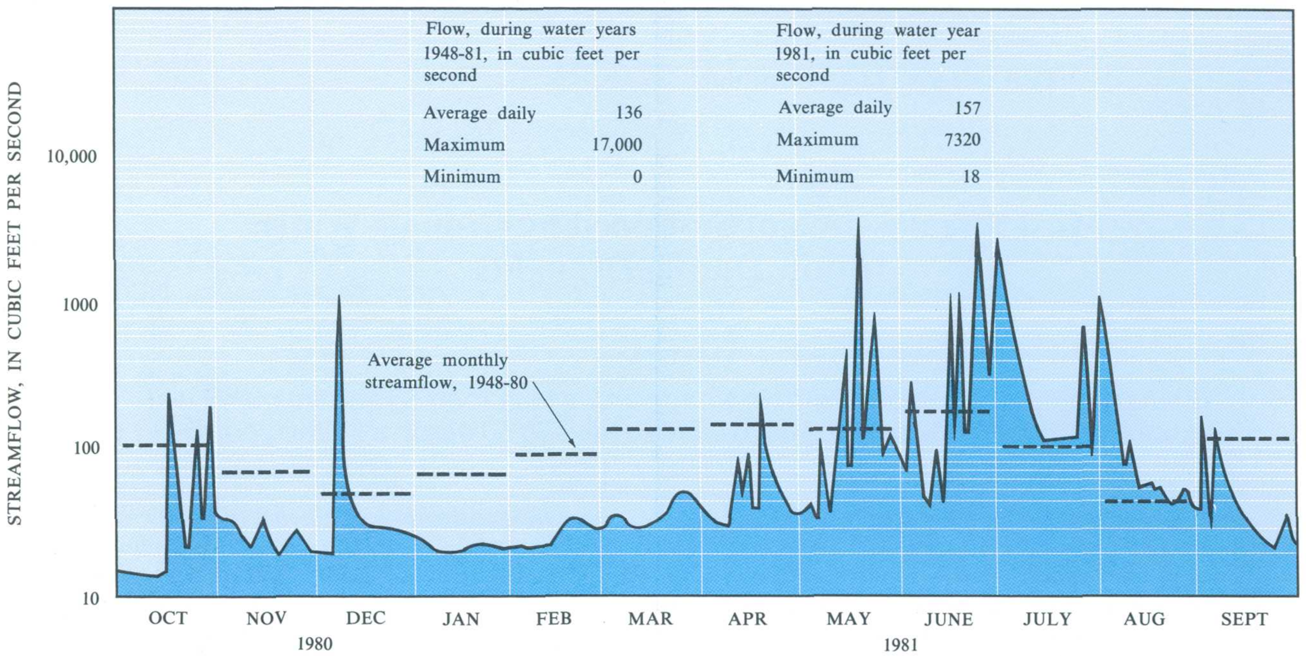



**Figure 5.1-1** Average daily streamflow for 1981 water year and average monthly streamflow for water years 1948-80 at Little Blue River near Lake City, Missouri, station 20.

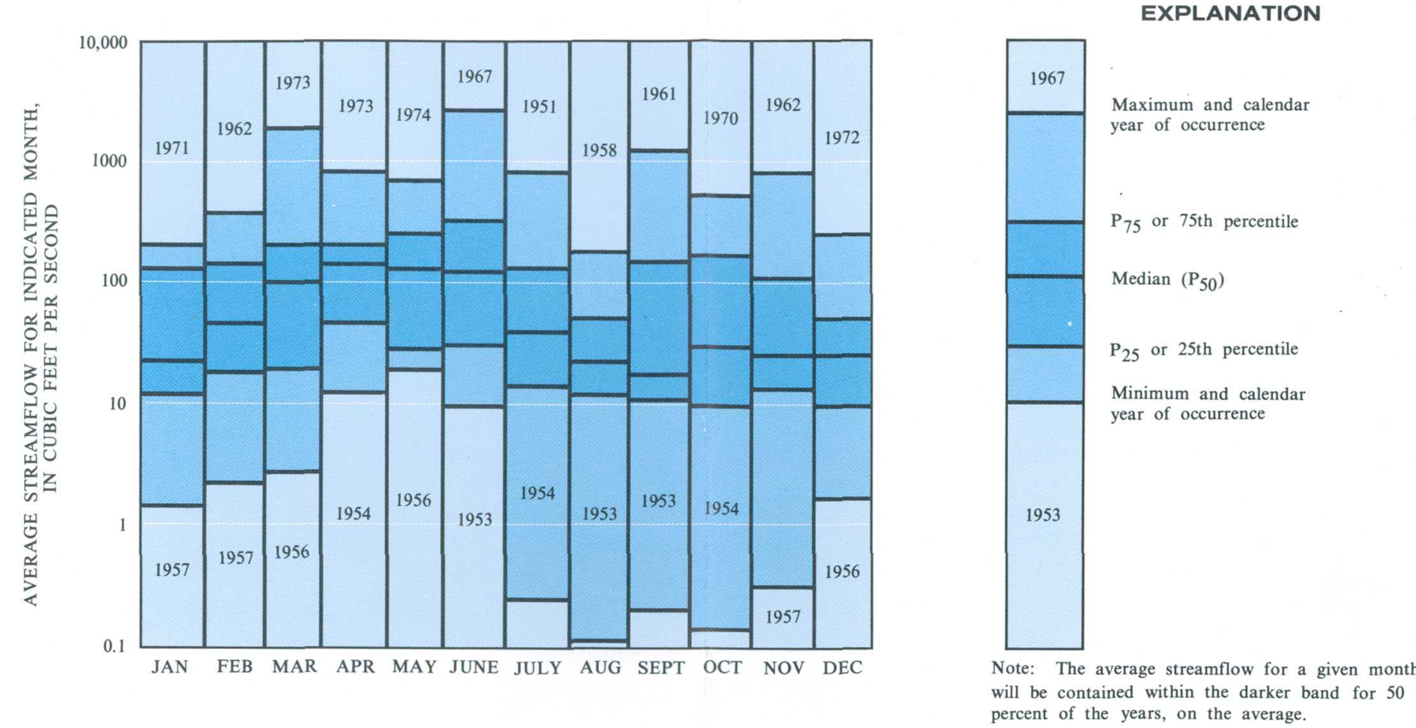



**Figure 5.1-2** Monthly flow data for Little Blue River near Lake City, Missouri, station 20, water years 1948-80.

**Table 5.1-1** Average annual flow at streamflow-gaging station.

| Map No. (fig. 4.0-1) | Station name and location | Drainage area, in square miles | Average annual flow, in cubic feet per second |
|---|---|---|---|
| 1 | Missouri River at Kansas City, Mo. | 485,200 | 54,620 |
| 2 | Blue River near Stanley, Kans. | 46.0 | 18.5 |
| 5 | Indian Creek at Overland Park, Kans. | 26.6 | 23.8 |
| 6 | Tomahawk Creek near Overland Park, Kans. | 23.9 | 10.4 |
| 7 | Blue River near Kansas City, Mo. | 188 | 142 |
| 14 | Rock Creek at Independence, Mo. | 5.20 | 4.6 |
| 16 | Little Blue River below Longview Damsite in Kansas City, Mo. | 50.7 | 36.8 |
| 18 | East Fork Little Blue River near Blue Springs, Mo. | 34.4 | 18.8 |
| 20 | Little Blue River near Lake City, Mo. | 184 | 136 |
| 22 | Sni-a-bar Creek near Tarsney, Mo. | 29.1 | 22.6 |
| 25 | Missouri River at Waverly, Mo. | 487,200 | 48,830 |
| 26 | South Fork Blackwater River near Elm, Mo. | 16.6 | 11.5 |
| 30 | Blackwater River at Valley City, Mo. | 547 | 451 |
| 33 | Blackwater River at Blue Lick, Mo. | 1,120 | 651 |
| 36 | Shiloh Branch near Marshall, Mo. | 2.87 | 1.4 |
| 37 | Marais des Cygnes River near Reading, Kans. | 177 | 100 |
| 40 | Marais des Cygnes River at Melvern, Kans. | 351 | 196 |
| 41 | Salt Creek near Lyndon, Kans. | 111 | 59.7 |
| 42 | Dragoon Creek near Burlingame, Kans. | 114 | 62.3 |
| 43 | Switzler Creek at Burlingame, Kans. | 26.3 | 7.3 |
| 46 | Hundred and Ten Mile Creek near Quenemo, Kans. | 322 | 170 |
| 47 | Marais des Cygne River near Pomona, Kans. | 1,040 | 475 |
| 48 | Marais des Cygnes River near Ottawa, Kans. | 1,250 | 634 |
| 51 | Pottawatomie Creek near Garnett, Kans. | 334 | 218 |
| 55 | Big Bull Creek near Hillsdale, Kans. | 147 | 93.5 |
| 71 | Marais des Cygnes River at Trading Post, Kans. | 2,880 | 1,686 |
| 72 | Big Sugar Creek at Farlinville, Kans. | 198 | 117 |
| 77 | Marais des Cygnes River near Kansas-Missouri State line, Kans. | 3,230 | 1,910 |
| 96 | Little Osage River at Fulton, Kans. | 295 | 199 |
| 104 | Marmaton River near Marmaton, Kans. | 292 | 255 |
| 106 | Marmaton River near Fort Scott, Kans. | 408 | 282 |
| 122 | Osage River at Osceola, Mo. | 8,220 | 5,210 |
| 125 | South Grand River at Archie, Mo. | 356 | 228 |
| 126 | South Grand River at Urich, Mo. | 670 | 444 |
| 128 | Big Creek at Blairstown, Mo. | 414 | 317 |
| 129 | Brushy Creek near Blairstown, Mo. | 1.15 | 1.2 |
| 135 | South Grand River near Brownington, Mo. | 1,660 | 1,046 |

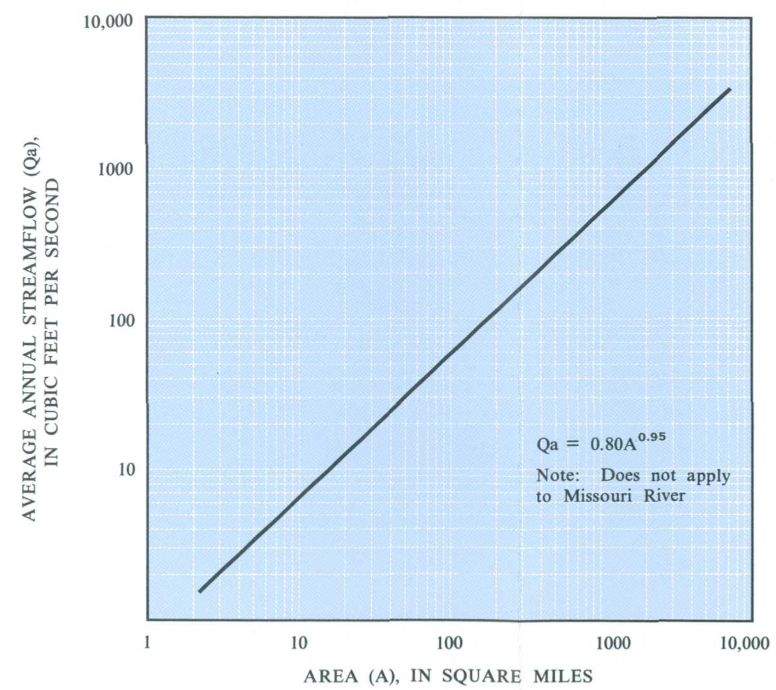



**Figure 5.1-3** Relationship of drainage area to average annual streamflow in Area 39.

# Most Streams are not Sustained by Ground-Water Inflow During Droughts

*Most unregulated streams with drainage areas less than 50 square miles will cease to flow for 7 or more consecutive days in 50 percent of the years.*

Low-flow data can be used to estimate the potential yield of a stream and are useful in water-supply management and design studies. In water-quality studies, the data are used to determine when temporary storage of effluents is necessary during critical low-flow periods. A commonly used streamflow characteristic is the average minimum flow for 7 consecutive days that has a 10-year recurrence interval (7-day $Q_{10}$). There is a special need for computation of the 7-day $Q_{10}$ at all possible sites because it is a value used in the design of waste-treatment facilities.

Low flows of most streams in Area 39 are not sustained during droughts because there are few aquifers capable of providing substantial quantities of ground-water inflow. Few unregulated streams continue to flow during droughts with recurrence intervals of 5 years or greater, and most unregulated streams with drainage areas less than 50 square miles will cease to flow for 7 consecutive days or more at some time during 50 percent of the years. The low-flow frequency curves shown in figure 5.2-1 have steep slopes that reflect the lack of ground-water storage. Storage reservoirs are needed in most basins to ensure adequate surface-water supplies.

Seven-day low-flow frequency data for streamflow-gaging stations are summarized in table 5.2-1. Low-flow frequency data for other time periods and on a seasonal basis are available from District offices of the U.S. Geological Survey in Lawrence, Kans. and Rolla, Mo.; and in reports by Carswell (1979), Jordan (1983), and Skelton (1976).

For perennial streams in Area 39, low-flow characteristics at ungaged sites are best estimated by making streamflow measurements at the site and relating them graphically to concurrent streamflows at nearby continuous-record stations. The equipment and information needed to follow these procedures are available at the District offices of the U.S. Geological Survey in each State.

Interpolation between gaged sites on streams in Area 39 needs to be considered when low-flow frequency estimates are required. By referring to the data in table 5.2-1, and the streamflow-gaging station locations in figure 4.0-1, the user of this report can decide if gaged sites on the stream are close enough to an area of interest to allow interpolation.

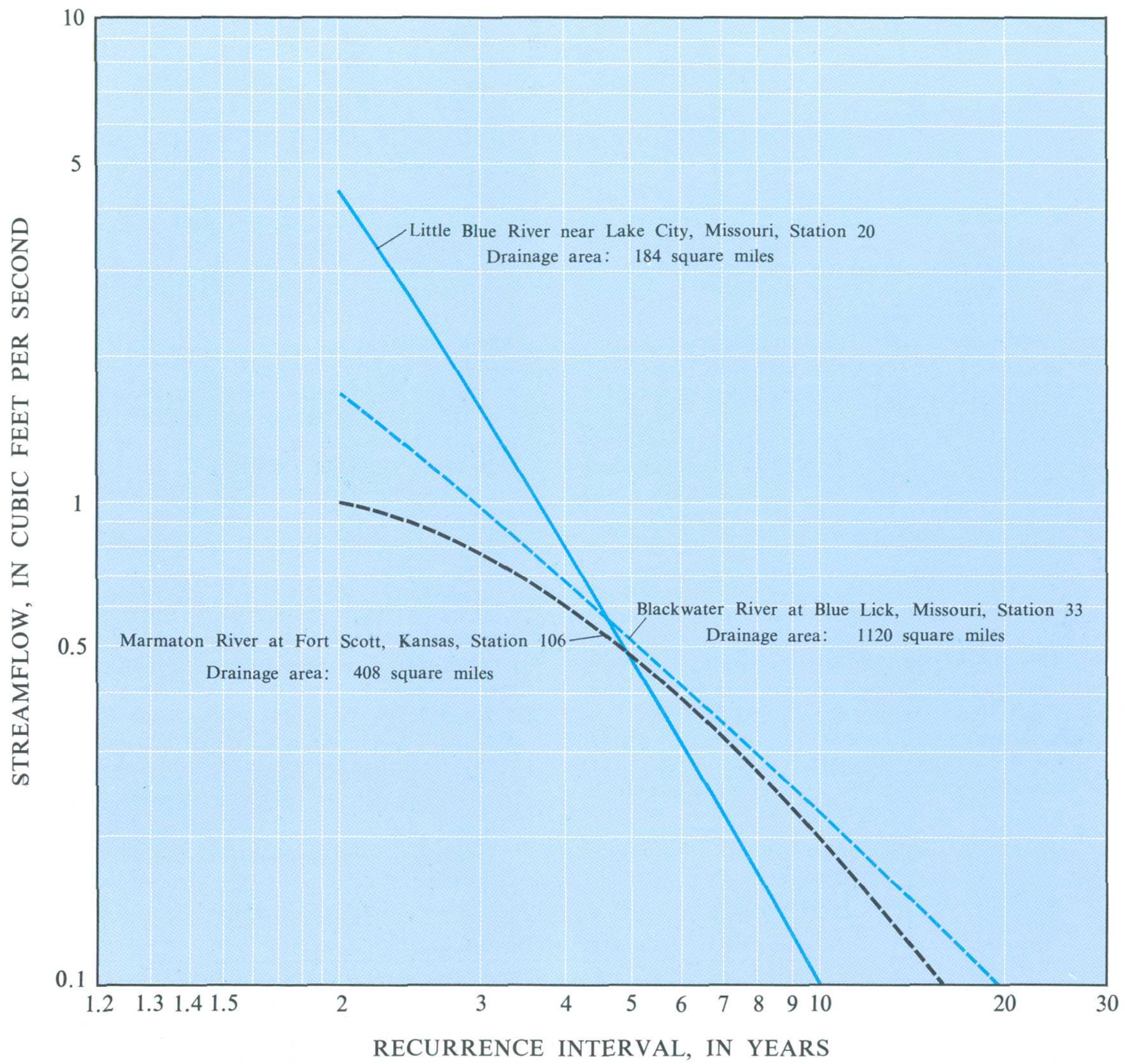



**Figure 5.2-1 Seven-day low-flow frequency curves for selected stations.**

**Table 5.2-1 Seven-day low-flow discharges, in cubic feet per second.**

| Map No. (fig. 4.0-1) | Station name | Drainage area, in square miles | Seven-day low flow, in cubic feet per second, for indicated recurrence interval, in years | | | |
|---|---|---|---|---|---|---|
| | | | 2 | 5 | 10 | 20 |
| 3 | Blue River at Kansas City, Mo. | --- | 0 | 0 | 0 | 0 |
| 5 | Indian Creek at Overland Park, Kans. | 26.6 | 0.1 | 0 | 0 | 0 |
| 7 | Blue River near Kansas City, Mo.[a] | 188 | --- | --- | --- | --- |
| 14 | Rock Creek at Independence, Mo. | 5.20 | 0 | 0 | 0 | 0 |
| 15 | Little Blue River at Longview Road in Kansas City, Mo. | 47.4 | 0.5 | --- | 0 | 0 |
| 17 | Little Blue River at Kansas City, Mo. | --- | 1.8 | --- | --- | --- |
| 18 | East Fork Little Blue River near Blue Springs, Mo. | 34.4 | 0 | 0 | 0 | 0 |
| 19 | Little Blue River near Blue Springs, Mo. | --- | 2.6 | --- | --- | --- |
| 20 | Little Blue River near Lake City, Mo. | 184 | 4.5 | 0.4 | 0.1 | 0 |
| 23 | Sni-a-bar Creek at Grain Valley, Mo. | --- | 0.4 | --- | 0 | 0 |
| 24 | Sni-a-bar Creek near Wellington, Mo. | --- | 0.2 | --- | 0 | 0 |
| 26 | South Fork Blackwater River near Elm, Mo. | 16.6 | 0 | 0 | 0 | 0 |
| 27 | Blackwater River near Warrensburg, Mo. | --- | 0.1 | --- | 0 | 0 |
| 28 | Post Oak Creek at Warrensburg, Mo. | --- | 0 | 0 | 0 | 0 |
| 30 | Blackwater River at Valley City, Mo. | 547 | 0.9 | --- | 0.1 | 0 |
| 31 | Davis Creek at Sweet Springs, Mo. | --- | 0.2 | --- | 0 | 0 |
| 32 | Blackwater River at Sweet Springs, Mo. | --- | 0.9 | --- | 0.1 | 0 |
| 33 | Blackwater River at Blue Lick, Mo. | 1,120 | 1.7 | 0.5 | 0.2 | 0.1 |
| 35 | Salt Fork Blackwater River near Marshall, Mo. | --- | 0.2 | --- | --- | --- |
| 36 | Shiloh Branch near Marshall, Mo. | 2.87 | 0 | 0 | 0 | 0 |
| 37 | Marais des Cygnes River near Reading, Kans. | 177 | 0 | 0 | 0 | 0 |
| 41 | Salt Creek near Lyndon, Kans. | 111 | 0 | 0 | 0 | 0 |
| 42 | Dragoon Creek near Burlingame, Kans. | 114 | 0 | 0 | 0 | 0 |
| 51 | Pottawatomie Creek near Garnett, Kans. | 334 | 0.2 | 0 | 0 | 0 |
| 72 | Big Sugar Creek at Farlinville, Kans. | 198 | 0.4 | 0 | 0 | 0 |
| 87 | Osage River near Rich Hill, Mo. | --- | 6.5 | --- | 0 | 0 |
| 88 | Miami Creek near Butler, Mo. | --- | 0 | 0 | 0 | 0 |
| 96 | Little Osage River at Fulton, Kans. | 295 | 0.09 | 0 | 0 | 0 |
| 101 | Little Osage River at Stotesbury, Mo. | 427 | 0.1 | --- | 0 | 0 |
| 102 | Little Osage River at Horton, Mo. | --- | 0.3 | --- | 0 | 0 |
| 106 | Marmaton River near Fort Scott, Kans. | 408 | 1.0 | 0.5 | 0.2 | 0 |
| 115 | Marmaton River at Nevada, Mo. | --- | 4.0 | --- | --- | 0 |
| 116 | Osage River near Schell City, Mo. | 5,530 | 10.0 | --- | 0 | 0 |
| 120 | Clear Creek near Eldorado Springs, Mo. | --- | 0 | 0 | 0 | 0 |
| 122 | Osage River at Osceola, Mo.[b] | 8,220 | --- | --- | --- | --- |
| 124 | South Grand River near Freeman, Mo. | --- | 0 | 0 | 0 | 0 |
| 125 | South Grand River at Archie, Mo. | 256 | 0.1 | 0 | 0 | 0 |
| 126 | South Grand River at Urich, Mo. | 670 | 0.1 | --- | 0 | 0 |
| 127 | Big Creek at Pleasant Hill, Mo. | --- | 0 | 0 | 0 | 0 |
| 128 | Big Creek at Blairstown, Mo. | 414 | 0.2 | --- | 0 | 0 |
| 129 | Brushy Creek near Blairstown, Mo. | 1.15 | 0 | 0 | 0 | 0 |
| 131 | Deepwater Creek near Montrose, Mo. | --- | 0 | 0 | 0 | 0 |
| 135 | South Grand River near Brownington, Mo. | 1,660 | 1.1 | 0.1 | 0 | 0 |
| 139 | Tebo Creek at Leesville, Mo. | --- | 0 | 0 | 0 | 0 |

[a] Low flows augmented by commercial plants upstream from station. Computation of probability data was not feasible.
[b] Regulated by power plant. Patterns of regulation were not consistent enough for computation of probability data.

# Flood Magnitudes Vary with Drainage Area, Slope, and Precipitation

## *Techniques are available to estimate the magnitude and frequency of flooding.*

A knowledge of the magnitude and frequency of flooding is important for the design of structures on streams and in floodplains. Frequency of flooding is expressed as a probability of occurrence, or recurrence interval. For example, a flood peak or volume with a recurrence interval of 50 years could be expected to occur, on the average, once in 50 years and has a 0.02 probability (two-percent chance) of occurring during any given year.

Flood-frequency equations (table 5.3-1) were developed by Jordan and Irza (1975) for Kansas streams and by Hauth (1974) for Missouri streams. The equations, which are applicable to unregulated natural streams only, may be applied to all ungaged areas of 0.4 square mile or greater in Area 39.

Results from flood-frequency equations for Kansas and Missouri for a given drainage area, slope, and rainfall intensity can be significantly different. The variations in basin slope and rainfall throughout Area 39 require that the results be adjusted to reduce the errors. A comparison of flood-frequency data for Area 39 streamflow-gaging stations (table 5.3-2) and estimates from the statewide equations indicates that the estimates generally will be improved if results from Kansas and Missouri equations are averaged for streams that have drainage areas less than 400 square miles. For all other ungaged sites, use equations for the appropriate State. Flood-frequency data for streamflow-gaging stations (table 5.3-2) should be used whenever possible.

Seven-day flood-volume data (average maximum flow for 7 consecutive days) for selected recurrence intervals also are presented in table 5.3-2 for streamflow-gaging stations in Area 39. Much additional flood-volume data are available in reports by Skelton (1973), Furness and others (1964), and in the files of the U.S. Geological Survey District offices in Lawrence, Kansas, and Rolla, Missouri.

During 1968 the U.S. Geological Survey began delineating "flood-prone" areas by approximate methods on 7½- and 15-minute topographic maps. These maps have proven to be useful because many flood-prone areas are occupied by industrial, commercial, and residential developments. Available flood-prone area maps indicated in figure 5.3-1 can be obtained from U.S. Geological Survey offices in Lawrence, Kansas, and Rolla, Missouri.

**Table 5.3-1 Summary of flood-frequency equations.**

±Q]t[ = flood peak, in cubic feet per second, for t-year recurrence interval; A = drainage area, in square miles; S = slope, in feet per mile, between points 10 and 85 percent of the distance along the main stream channel from the site to the basin divide; P]2[ = 24-hour rainfall amount, in inches, for 2-year recurrence interval (Hershfield, 1961), determined at the centroid of the basin. Equations only apply to unregulated natural streams.[2]

| Recurrence interval, t, in years | C | x | y | Standard error, in percent |
|---|---|---|---|---|
| Kansas streams: | Q]t[ = C]t[ A[x)t(] P]2[[y)t(] (from Jordan and Irza, 1975) | | | |
| 2 | 0.707 | 0.548 | 4.752 | 42.5 |
| 5 | 3.98 | .530 | 4.021 | 41.5 |
| 10 | 9.92 | .525 | 3.591 | 43.0 |
| 25 | 25.6 | .524 | 3.127 | 48.   0 |
| 50 | 47.6 | .523 | 2.821 | 53.0 |
| 100 | 83.8 | .524 | 2.529 | 58.0 |
| Missouri streams: | Q]t[ = C]t[ A±x]t[A[-0.02]$^{2}$ S[y)t(] (from Hauth, 1974) | | | |
| 2 | 53.5 | 0.851 | 0.356 | 38.6 |
| 5 | 64.0 | .886 | .450 | 34.7 |
| 10 | 67.6 | .905 | .500 | 34.5 |
| 25 | 73.7 | .924 | .542 | 35.0 |
| 50 | 79.8 | .926 | .560 | 33.3 |
| 100 | 85.1 | .934 | .576 | 33.3 |

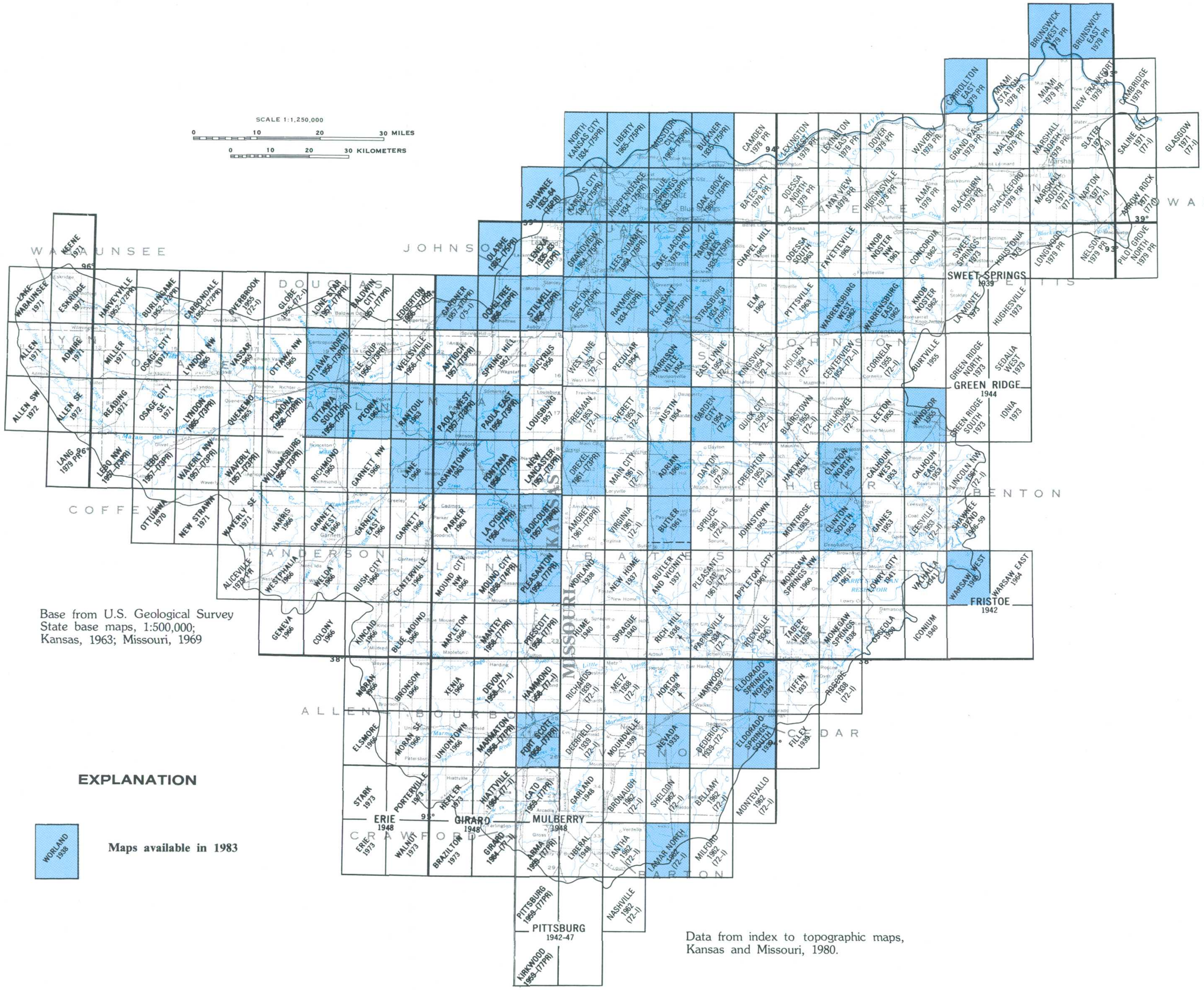



Figure 5.3-1 Maps of flood-prone areas.

## Table 5.3-2 Peak flows and 7-day high flows for recurrence intervals of 2, 10, 50, and 100 years.

Table 5.3-2. Peak flows and 7-day high flows for recurrence intervals of 2, 10, 50, and 100 years.

| Map no. (fig. 4.0-1) | Station name | Drainage area, in square miles | Peak flow, in cubic feet per second | | | | 7-day high flow, in acre-feet | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2 | 10 | 50 | 100 | 2 | 10 | 50 | 100 |
| 2 | Blue River near Stanley, Kans. | 46.0 | 3,730 | 6,390 | 8,560 | 9,450 | -- | -- | -- | -- |
| 5 | Indian Creek at Overland Park, Kans. | 26.6 | 3,680 | 6,350 | 8,570 | 9,470 | 3,750 | 7,470 | 11,000 | 12,500 |
| 6 | Tomahawk Creek near Overland Park, Kans. | 23.9 | 2,470 | 5,580 | 8,640 | 9,990 | -- | -- | -- | -- |
| 7 | Blue River near Kansas City, Mo. | 188 | 9,100 | 21,300 | 34,700 | 41,000 | 19,400 | 46,200 | 70,600 | 80,700 |
| 20 | Little Blue River near Lake City, Mo. | 184 | 4,000 | 7,990 | 11,600 | 13,100 | 17,500 | 40,500 | 57,303063,200 | |
| 26 | South Fork Blackwater River near Elm, Mo. | 16.6 | 2,200 | 4,540 | 6,630 | 7,520 | 1,750 | 4,510 | 7,320 | 8,540 |
| 30 | Blackwater River at Valley City, Mo. | 547 | 24,100 | 60,100 | 97,400 | 114,000 | 71,500 | 167,000 | 237,000 | 262,000 |
| 33 | Blackwater River at Blue Lick, Mo. | 1,120 | 10,000 | 23,500 | 38,700 | 46,100 | 92,000 | 227,000 | 395,000 | 441,000 |
| 34 | Trent Branch near Waverly, Mo. | 0.97 | 305 | 703 | 1,090 | 1,270 | -- | -- | -- | -- |
| 36 | Shiloh Branch near Marshall, Mo. | 2.87 | 561 | 1,010 | 1,370 | 1,520 | 222 | 494 | 769 | 894 |
| 37 | Marais des Cygnes River near Reading, Kans | 177 | 8,010 | 19,800 | 35,400 | 43,800 | 15,700 | 36,200 | 61,200 | 73,800 |
| 40 | Marais des Cygnes River at Melvern, Kans.[1] | 351 | 7,510 | 25,900 | 47,600 | 57,600 | -- | -- | -- | -- |
| 41 | Salt Creek near Lyndon, Kans. | 111 | 4,220 | 13,300 | 23,900 | 28,800 | 10,900 | 22,800 | 25,400 | 25,800 |
| 42 | Dragoon Creek near Burlingame, Kans. | 114 | 4,890 | 12,100 | 20,900 | 25,300 | 10,400 | 23,200 | 36,000 | 41,500 |
| 44 | Dragoon Creek tributary near Lyndon, Kans. | 3.76 | 1,040 | 4,590 | 10,000 | 13,000 | -- | -- | -- | -- |
| 46 | Hundred and Ten Mile Creek near Quenemo, Kans.[1] | 322 | 7,560 | 24,900 | 43,800 | 52,200 | -- | -- | -- | -- |
| 47 | Marais des Cygnes River near Pomona, Kans.[1] | 1,040 | 9,380 | 21,200 | 52,000 | 70,300 | -- | -- | -- | -- |
| 48 | Marais des Cygnes River near Ottawa, Kans.[1] | 1,250 | 11,500 | 41,900 | 94,500 | 127,000 | -- | -- | -- | -- |
| 50 | Rock Creek near Ottawa, Kans. | 10.2 | 2,980 | 6,760 | 11,600 | 14,100 | -- | -- | -- | -- |
| 51 | Pottawatomie Creek near Garnett, Kans. | 334 | 11,600 | 30,100 | 53,100 | 64,900 | 34,400 | 81,200 | 128,000 | 149,000 |
| 52 | South Fork Pottawatomie Creek tributary near Garnett, Kans. | 0.35 | 200 | 450 | 724 | 855 | -- | -- | -- | -- |
| 53 | Pottawatomie Creek at Lane, Kans. | 513 | 13,100 | 37,700 | 72,700 | 92,000 | -- | -- | -- | -- |
| 55 | Big Bull Creek near Hillsdale, Kans.[1] | 147 | 6,770 | 20,100 | 39,400 | 50,100 | -- | -- | -- | -- |
| 56 | Big Bull Creek at Paola, Kans.[1] | 230 | 6,960 | 18,400 | 33,500 | 41,600 | -- | -- | -- | -- |
| 71 | Marais des Cygnes River at Trading Post, Kans.[1] | 2,880 | 20,000 | 57,200 | 110,000 | 139,000 | -- | -- | -- | -- |
| 72 | Big Sugar Creek at Farlinville, Kans. | 198 | 6,310 | 19,500 | 41,700 | 55,400 | 17,200 | 45,300 | 81,800 | 101,000 |
| 89 | Middle Creek near Kincaid, Kans. | 2.02 | 618 | 1,740 | 2,960 | 3,510 | -- | -- | -- | -- |
| 96 | Little Osage River at Fulton, Kans. | 295 | 7,570 | 16,800 | 25,000 | 28,400 | 32,900 | 73,600 | 94,800 | 101,000 |
| 103 | Marmaton River tributary near Branson, Kans. | 0.88 | 204 | 481 | 734 | 839 | -- | -- | -- | -- |
| 104 | Marmaton River near Marmaton, Kans. | 292 | 13,900 | 21,100 | 27,300 | 29,900 | -- | -- | -- | -- |
| 105 | Marmaton River tributary near Fort Scott, Kans. | 2.80 | 850 | 1,750 | 2,490 | 2,740 | | | | |
| 106 | Marmaton River near Fort Scott, Kans. | 408 | 12,200 | 31,200 | 50,200 | 58,500 | 46,900 | 115,000 | 162,000 | 178,000 |
| 117 | North Fork Panther Creek tributary near Appleton City, Mo. | 0.08 | 49 | 75 | 96 | 105 | -- | -- | -- | -- |
| 122 | Osage River at Osceola, Mo. | 8,220 | 39,800 | 75,200 | 110,000 | 126,000 | 445,000 | 911,000 | 1,310,000 | 1,470,000 |
| 123 | Big Muddy Creek at Lowry City, Mo. | 0.31 | 124 | 212 | 276 | 300 | -- | -- | -- | -- |
| 128 | Big Creek near Blairstown, Mo. | 414 | 7,900 | 13,700 | 19,700 | 22,600 | 42,600 | 84,800 | 130,400 | 152,300 |
| 129 | Brushy Creek near Blairstown, Mo. | 1.15 | 463 | 931 | 1,410 | 1,620 | 155 | 278 | 444 | 527 |
| 132 | Granddaddy Creek near Urich, Mo. | 0.92 | 266 | 663 | 1,710 | 1,430 | -- | -- | -- | -- |
| 135 | South Grand River near Brownington, Mo. | 1,660 | 13,800 | 32,100 | 51,200 | 59,900 | 141,000 | 311,000 | 518,000 | 616,000 |

[1] Frequency data represent stream conditions before regulation.

# Flow-Duration Curves Indicate Similar Flow Characteristics for Unregulated Streams

*Steep slopes of flow-duration curves for unregulated streams indicate highly variable flows.*

The flow-duration curve is a cumulative frequency curve that shows the percentage of time that a flow rate was exceeded (Searcy, 1959). A steep slope indicates highly variable flow, whereas a flat slope indicates more uniform flow, which can be a result of ground- or surface-water storage contributions. Flow-duration data provide a convenient means of comparing flow characteristics of streams and estimating the percentage of time that a given flow will be exceeded, providing the period of record is of sufficient length to be indicative of long-time trends. Flow-duration data for continuous-record streamflow-gaging stations in the area are shown in table 5.4-1.

Typical flow-duration curves indicate similar flow characteristics for unregulated streams in Area 39 (5.4-1). The slopes are steep, indicating most streamflow is from direct surface runoff. The flow of these streams is not well sustained during dry weather because there are few aquifers capable of providing substantial quantities of ground-water inflow.

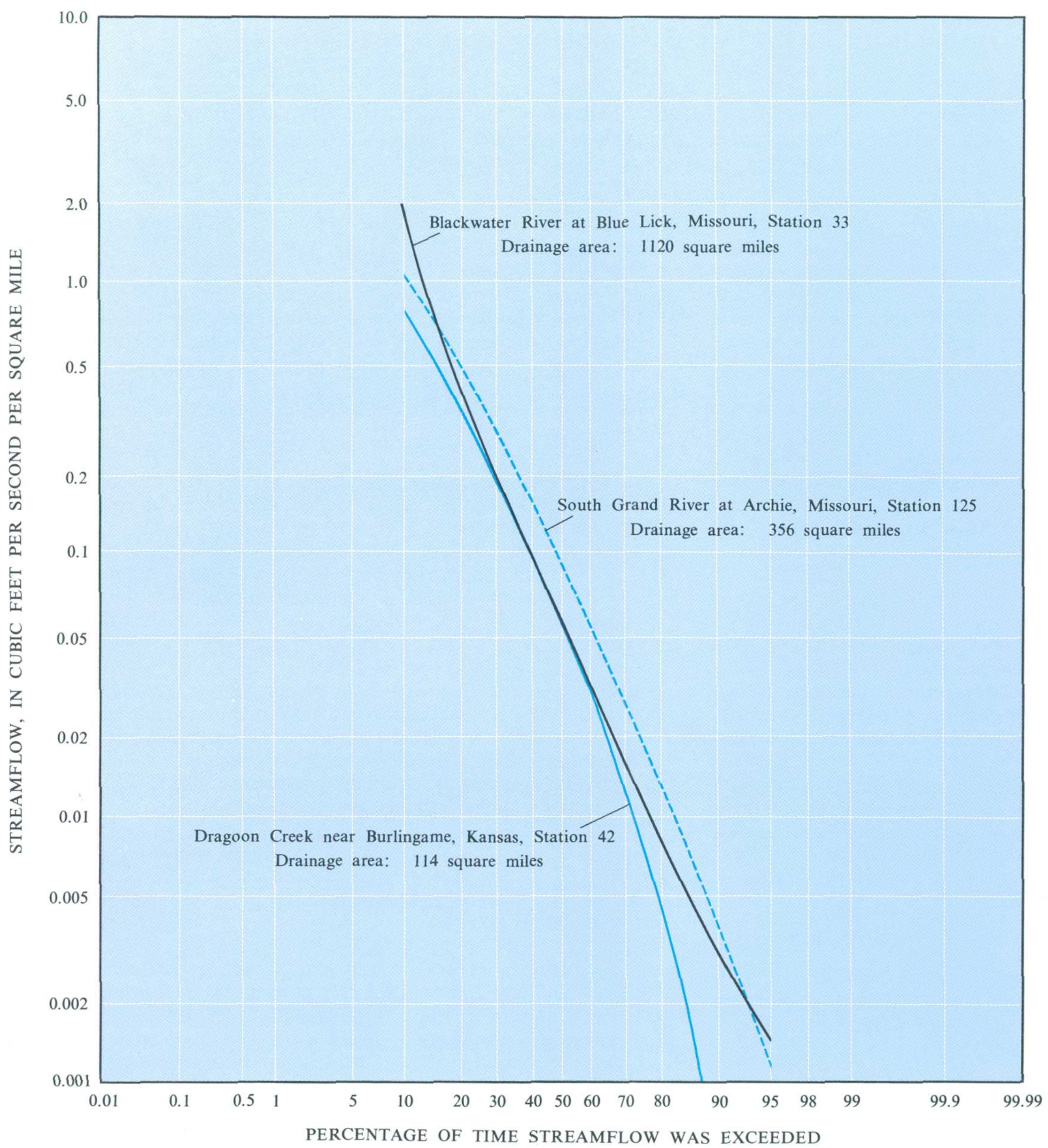



**Figure 5.4-1 Flow-duration curves for selected continuous-record streamflow-gaging stations on unregulated streams.**

**Table 5.4-1 Flow duration data.**

| Map number (fig. 4.0-1) | Station name | Drainage area, in square miles | Flow, in cubic feet per second, that was exceeded for indicated percent of time 95 | 90 | 70 | 50 | 10 |
|---|---|---|---|---|---|---|---|
| 1 | Missouri River at Kansas City, Mo. | 485,200 | 13,000 | 16,000 | 30,000 | 40,000 | 88,000 |
| 2 | Blue River near Stanley, Kans. | 46.0 | 0.01 | 0.01 | 0.33 | 1.6 | 37 |
| 5 | Indian Creek at Overland Park, Kans. | 26.6 | 0.1 | 0.5 | 2.1 | 5.0 | 35 |
| 6 | Tomahawk Creek near Overland Park, Kans. | 23.9 | 0.12 | 0.14 | 0.34 | 1.2 | 19 |
| 7 | Blue River near Kansas City, Mo. | 188 | 2.1 | 3.7 | 16 | 35 | 250 |
| 16 | Little Blue River below Longview Damsite in Kansas City, Mo. | 50.7 | 1.5 | 2.0 | 4.2 | 6.9 | 32 |
| 20 | Little Blue River near Lake City, Mo. | 184 | 1.5 | 4.2 | 20 | 42 | 260 |
| 22 | Sni-a-bar Creek near Tarsney, Mo. | 29.1 | 0 | 0 | 0.3 | 3.2 | 32 |
| 25 | Missouri River at Waverly, Mo. | 487,200 | 13,000 | 16,000 | 30,000 | 40,000 | 90,000 |
| 26 | South Fork Blackwater River near Elm, Mo. | 16.6 | 0 | 0 | 0 | 0.7 | 14 |
| 30 | Blackwater River at Valley City, Mo. | 547 | 1.5 | 2.8 | 13 | 46 | 780 |
| 33 | Blackwater River at Blue Lick, Mo. | 1,120 | 1.7 | 3.3 | 20 | 78 | 2,200 |
| 34 | Shiloh Branch near Marshall, Mo. | 2.87 | 0 | 0 | 0 | 0 | 1.1 |
| 37 | Marais des Cygnes River near Reading, Kans. | 177 | 0.03 | 0.26 | 3.8 | 14 | 155 |
| 41 | Salt Creek near Lyndon, Kans. | 111 | 0 | 0 | 0.8 | 5.1 | 73 |
| 42 | Dragoon Creek near Burlingame, Kans. | 114 | 0 | 0 | 2.0 | 8.3 | 89 |
| 43 | Switzler Creek at Burlingame, Kans. | 26.3 | 0.01 | 0.02 | 0.06 | 0.2 | 12 |
| 46 | Hundred and Ten Mile Creek near Quenemo, Kans. | 322 | 12 | 14 | 18 | 25 | 466 |
| 47 | Marais des Cygnes River near Pomona, Kans.[1] | 1,040 | 30 | 34 | 43 | 55 | 1,330 |
| 48 | Marais des Cygnes River near Ottawa, Kans.[1] | 1,250 | 32 | 36 | 46 | 60 | 1,420 |
| 51 | Pottawatomie Creek near Garnett, Kans. | 334 | 0 | 0.1 | 3.3 | 19 | 330 |
| 77 | Marais des Cygnes River Kansas-Missouri State Line, Kans.[1] | 3,230 | 7.7 | 19 | 70 | 186 | 4,600 |
| 96 | Little Osage River at Fulton, Kans. | 295 | 0 | 0.1 | 3.8 | 23 | 340 |
| 104 | Marmaton River near Marmaton, Kans. | 292 | 0.05 | 0.13 | 2.6 | 25 | 412 |
| 106 | Marmaton River near Fort Scott, Kans. | 408 | 1.0 | 1.2 | 4.3 | 31 | 440 |
| 122 | Osage River at Osceola, Mo.[1] | 8,220 | 64 | 130 | 630 | 1,600 | 16,000 |
| 125 | South Grand River at Archie, Mo. | 356 | 0.4 | 1.4 | 12 | 39 | 410 |
| 128 | Big Creek near Blairstown, Mo. | 414 | 0.1 | 0.5 | 9.2 | 35 | 610 |
| 129 | Brushy Creek near Blairstown, Mo. | 1.15 | 0 | 0.01 | 0.05 | 0.09 | 1.1 |

[1] Includes periods of flow regulation by large reservoirs.

# Water-Quality Data are Available for Evaluating the Impacts of Surface Coal Mining on Area Streams

*Drainage from surface-mined areas can affect values of pH and specific conductance and increase concentrations of dissolved solids, iron, manganese, and suspended sediment in receiving streams.*

Data useful for determining the effects of mining on water quality are available for 42 stations on streams draining coal-mined areas and 21 stations on streams draining unmined areas. Locations of these stations are shown in figure 6.1-1; station descriptions are included in Section 10.1. Statistical summaries of the water-quality data available for these stations are presented in Section 10.2. Water-quality data are available for 13 additional stations shown in figure 4.0-1 and listed in Section 10.1 but not included in figure 6.1-1, Section 10.2, or any of the following discussions of water quality. Stations 8, 9, 10, and 13 are stations on streams draining urban areas; stations 61, 62, 63, 66, and 67 are sediment ponds; stations 75 and 76 were sampled only for stream-bed material; and stations 111 and 112 are strip pits.

Ground-water discharge from surface-mined areas typically contains large concentrations of sulfate, dissolved solids, and dissolved manganese. During low-flow periods these large concentrations can contaminate receiving streams. In addition, surface runoff from active and abandoned surface mines can contribute large concentrations of suspended sediment and suspended iron to receiving streams.

When groundwater in surface-mined areas contacts iron sulfide minerals, pyrite and marcasite ($FeS_2$), that are associated with shale and coal, the direct oxidation of $FeS_2$ releases ferrous iron, sulfate, and acidity into solution (Stumm and Morgan, 1981).

(1) $$FeS_2 + 7/2O_2 + H_2O \rightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+$$

The ferrous iron is oxidized to ferric iron, which then hydrolyzes to form insoluble ferric oxyhydroxide, commonly called "yellow boy", and releases additional acidity.

(2) $$Fe^{2+} + \frac{1}{4}O_2 + 5/2H_2O \rightarrow Fe(OH)_3 + 2H^+$$

The acidity released by reactions 1 and 2 reacts with calcite ($CaCO_3$) in limestone rocks and sediment weathered from limestone rocks, releasing calcium and bicarbonate ions.

(3) $$CaCO_3 + H^+ \rightarrow Ca^{2+} + HCO_3^-$$

Excess acidity could lower pH to levels that would allow high concentrations of iron to remain in solution. However, the abundance of limestone rock in the study area utilizes most of the acidity in weathering calcite (equation 3), which keeps pH neutral and causes most of the dissolved iron to precipitate. Because manganese (derived from manganese oxide minerals weathered from sandstone) remains in solution longer than iron due to the relative stability of the $Mn^{2+}$ ion in oxygenated, neutral (pH = 7.0) water, high concentrations of dissolved manganese are common in streams receiving coal-mine drainage.

During periods of runoff, the concentrations of sulfate, dissolved solids, and dissolved manganese are diluted. However, high concentrations of suspended sediment and adsorbed iron may impair water quality. Concentrations of suspended iron generally are greater than suspended manganese because area soils contain more iron than manganese.

Published reports of investigations in Area 39 concerning hydrologic characteristics and the effects of coal-mine drainage are:

(1) Kenny, J. F., Bevans, H. E., and Diaz, A. M., 1982, Physical and hydrologic environments of the Mulberry coal reserves in eastern Kansas: U.S. Geological Survey Water-Resources Investigations 82-4074, 50 p.

This report describes the physiographic, geologic, and hydrologic environment of an area, including southern Miami, Linn, and northern Bourbon Counties, Kansas, that contains strippable reserves of Mulberry coal. Available streamflow and water-quality data are interpreted to describe hydrologic characteristics of major streams.

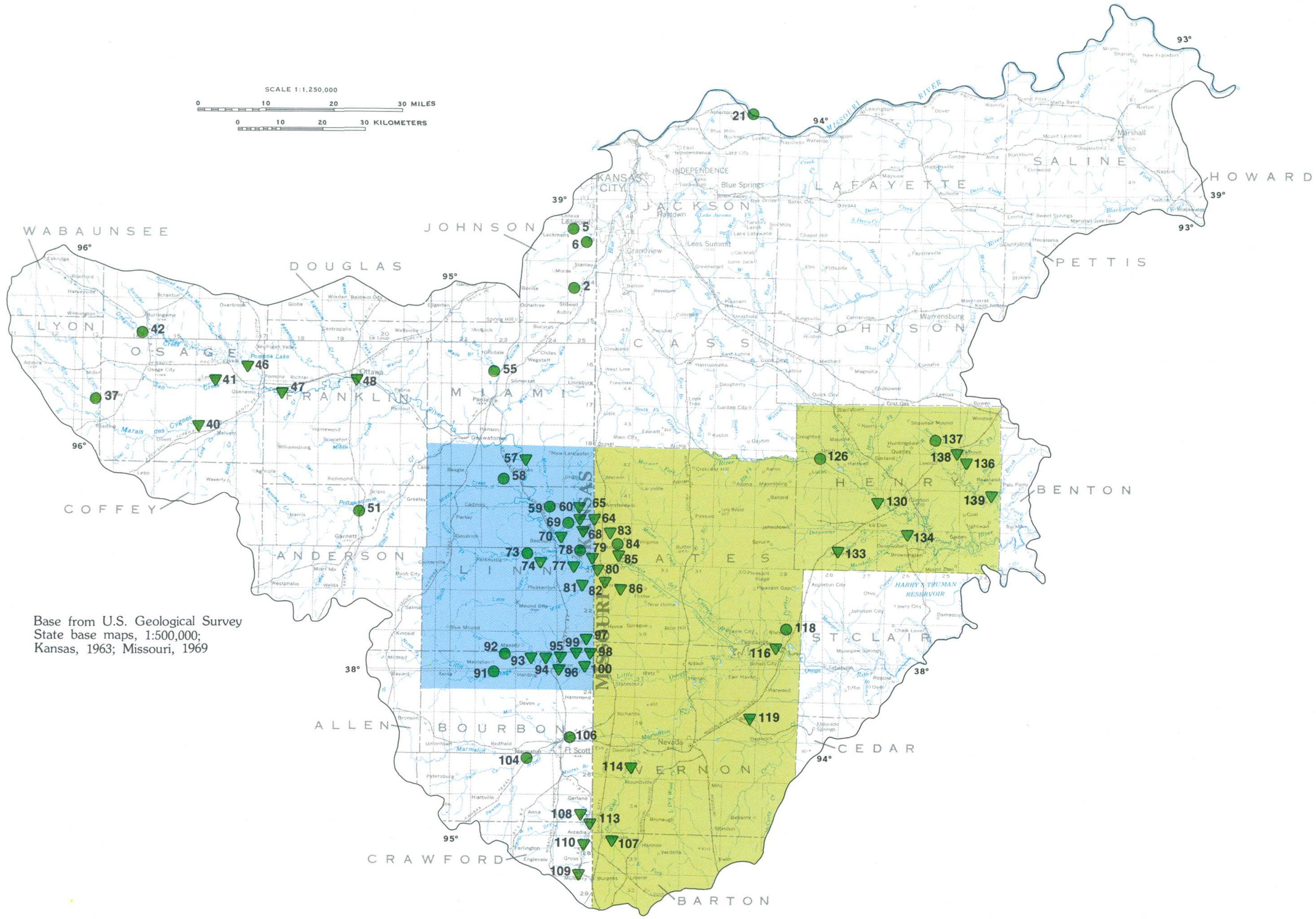
(2) Bevans, H. E., 1984, Hydrologic responses of streams to mining Mulberry coal in eastern Kansas: U.S. Geological Survey Water-Resources Investigations 84-4047, 30 p.

Current (1983) water-quality characteristics of streams draining the Mulberry coal reserves in southern Miami, Linn, and northern Bourbon Counties, Kansas are described. Natural background conditions, effects of previous coal mining, and impacts of active coal mining are determined.

(3) Vaill, J. E., and Barks, J. H., 1980, Physical environments and hydrologic characteristics of coal-mining areas in Missouri: U.S. Geological Survey Water-Resources Investigations 80-67, 33 p.

The physical setting, climate, coal-mining practices, general hydrology, and current (1980) hydrologic data base for the north-central and western coal-mining regions of Missouri are described. The western region includes Barton, Vernon, Bates, and Henry Counties, which are part of Area 39.

Areas included in these 3 investigations are indicated on figure 6.1-1.




Base from U.S. Geological Survey State base maps, 1:500,000; Kansas, 1963; Missouri, 1969

## EXPLANATION

### SURFACE-WATER QUALITY STATIONS

● Surface-water quality station on stream draining unmined area

▲ Surface-water quality station on stream draining coal-mined area

**82** Station number

For description of the stations, see Section 10.1

### AREAS INCLUDED IN PREVIOUS COAL-HYDROLOGY INVESTIGATIONS

(blue) Kenny, J.F., Bevans, H.E., and Diaz, A.M., 1982, Physical and hydrologic environments of the Mulberry coal reserves in eastern Kansas: U.S. Geological Survey Water-Resources Investigations 82-4074, 50 pages.

(blue) Bevans, H.E., 1983, Hydrologic responses of streams to mining Mulberry coal in eastern Kansas: U.S. Geological Survey Water-Resources Investigations 83-4047, 30 pages.

(green) Vaill, J.E., and Barks, J.H., 1980, Physical environment and Hydrologic characteristics of coal-mining areas in Missouri: U.S. Geological Survey Water-Resources Investigations 80-67, 33 pages.

**Figure 6.1-1 Surface-water quality stations and areas included in previous coal-hydrology investigations.**

# Values of pH Indicate Neutral to Slightly Alkaline Water in Most Streams

*The pH of most streams is greater than 6.0 due to buffering by limestone.*

The pH[1] of natural water generally is between 6.5 and 8.5 (Hem, 1970, p. 93) and is regulated principally by the carbonate system, which is composed of carbon dioxide ($CO_2$), carbonic acid ($H_2CO_3$), bicarbonate ions ($HCO_3^-$), and carbonate ions ($CO_3^{2-}$). This normal range can be affected by industrial wastes, coal-mine drainage, or photosynthetic processes of aquatic organisms in poorly buffered water. Prolonged extremes in pH can change the solubility and toxicity of many chemical compounds, increase the corrosiveness of the water, and adversely affect aquatic life, making the water unsuitable for many purposes.

Surface coal mining can significantly alter the pH of adjacent streams through chemical reactions in spoil piles. Hydrogen ions are released when sulfide minerals, primarily pyrite and marcasite, associated with the coal are oxidized. Oxidation occurs naturally, but mining accelerates the process by exposing large quantities of iron sulfides to weathering. Mine drainage, which may have pH values of about 2.5 to 5.0, commonly is neutralized by carbonate minerals in the spoil piles or alkaline water in the receiving stream and usually is a problem only adjacent to the mined area. The Surface Mining Control and Reclamation Act of 1977 has established a permissible range of pH from 6.0 to 9.0 for mine-area effluents. A pH of less than 6.0 may be an indication of acid-mine drainage.

Data on pH are available for 63 stations; statistical summaries are presented in Section 10.2. Values of pH indicate neutral to slightly alkaline water in most streams in the area. Median values of pH range from 7.1 to 8.0 for 21 stations on streams draining unmined areas and range from 3.0 to 8.1 for 42 stations on streams draining coal-mined areas as shown in figure 6.2-1. A few of the streams draining mined areas showed no appreciable water-quality degradation because of buffering and dilution effects of their large drainage areas. Only two of the streams draining mined areas (stations 82 and 119) had pH values less than 6.0, indicating that in most cases the coal-mine drainage is buffered by the thin beds of limestone associated with the coal-bearing Pennsylvanian strata and by the water in the receiving stream.

Alkalinity[2] in most natural water primarily is due to the carbonate and bicarbonate ions, but borate, hydroxide, phosphate, and silicate ions also may contribute (Hem, 1970, p. 152). Alkalinity is important because it buffers the solution against pH changes and decreases the solubility of some metals. A minimum alkalinity of 20 mg/L (milligrams per liter) is recommended by the U.S. Environmental Protection Agency (1976) for freshwater aquatic life.

Alkalinity data are available for 54 stations; statistical summaries are presented in Section 10.2. Mean concentrations of alkalinity as calcium carbonate range from 60 to 310 mg/L for 14 stations on streams draining unmined areas and range from 0 to 240 mg/L for 40 stations on streams draining coal-mined areas.

[1] The pH of a solution is a measure of its hydrogen ion activity and is expressed as the negative base 10 logarithm of the hydrogen ion activity in moles per liter at a given temperature. Values of pH range from 0 to 14, with a pH of 7.0 at 25° Celsius representing neutral water. Progressively smaller values indicate increasingly acidic water, and progressively larger values indicate increasingly alkaline water.

[2] The alkalinity of water is defined as the capacity to neutralize acid and is commonly expressed as milligrams per liter of calcium carbonate.

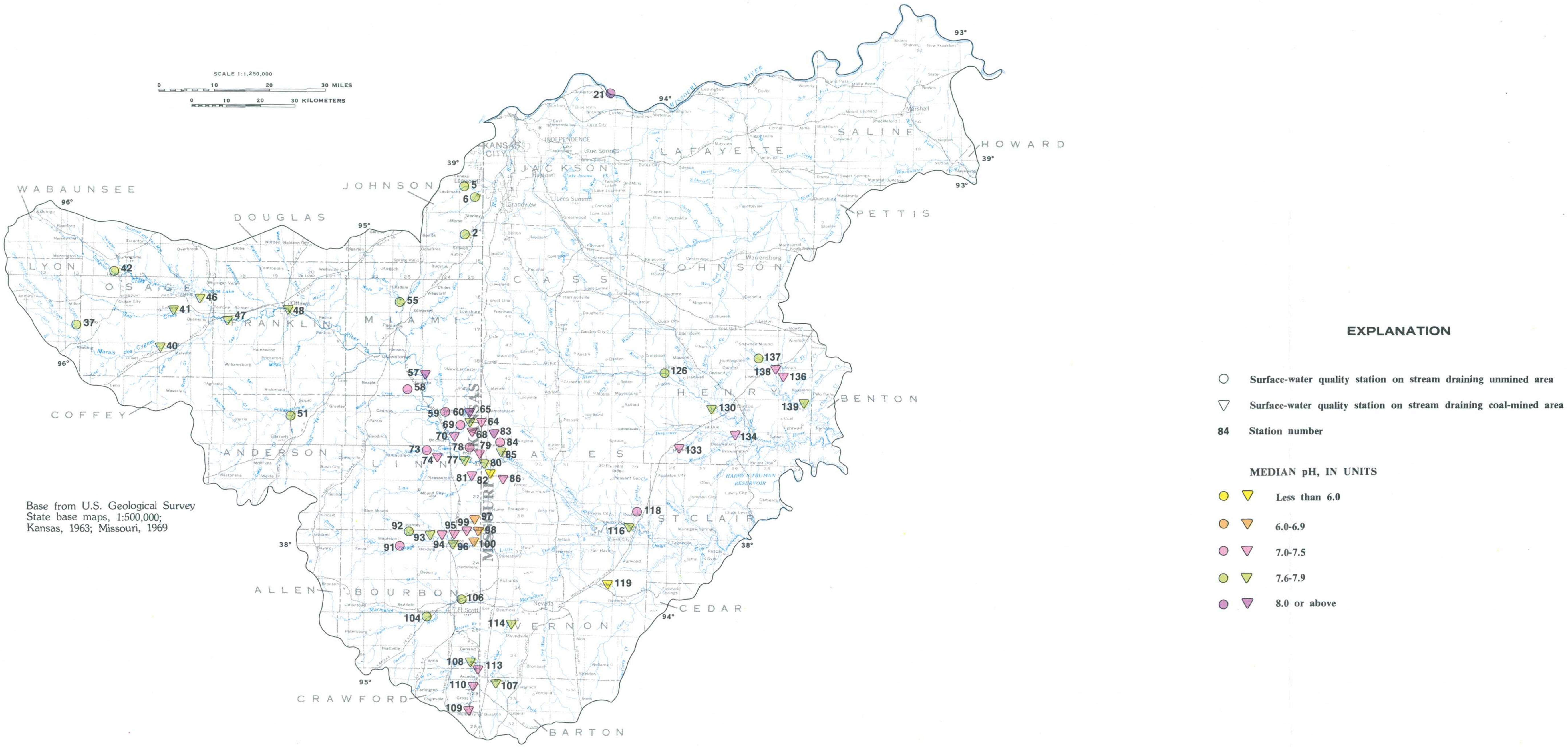



**Figure 6.2-1 Median values of pH for streams draining coal-mined and unmined areas.**

# Concentrations of Dissolved Solids Often are Increased by Coal Mining

*Ground-water discharge from coal-mined areas causes large concentrations of dissolved solids in receiving streams during low-flow periods.*

Mean concentrations of dissolved solids[1] for streams draining coal-mined and unmined areas are shown in figure 6.3-1. Statistical summaries of these data are presented in Section 10.2. The Missouri River at Sibley, Missouri (Station 21) had the largest mean concentration of dissolved solids for streams draining unmined areas. However, very little of the flow in the Missouri River at Sibley is from Area 39. Because mean concentrations less than or equal to 375 milligrams per liter occurred in the remaining streams draining unmined areas, this value was used as the maximum of the low range. Multiples of 375 (750, 1500, and 3000 milligrams per liter) were used as maximums for the next three ranges to indicate the severity of contamination, and greater than 3000 milligrams per liter was used as the largest range.

The streams that have the largest mean concentrations of dissolved solids are small streams that drain extensively coal-mined areas. Several of the streams that drain mined areas have mean concentrations of dissolved solids less than 375 milligrams per liter because most of their flow is from unmined areas. A previous investigation including streams in Crawford County, Kansas, has shown that mean instream concentration of dissolved solids is directly related to the percentage of the drainage basin that has been coal mined (Bevans, 1980).

Streams contaminated by coal-mine drainage have the largest instream concentrations of dissolved solids during low-flow periods when ground-water discharge from the mined areas is a significant part of the streamflow, as illustrated in figure 6.3-2.

Regression equations relating the mean concentration of dissolved solids to mean specific conductance[2] have been developed for streams draining coal-mined and unmined parts of Area 39. The regression equations and lines shown in figure 6.3-3 are valid for the range of dissolved solids concentrations and specific conductance values used to compute them, as indicated by the lengths of the lines. The ranges in dissolved solids concentrations and specific conductance values are much greater for streams draining mined areas because of increased weathering caused by disruption and exposure of subsurface rock strata during coal mining. The slope of the regression line is greater for streams draining mined areas because sulfate, the primary anion in solution, has a lower ionic activity and is not as strongly related to specific conductance as bicarbonate, the primary anion in streams draining unmined areas.

[1] The concentration of dissolved solids in milligrams per liter is determined by weighing the dry residue of a filtered water sample (0.45 micron filter) that has been evaporated by drying at 180° Celsius for 1 hour or estimated by summing the concentrations of the dissolved constituents (Skougstad and others, 1979). For most alkaline waters, dissolved solids include silica, calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, and nitrate. In acid waters, dissolved metals can contribute significantly to the concentration of dissolved solids.

[2] Specific conductance, in micromhos per centimeter at 25° Celsius, is a measurement of the ability of water to conduct an electrical current. The presence of ions in solution increases the ability of water to conduct an electrical current. Because most of the dissolved constituents in water are present in ionic form, excluding silica, specific conductance is directly related to the concentration of dissolved solids.

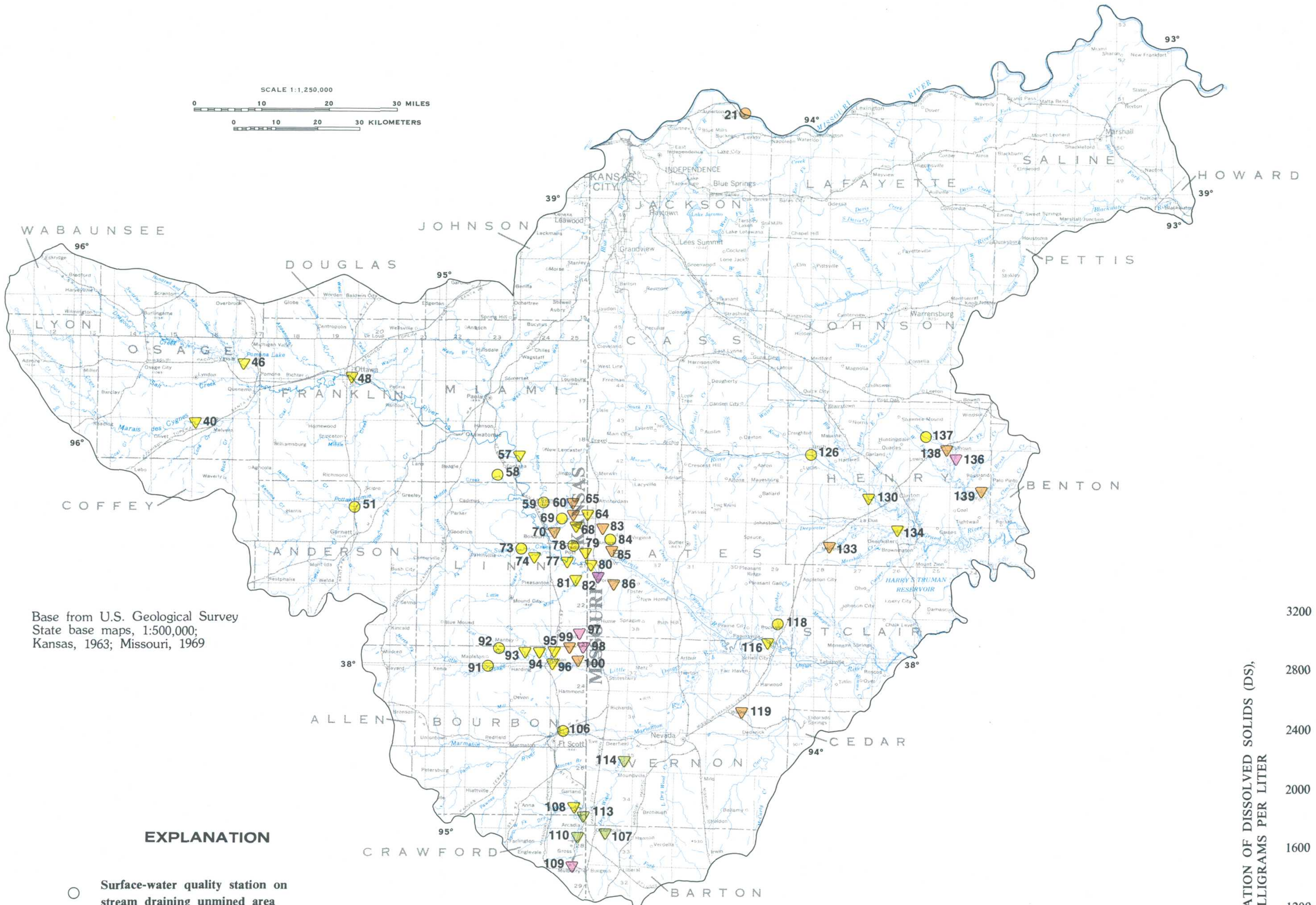



Figure 6.3-1 Mean concentrations of dissolved solids for streams draining coal-mined and unmined areas.

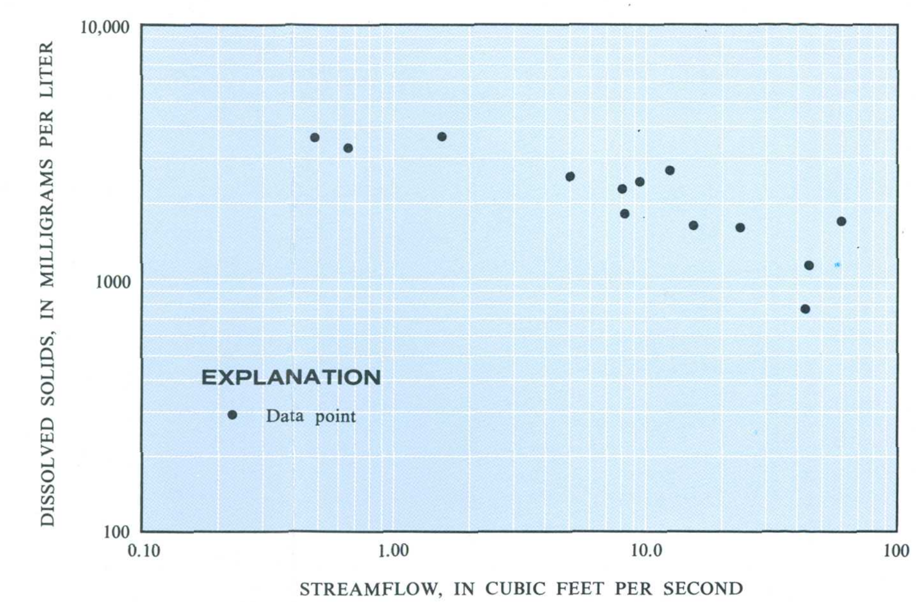



Figure 6.3-2 Relationship between streamflow and concentration of dissolved solids for Cox Creek 2 miles north of Arcadia, Kansas (station 113).

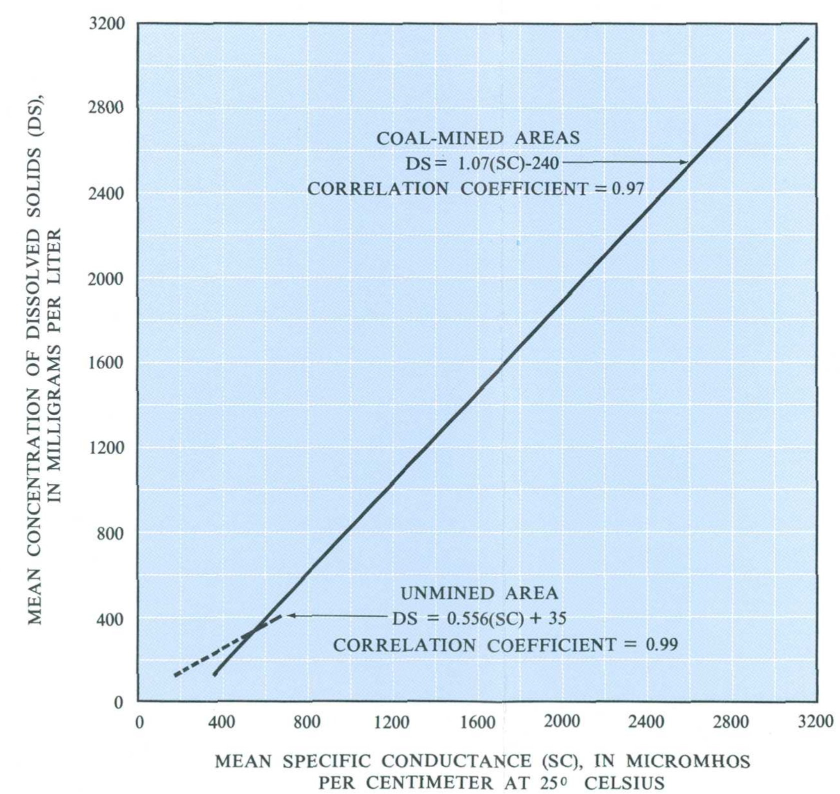



Figure 6.3-3 Relationships between mean specific conductance of dissolved solids for streams draining coal-mined and unmined areas.

# Streams Draining Coal-Mined Areas Often Have Large Concentrations of Sulfate

*Sulfate derived from the oxidation of sulfide minerals is the primary chemical constituent indicating coal-mine drainage.*

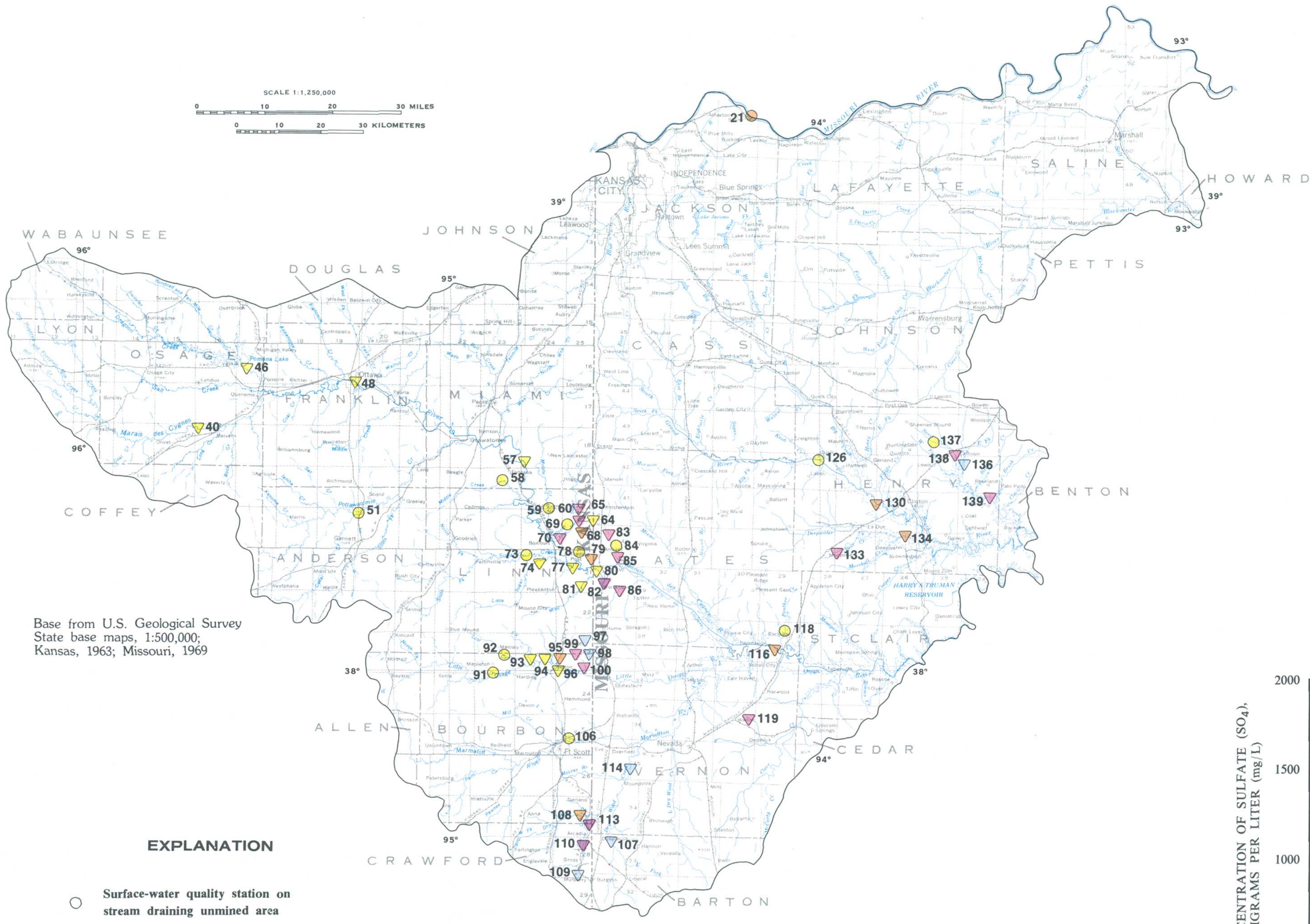
Geochemical reactions in coal-mined areas that result in large concentrations of sulfate in streams draining them are initiated when water and oxygen contact sulfide minerals (pyrite, marcasite, sphalerite, and galena) in abandoned and reclaimed overburden, or in high-walls and floors of active surface mines. The primary sources of sulfate, the iron sulfide minerals pyrite and marcasite ($FeS_2$), are oxidized releasing ferrous iron, sulfate, and acidity into solution (Stumm and Morgan, 1981):

$$FeS_2 + 7/2O_2 + H_2O \rightarrow Fe_2^{+} + 2SO_4^{2-} + 2H^{+}. \quad (1)$$

Ranges of mean concentrations of sulfate for streams draining coal-mined and unmined areas are shown in figure 6.4-1. Statistical summaries of these data are presented in Section 10.2. The largest mean concentration of sulfate for streams draining unmined areas occurred at the Missouri River at Sibley, Missouri (Station 21). However, very little of the flow in the Missouri River at Sibley is from Area 39. The rest of the streams draining unmined areas had concentrations of sulfate less than or equal to 75 milligrams per liter. Therefore 75 milligrams per liter is used as the maximum of the low range. Multiples of 75 (150, 600, and 1200 milligrams per liter) are used to indicate the severity of contamination. Concentrations greater than 1200 milligrams per liter indicate the most severe contamination.

Small streams draining extensively coal-mined areas have the highest mean concentrations of sulfate. The streams draining coal-mined areas have the highest concentrations of sulfate during low-flow periods when ground-water discharge from the mined areas is a significant part of the streamflow, as illustrated in figure 6.4-2.

A previous investigation of coal-mined areas in southeast Kansas (Bevans, 1980) determined that mean concentrations of sulfate are directly related to the percentage of the drainage area that has been strip mined. This relationship is shown in figure 6.4-3.




Base from U.S. Geological Survey State base maps, 1:500,000; Kansas, 1963; Missouri, 1969

**EXPLANATION**

○ Surface-water quality station on stream draining unmined area

▽ Surface-water quality station on stream draining coal-mined area

84 Station number

MEAN CONCENTRATION OF SULFATE, IN MILLIGRAMS PER LITER

- 75 or less
- 76-150
- 151-600
- 601-1200
- Greater than 1200

**Figure 6.4-1 Mean concentrations of sulfate in streams draining coal-mined and unmined areas.**

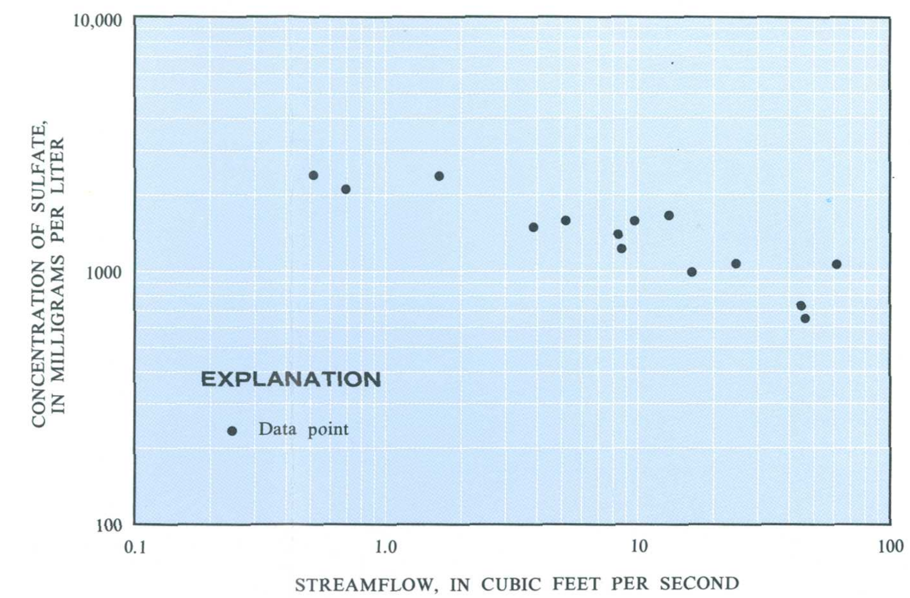
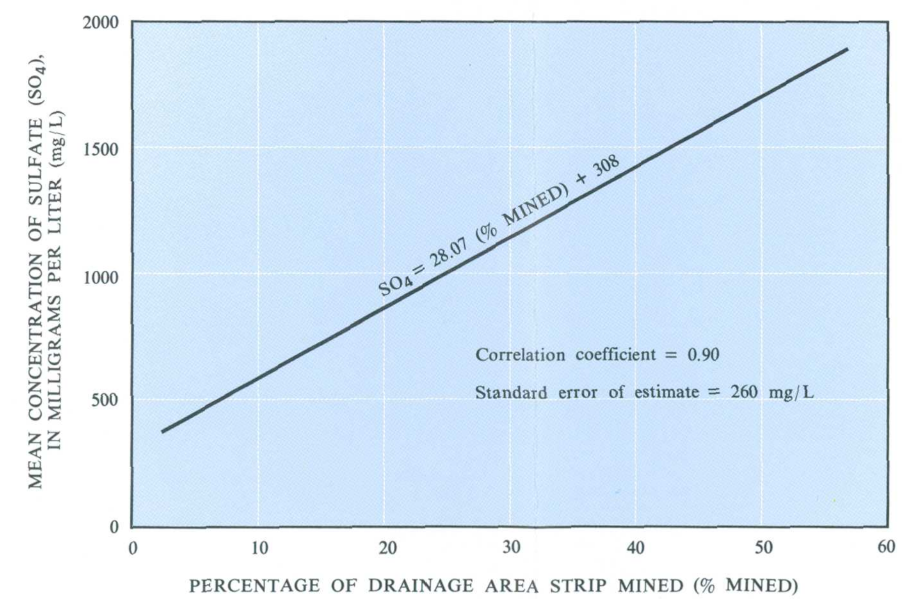



**Figure 6.4-2 Relationship between streamflow and concentration of sulfate for Cox Creek 2 miles north of Arcadia, Kansas (station 113).**




Data modified from Bevans, 1980.

**Figure 6.4-3 Relation of mean concentration of sulfate to percentage of drainage area mined.**

# Mean Concentrations of Total and Dissolved Iron are Larger in Streams Draining Mined Areas

*Maximum total recoverable-iron concentrations for 16 of the streams draining coal-mined areas and 3 of the streams draining unmined areas exceeded the maximum permissible limit established by the Surface Mining Control and Reclamation Act of 1977.*

Iron is the fourth most abundant element in the Earth's crust and is an important constituent of rocks and soils. In the sedimentary rocks of the Pennsylvanian System, it primarily occurs in the ferrous form ($Fe^{2+}$) as the iron sulfides, pyrite and marcasite. Weathering of soils and rocks containing these minerals accounts for much of the iron in natural waters. In aquatic environments, iron is present as both the ferrous and ferric ($Fe^{3+}$) ions, with the predominant form and concentration largely controlled by pH, redox potential, dissolved oxygen and carbon dioxide concentrations, and sulfur species (Hem, 1970, p. 117).

Industrial wastes and mine drainage are also sources of iron. Surface coal mining exposes large quantities of iron-bearing rocks and soils to the environment, accelerating the natural weathering process.' Iron sulfides ($FeS_2$) react with water and oxygen releasing ferrous iron, sulfate, and acidity into solution (Stumm and Morgan, 1981),

$$FeS_2 + 7/2O_2 + H_2O \rightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+ \quad (1)$$

In the presence of acidity and oxygen, ferrous iron is oxidized to ferric iron ($Fe^{3+}$).

$$Fe^{2+} + ¼O_2 + H^+ \rightarrow Fe^{3+} + ½H_2O. \quad (2)$$

At the pH of acid-mine drainage (2.5-5.0), ferric iron remains in solution, but on mixing with the oxygenated, neutral or alkaline water of the receiving stream, precipitates as ferric oxyhydroxide, $Fe(OH)_3$, and releases additional acidity.

$$Fe^{3+} + 3H_2O \rightarrow Fe(OH)_3 + 3H^+ \quad (3)$$

The ochre-yellow precipitate known as "yellow boy" gives the water a reddish appearance when in suspension, adsorbs to stream sediments, or settles on streambeds, adversely affecting bottom-dwelling aquatic life.

Dissolved-iron data are available for 43 stations; statistical summaries are presented in Section 10.2. Mean concentrations of dissolved iron (figure 6.5-1) range from 30 to 1,800 μg/L (micrograms per liter) for 11 stations on streams draining unmined areas; for 31 stations on streams draining coal-mined areas, values range from 10 to 3,400 μg/L (station 82 has a mean concentration of 140,000 μg/L because of high acidity). A few of the streams draining mined areas showed no appreciable water-quality degradation because of buffering and dilution effects of their large drainage areas.

At concentrations of more than 300 μg/L, iron imparts a disagreeable taste to water and causes staining. The U.S. Environmental Protection Agency (1976) has established a criteria of 300 μg/L dissolved iron for domestic water supplies, which is for aesthetic rather than toxicological reasons, and 1,000 μg/L for freshwater aquatic life. Three of the streams draining coal-mined areas and two of the streams draining unmined areas had maximum dissolved-iron concentrations that exceeded both limits.

Total recoverable-iron[1] data are available for 51 stations; statistical summaries are presented in Section 10.2. Mean concentrations of total recoverable iron range from 260 to 16,000 μg/L for 13 stations on streams draining unmined areas; for 37 stations on streams draining coal-mined areas, values range from 280 to 45,000 μg/L (station 82 has a mean concentration of 150,000 μg/L). The Surface Mining Control and Reclamation Act of 1977 has established a maximum permissible limit of 7,000 μg/L total recoverable iron in mine-area effluents. Sixteen of the streams draining coal-mined areas and three of the streams draining unmined areas had maximum total recoverable-iron concentrations that exceeded this limit.

A significant correlation usually exists between total recoverable-iron and suspended-sediment concentrations, as is the case in Area 39. The regression equation describing the relationship for 5 streams (31 measurements) draining unmined areas is:

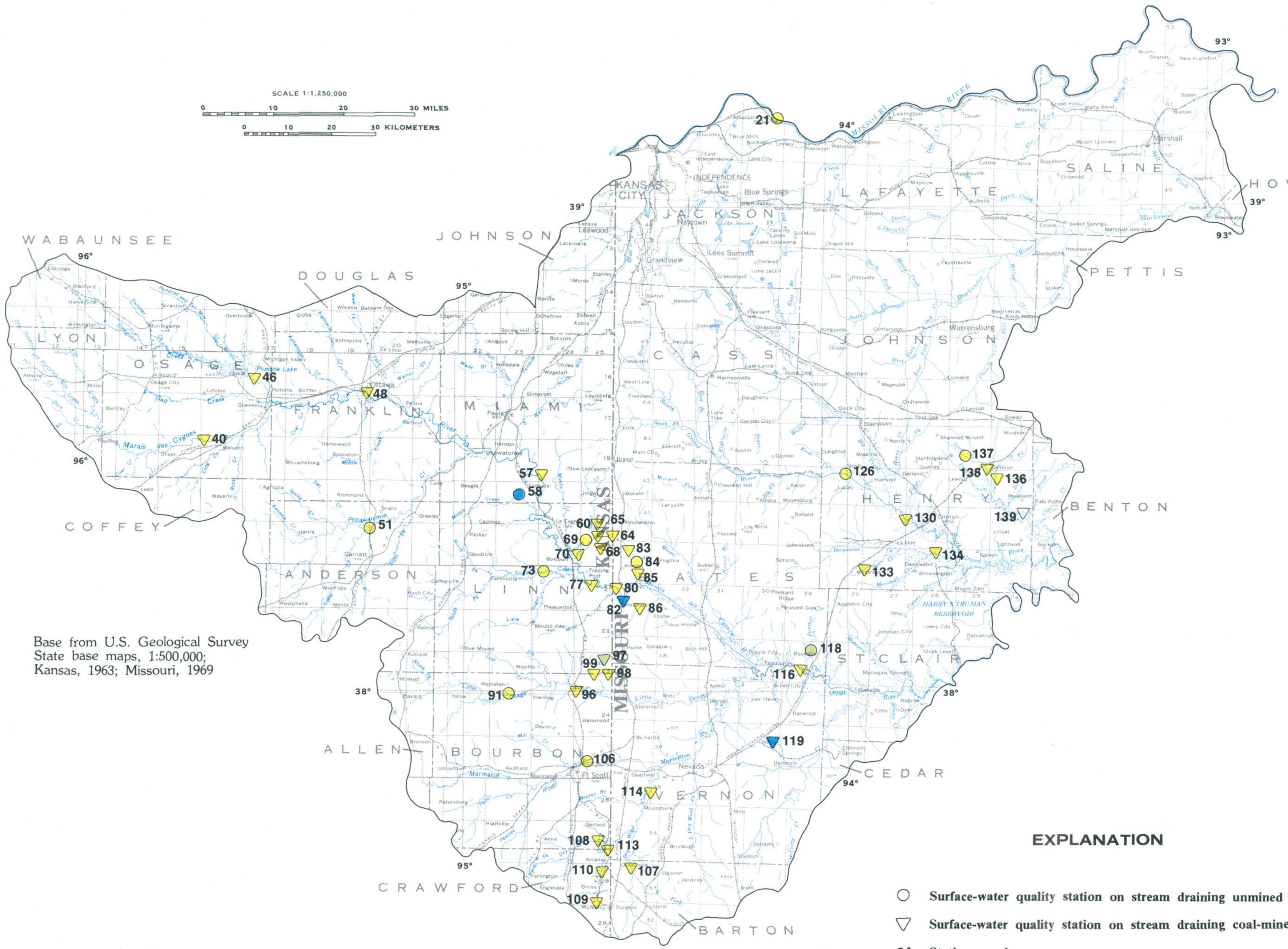
$$TFe = 86.6\, SSC^{0.80}; \quad (4)$$

where TFe is the total recoverable-iron concentration, in micrograms per liter; and SSC is the suspended-sediment concentration, in milligrams per liter. The regression equation for 19 streams (99 measurements) draining coal-mined areas is:

$$TFe = 84.4\, SSC^{0.78}. \quad (5)$$

The correlation coefficient for equation (4) is 0.92 and for equation (5) is 0.86. The regression equations for the coal-mined and unmined areas are essentially the same because most of the total recoverable iron consists of insoluble iron precipitates that are adsorbed to suspended sediment. In most streams, the dissolved-iron concentration accounts for less than 10 percent of the total recoverable iron. Exceptions to this are at sites where the water is acidic (pH less than 7.0), and the solubility of iron is increased. Data from the coal-mined and unmined areas have been combined, and the relationship is shown graphically in figure 6.5-2. As indicated by the slope of the line, the total recoverable-iron concentration increases with increasing suspended-sediment concentration.

[1] Total recoverable iron includes dissolved iron and iron precipitates in suspension or adsorbed to suspended sediment.




Base from U.S. Geological Survey
State base maps, 1:500,000;
Kansas, 1963; Missouri, 1969

**Figure 6.5-1** Mean concentrations of dissolved iron for streams draining coal-mined and unmined areas.

**EXPLANATION**

○ Surface-water quality station on stream draining unmined area

▽ Surface-water quality station on stream draining coal-mined area

**84** Station number

MEAN CONCENTRATION OF DISSOLVED IRON, IN MICROGRAMS PER LITER

○ ▽ 10-300

○ ▽ 301-1000

● ▼ Greater than 1000

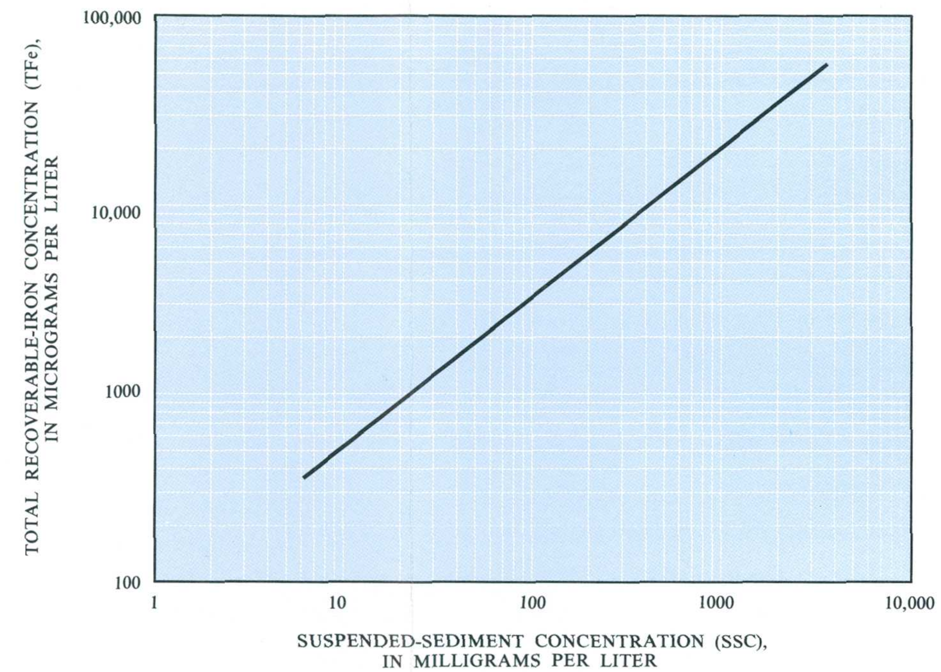



**Figure 6.5-2** Relationship between total-recoverable iron and suspended sediment for streams draining coal-mined and unmined areas.

# Mean Concentrations of Total and Dissolved Manganese are Larger in Streams Draining Mined Areas

*Maximum total recoverable-manganese concentrations for four of the streams draining coal-mined areas exceeded the maximum permissible limit established by the Surface Mining Control and Reclamation Act of 1977.*

Manganese is one of the most common elements in rocks and soils. In the sedimentary rocks of the Pennsylvanian System in Area 39, manganese primarily occurs as manganese carbonate (rodochrosite) or as oxides and hydroxides in which the oxidation state of the element is +2, +3, or +4. Weathering of soils and rocks are primary sources of manganese in natural waters. In aqueous environments, manganese is present as the carbonate or as oxides and hydroxides, with the $Mn^{2+}$ ion being the predominant dissolved species. Manganese also forms complexes with many kinds of organic material. Solubility is controlled by several factors including pH, redox potential, and dissolved oxygen and carbon dioxide concentrations (Hem, 1970, p. 129).

Industrial wastes and mine drainage are also sources of manganese. Surface coal mining exposes large quantities of rocks and soils containing iron sulfides and manganese compounds to the environment. Oxidation of the iron sulfides produces acidity that accelerates the natural weathering process of the manganese compounds. Dissolved manganese may persist in a stream receiving coal-mine drainage longer than dissolved iron because of the relative stability of the $Mn^{2+}$ ion in oxygenated, near neutral (pH 7.0) waters. In more alkaline waters (pH greater than 7.0), manganese oxides precipitate as a yellowish-red or brownish-black precipitate that adsorbs to stream sediments and settles on streambeds.

Dissolved-manganese data are available for 43 stations; statistical summaries are presented in Section 10.2. Mean concentrations of dissolved manganese range from 25 to 5,500 $\mu$g/L (micrograms per liter) for 11 stations on streams draining unmined areas and range from less than 1 to 6,000 $\mu$g/L for 32 stations on streams draining coal-mined areas, as shown in figure 6.6-1. A few of the streams draining mined areas showed no appreciable water-quality degradation because of their large drainage areas and dilution effects.

At concentrations greater than 50 $\mu$g/L, manganese imparts a disagreeable taste to water and causes a brownish staining of laundry. The U.S. Environmental Protection Agency (1976) has established a criteria of 50 $\mu$g/L dissolved manganese for domestic water supplies, which is for aesthetic rather than toxicological reasons. No criteria has been established for freshwater aquatic life which can tolerate a wide range of dissolved-manganese concentrations (McKee and Wolf, 1963).

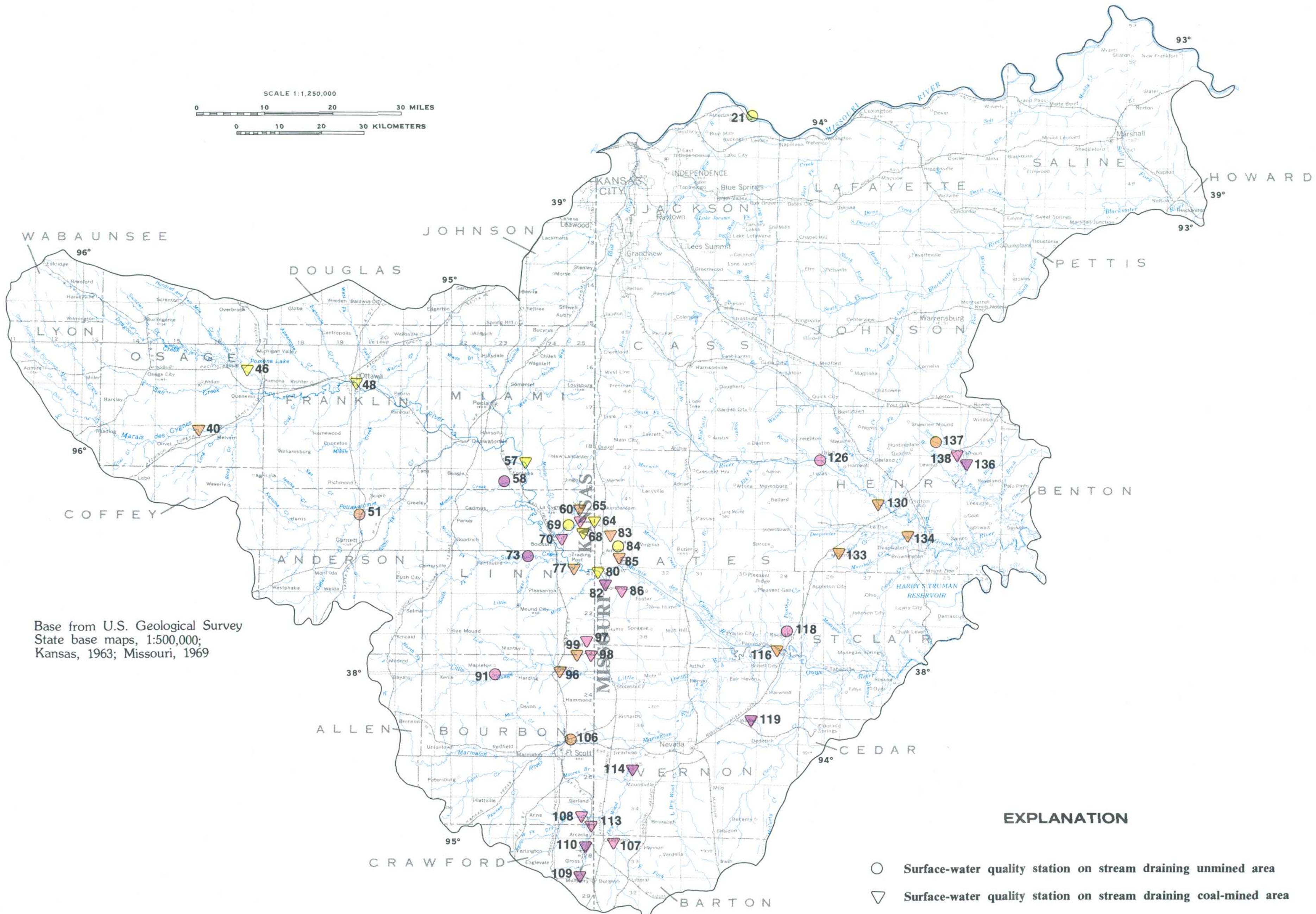
Total recoverable-manganese[1] data are available for 53 stations; statistical summaries are presented in Section 10.2. Mean concentrations of total recoverable manganese range from 50 to 1,600 $\mu$g/L for 13 stations on streams draining unmined areas and range from 12 to 5,900 $\mu$g/L for 40 stations on streams draining coal-mined areas. The Surface Mining Control and Reclamation Act of 1977 has established a maximum permissible limit of 4,000 $\mu$g/L total recoverable manganese in mine-area effluents. Four of the streams draining coal-mined areas had a maximum total recoverable-manganese concentration that exceeded this limit.

At stations sampled in Area 39, the dissolved-manganese concentration accounted for 0 to 100 percent of the total recoverable manganese. This wide variation is due to manganese remaining in solution at near neutral pH, but precipitating as manganese oxides as the water becomes increasingly alkaline. Manganese oxides have a tendency to form coatings on other mineral surfaces (Hem, 1970, p. 128), and a significant correlation often exists between total recoverable-manganese and suspended-sediment concentrations. The regression equation describing the relationship for 5 streams (31 measurements) draining unmined areas is:

$$TMn = 29.4\, SSC^{0.40}; \qquad (1)$$

where TMn is the total recoverable-manganese concentration, in micrograms per liter; and SSC is the suspended-sediment concentration in milligrams per liter. The correlation coefficient is 0.66. The equation is shown graphically in figure 6.6-2. As indicated by the slope of the line, the total recoverable-manganese concentration increases with increasing suspended-sediment concentration. The relationship for 19 streams (103 measurements) draining coal-mined areas is not significant (correlation coefficient 0.08) because more of the manganese is in solution rather than adsorbed to suspended sediment.

[1] Total recoverable manganese includes dissolved manganese and manganese precipitates in suspension or adsorbed to suspended sediment.




Base from U.S. Geological Survey
State base maps, 1:500,000;
Kansas, 1963; Missouri, 1969

**EXPLANATION**

○ Surface-water quality station on stream draining unmined area

▽ Surface-water quality station on stream draining coal-mined area

83 Station number

MEAN CONCENTRATION OF DISSOLVED MANGANESE, IN MICROGRAMS PER LITER

○ ▽ 50 or less

○ ▽ 51-250

○ ▽ 251-1500

○ ▽ Greater than 1500

**Figure 6.6-1 Mean concentrations of dissolved manganese for streams draining coal-mined and unmined areas.**

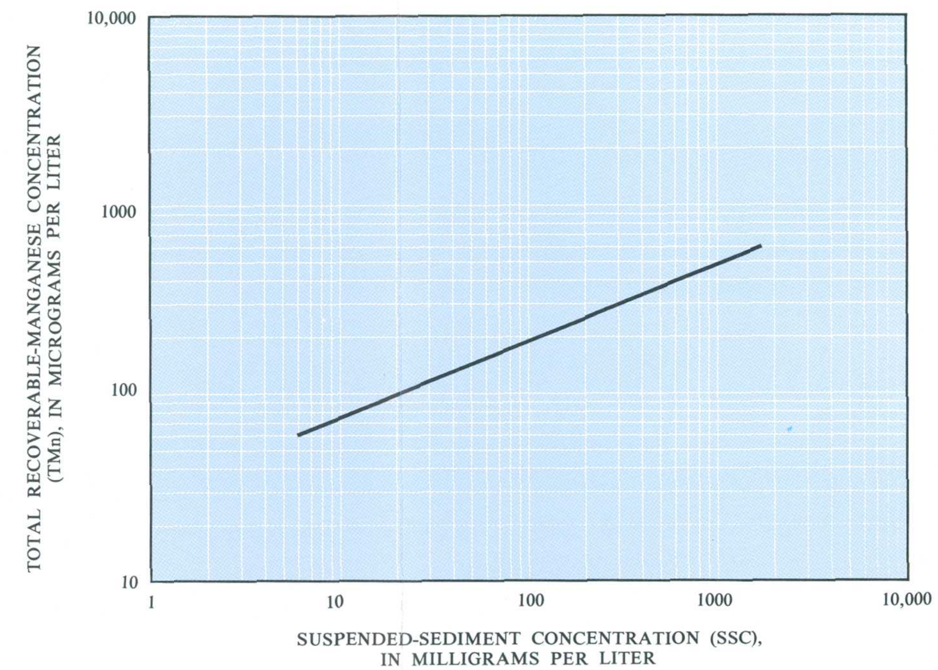



**Figure 6.6-2 Relationship between total-recoverable manganese and suspended sediment for streams draining unmined areas.**

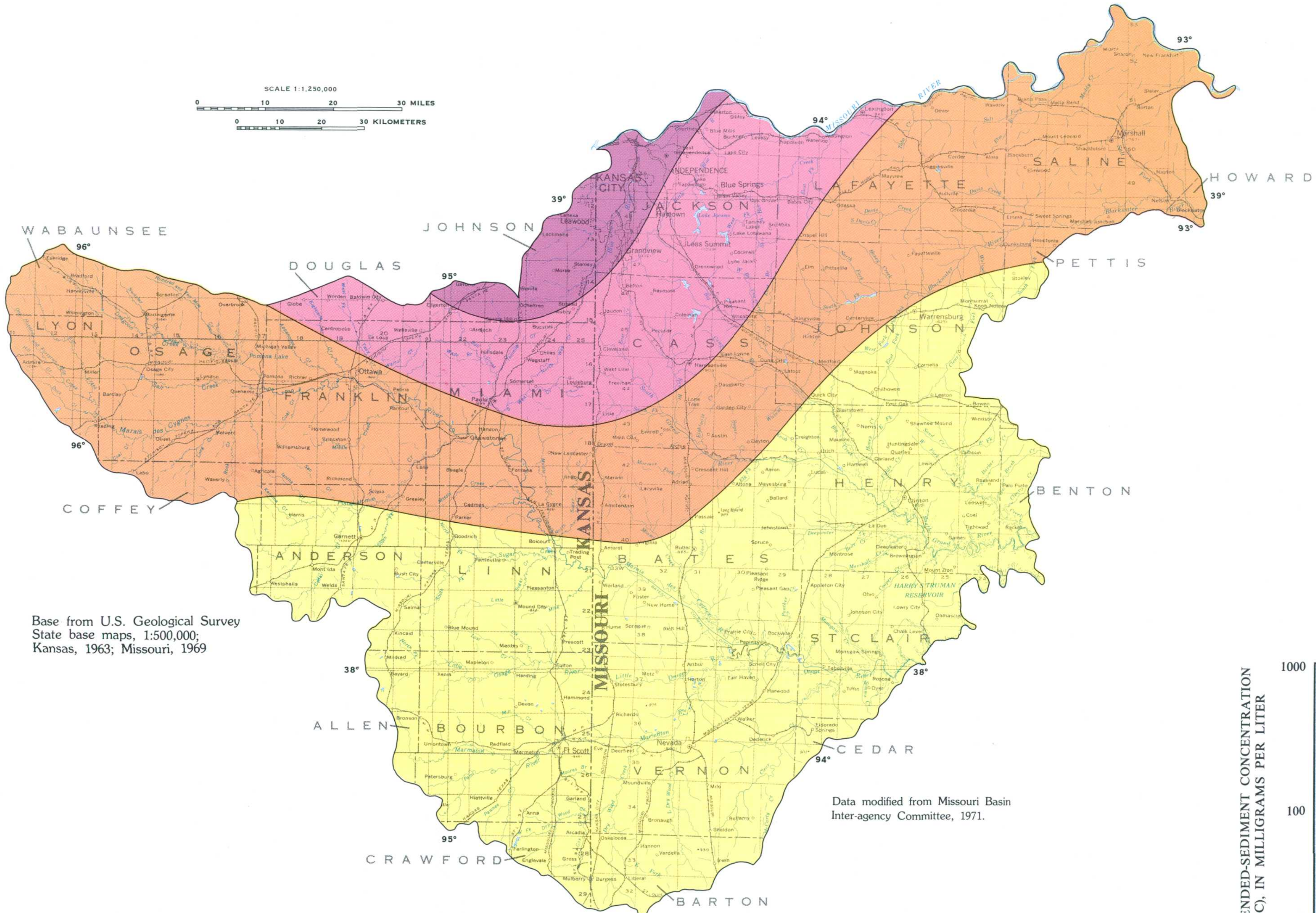
# Sediment Yields Range from Less than 500 to Greater than 3,000 Tons per Square Mile per Year

*Sediment yields are dependent on climatic and drainage-basin characteristics.*

Sediment yields range from less than 500 tons per square mile per year in the southern part of the study area to greater than 3000 tons per square mile per year in the northern part (figure 6.7-1). Sediment yields are dependent on climatic characteristics (rainfall amounts and intensities) and drainage-basin characteristics (contributing drainage area, land use, vegetation, land slope, and soils).

A previous investigation in the Missouri River Basin determined that sediment yields in the plains generally increase with increases in mean streamflow, thickness of loess, and land slope (Jordan, 1979). Smaller drainage basins generally yield more sediment per square mile than larger ones.

Observed concentrations of suspended sediment in the study area ranged from 4 to 14,600 milligrams per liter. The minimum and maximum concentrations were observed in streams draining unmined areas. The concentration of suspended sediment at any particular station generally increases with streamflow (fig. 6.7-2). The erosion of cleared, actively mined, newly reclaimed, or abandoned surface-mine areas may increase sediment yields to streams. An investigation in Linn County, Kansas, determined that active strip mining increased sediment yields by approximately 25 percent even though sediment ponds were installed (Bevans, 1984). However, due to current reclamation practices of replacing topsoil, grading to approximate original topography, and revegetating, the increase in suspended sediment yield probably is temporary.




**EXPLANATION**

**SEDIMENT YIELD, IN TONS PER SQUARE MILE PER YEAR**

- **Less than 500**
- **500-1000**
- **1000-3000**
- **3000-6000**

**Figure 6.7-1 Sediment yield for drainage basins of 100 square miles or larger.**

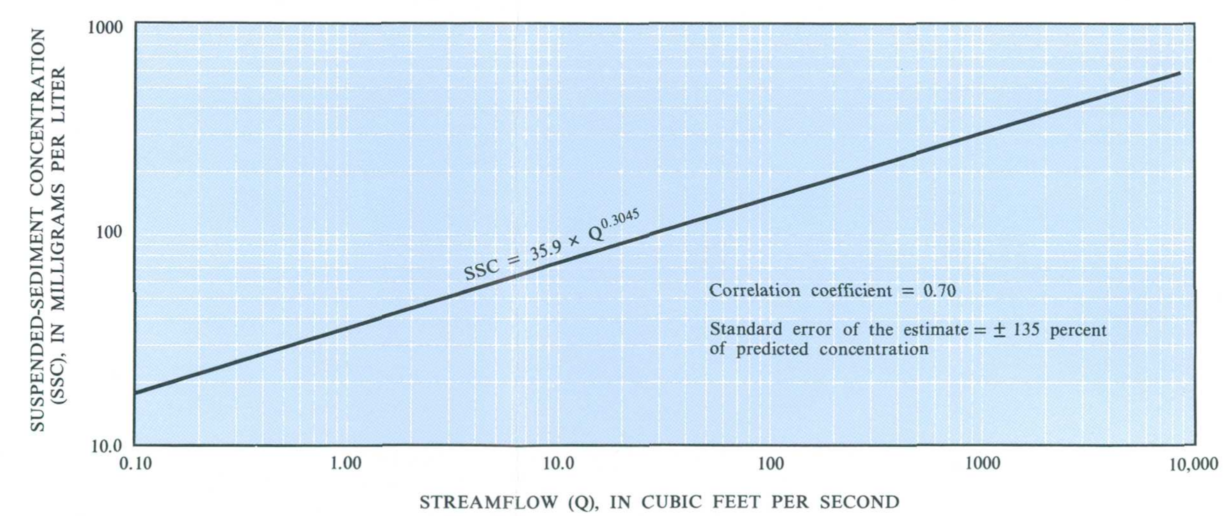



**Figure 6.7-2 Regression relationship of streamflow to concentration of suspended sediment for the Little Osage River near Fulton, Kansas (station 96).**

# Ground Water Occurs in Unconsolidated Deposits and in Bedrock Formations

*Ground water is stored in and moves through intergranular (primary) openings in the unconsolidated rocks and through fracture, joint, and solution (secondary) openings in the consolidated rocks. Water discharges from the shallow aquifers to streams and springs.*

Unconsolidated deposits consisting of varying amounts of clay, silt, sand and gravel are present along the major streams in the area. The deposits are present as alluvium underlying the floodplain and as terrace deposits bordering the major river valleys. Terrace deposits are erosional remnants of older alluvium that occur in step-like succession above the floodplain. The saturated part of the alluvium and terrace deposits constitute the unconsolidated aquifers (fig. 7.1-1). Ground water available to wells occurs in the openings between the individual sand and gravel particles making up the aquifers.

In Kansas the principal area of unconsolidated deposits is along the Marais des Cygnes River. The alluvium and terrace deposits along the Marais des Cygnes River valley in Miami County, Kansas have a maximum thickness of 55 feet. The thickness of saturated material ranges from 0 to 46 feet. In Missouri the principal area of unconsolidated deposits is along the Missouri River in Jackson, Lafayette, and Saline Counties. The average saturated thickness of the Missouri River alluvium in this reach of the river is about 70 feet.

Recharge to the alluvium is from overbank flooding, sustained high-river stage, by direct penetration of rainfall, and by underflow from bedrock aquifers. Recharge to the terrace deposits is by direct penetration of rainfall and by underflow from bedrock aquifers.

Water that enters the unconsolidated aquifers moves slowly (less than 2,000 feet per year in the Missouri River alluvial aquifer and less than 200 feet per year in the Marais des Cygnes River alluvial aquifer) toward the river and in a downstream direction. During periods of prolonged high-river stage the direction of ground water movement may temporarily be reversed, especially in the area close to the river. Most ground-water discharge from the unconsolidated aquifers is to the rivers. Other discharge may be attributed to evapotranspiration and pumping from wells.

Bedrock formations ranging in age from Pennsylvanian (youngest) to Ordovician (oldest) contain aquifers in the area (fig. 7.1-1). The shallowest, most widespread aquifers are in the interbedded limestones, shales and sandstones of Pennsylvanian age. The rocks are at the surface throughout most of the area. In the easternmost part of the area Pennsylvanian rocks are absent and Mississippian and Ordovician rocks crop out. Aquifers are present in both Mississippian rocks which are predominantly limestone, and in Ordovician rocks which are predominantly dolomite. Water occurs in the bedrock formations in fractures, joints and in solution-enlarged openings in carbonate rock.

Recharge occurs chiefly by direct precipitation on the outcrop area. The water penetrates down to the zone of saturation, the surface of which is called the water table. The unconfined (water table) aquifers respond quickly to rainfall whereas the deeper (confined) aquifers show no response to rainfall events. The confined aquifers may receive recharge from overlying or underlying aquifers when the head in the confined aquifer is less than the head in the overlying or underlying aquifer (fig. 7.1-1). Confined aquifers may also receive recharge by underflow from adjacent areas.

Movement of ground water in the consolidated rocks takes place very slowly (less than 100 feet per year) along bedding planes and fractures. The direction of movement of the ground water in Missouri and eastern Kansas is toward the northwest.

Discharge from the shallow consolidated aquifers occurs as seepage into rivers, as springs, as evapotranspiration and as percolation into underlying aquifers. In the deep consolidated aquifers ground water discharge occurs as underflow to adjacent areas. Artificial discharge from the aquifers occurs as pumpage from wells.

Dewatering of the strip mines normally is not practiced but strip-mining operations may disrupt the continuity of aquifers in Pennsylvanian coal-bearing rocks and may dewater them locally. "However, in the long term, the fractured and heterogeneous reclaimed overburden probably will have greater porosities and transmissivities than adjacent bedrock aquifers." (Kenny, Bevans, and Diaz, 1982, p. 42).

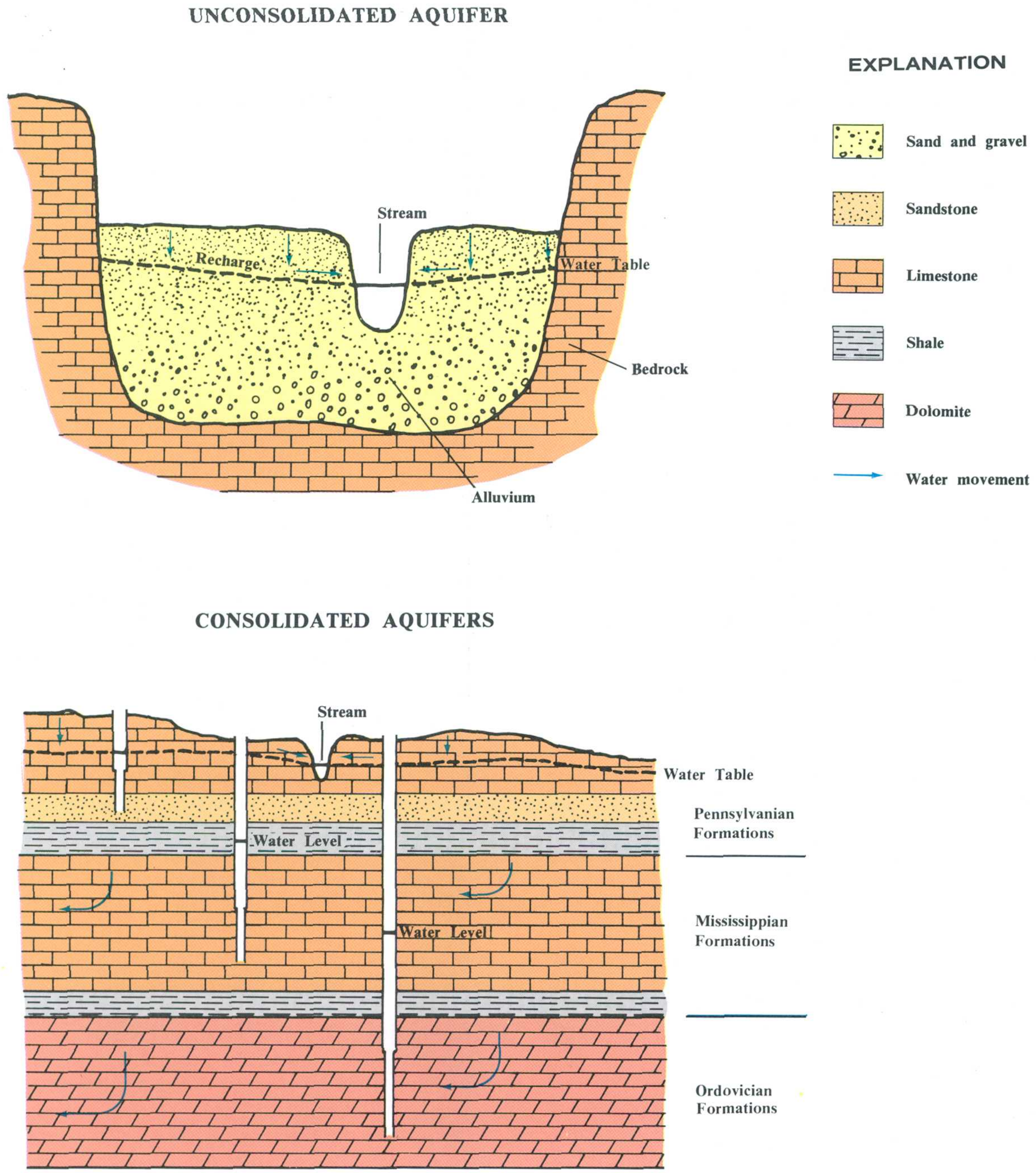



Figure 7.1-1 Water movement in aquifers.

# Unconsolidated Deposits and Bedrock Formations are Sources of Water Supplies

*The aquifers in rocks of Quaternary and Ordovician age are important sources of high-yield wells in parts of Area 39. Aquifers in rocks of Pennsylvanian and Mississippian age are locally important sources of low- to moderate-yield wells.*

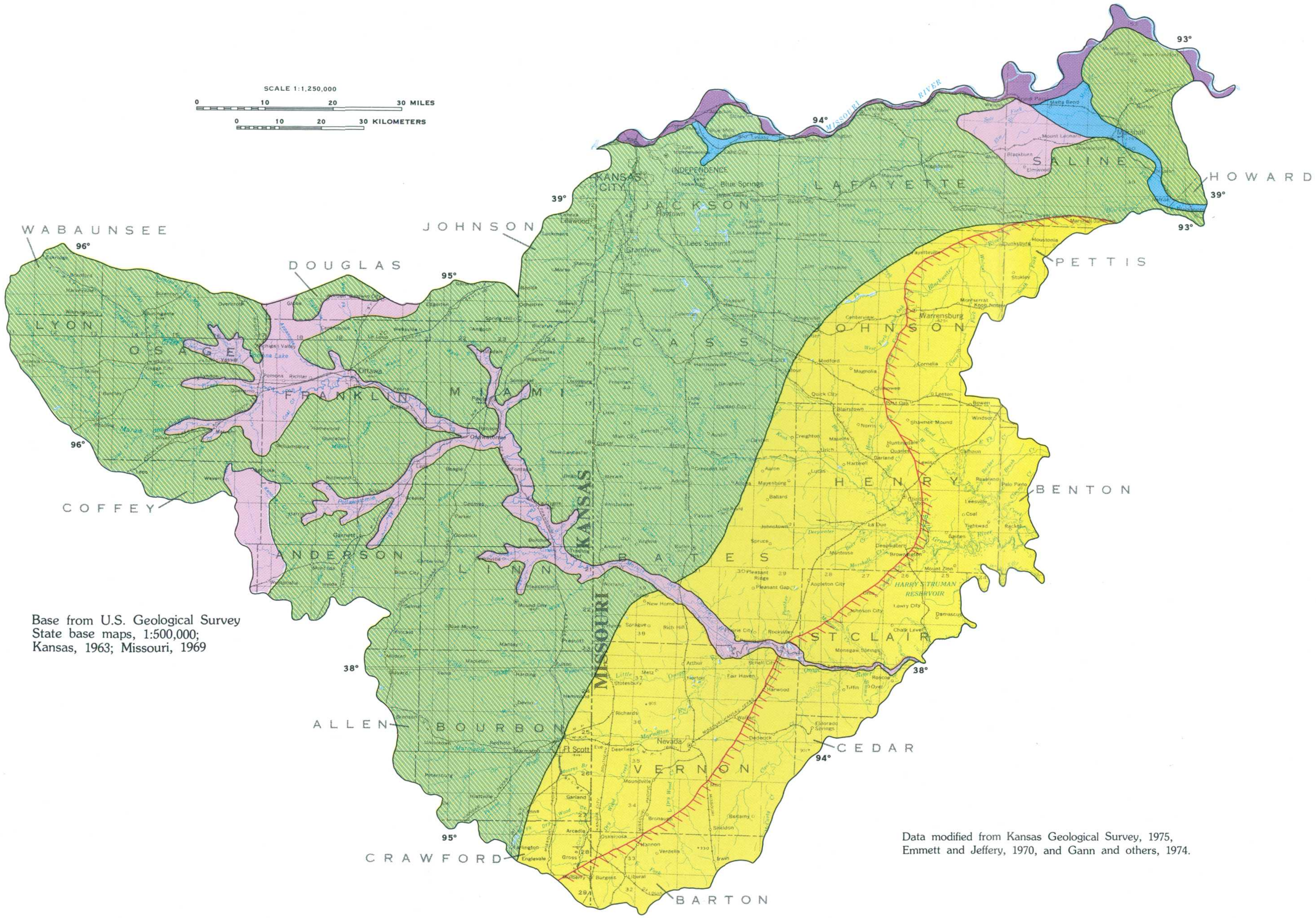
Alluvium and terrace deposits are aquifers along major streams in Kansas and Missouri and are used as sources of water supply. Wells drilled into the alluvium and terrace deposits are capable of yielding from 10 to 2,000 gallons per minute (fig. 7.2-1). The higher yielding wells are restricted to the Missouri River alluvium where irrigation wells have reported pumping rates in excess of 1,000 gallons per minute and specific capacities ranging from 50 to 150 gallons per minute per foot of drawdown. The specific capacity of a well is the rate of discharge of water from the well divided by the drawdown of water level within the well.

Aquifers in rocks of Pennsylvanian and Mississippian age locally will yield sufficient quantities of water to wells for domestic use but they are not important as large-yield sources. The interbedded cyclic deposits of limestone, sandstone, shale, and local coal deposits of the Pennsylvanian System act as a leaky confining bed for the underlying aquifer in rocks of Mississippian age. Modest amounts of water can be obtained from the sandstone lenses and fractured limestone in the system. Wells finished in the Pennsylvanian have average yields of 1 to 15 gallons per minute but locally yields of up to 40 gallons per minute can be obtained.

The confined Mississippian System generally is comprised of limestone with minor shale, dolomite and sandstone layers. Mississippian formations crop out on the eastern side of Area 39; the beds dip to the northwest. In western Missouri and eastern Kansas the Mississippian is economically inaccessable because of the thick Pennsylvanian cover, but where the aquifer can be used well yields vary from 3 to 60 gallons per minute and average 15 to 20 gallons per minute. Productivity of the aquifer is due to secondary permeability from fractures and solution-enlarged openings. In some areas a 5- to 20-foot layer of residual chert at the top of the Mississippian section is capable of yielding up to 30 gallons per minute to wells.

Although rocks of Ordovician age are present in the subsurface throughout the area they contain fresh water only in the eastern ten percent of the area. Mineralization of the ground water increases from southeast to northwest to such an extent that it renders the water unfit for human consumption. In the eastern part of the area where fresh ground water is present, yields from wells range from 25 to 600 gallons per minute (fig. 7.2-1). The higher yielding wells are open to the Roubidoux Formation and Gasconade Dolomite of Ordovician age.

In summary, ground-water use in this part of Kansas is restricted to the unconsolidated aquifers along the major streams and to shallow, low-yield wells in rocks of Pennsylvanian age. The deeper consolidated aquifers contain highly mineralized water, unfit for human consumption. Wells in Pennsylvanian rocks in Missouri yield small quantities of water for domestic and stock supply. The deeper consolidated aquifers are used only in the eastern part of the area where they contain fresh water. Large supplies of fresh water are also available from the unconsolidated deposits along the Missouri River.




**EXPLANATION**

- Favorable for developing wells with yields as great as 100 gallons per minute in unconsolidated aquifer
- Favorable for developing wells with yields as great as 1000 gallons per minute in unconsolidated aquifer
- Favorable for developing wells with yields as great as 2000 gallons per minute in Missouri River Alluvium
- Favorable for developing wells with yields as great as 600 gallons per minute in consolidated aquifer. High yields are limited to wells open to the Roubidoux Formation and Gasconade Dolomite of Ordovician age
- Ground-water of marginal quality in consolidated aquifers of Mississippian and Ordovician age. Wells of Pennsylvanian age yield less than 15 gallons per minute
- Approximate northwestern limit of freshwater (less than 1000 milligrams per liter of dissolved Solids) in consolidated aquifer

**Figure 7.2-1 Ground-water sources and yields.**

# Ground-Water Quality Varies with Geology and Depth to Water

*Ground water in shallow aquifers is susceptible to contamination by seepage from surface coal mines.*

Ground-water quality data are available from the National Data Storage and Retrieval System (WATSTORE), described in section 9.3, for 41 wells in Quaternary rocks, 186 in Pennsylvanian, 28 in Mississippian, and 104 in Ordovician. These wells are listed in section 10.3. Available data on pH, dissolved solids, and dissolved iron are summarized in table 8.0-1.

Geologic formations of Quaternary, Pennsylvanian, Mississippian, and Ordovician age can provide ground water of adequate quality for most uses. However, water in shallow aquifers is very susceptible to contamination by seepage from surface coal mining. Water in deep aquifers is often naturally highly mineralized.

The mineralogy of the aquifer is a primary factor controlling ground-water chemistry. Calcium, magnesium and bicarbonate are the principal dissolved constituents in water from limestone and dolomite formations. Dissolved sodium, chloride, and sulfate are often principal constituents in water from shale formations. Dissolved silica can be a principal constituent in water from sandstone formations.

The chemical composition of water in alluvial, terrace, and glacial deposits of Quaternary age generally is similar to water in the adjacent bedrock. However, because Quaternary deposits generally are more permeable and can be recharged more easily by precipitation or streamflow, concentrations of dissolved solids are generally less than in water from adjacent bedrock. Because Quaternary rocks are shallow and permeable, they are very susceptible to contamination from surface coal mining, and natural variation in concentrations of dissolved solids can be great at any one location. The median pH of available water samples from Quaternary rocks is 7.0, the mean concentration of dissolved solids is 606 milligrams per liter, and the mean concentrations of dissolved iron is 94 micrograms per liter (table 8.0-1).

Bedrock of Pennsylvanian age is present throughout the study area except for scattered areas along the eastern edge. Shale is the most common rock type with limestone, sandstone, and small amounts of coal and underclay following in order of relative abundance (Seevers, 1969). Ground water is generally hard, and concentrations of dissolved solids increase with depth. The median pH of water samples available from Pennsylvanian rocks is 7.4, the mean concentration of dissolved solids is 6,466 milligrams per liter and the mean concentration of dissolved iron is 476 micrograms per liter (table 8.0-1).

Bedrock of Mississippian age is present throughout Area 39 except in small isolated areas along the eastern edge. Mississippian rocks are predominantly limestone and dolomite with some shale and sandy shale. Ground water is generally hard, and concentrations of dissolved solids increase with depth. Dissolved-solids concentrations in ground water in Mississippian rocks increase rapidly from about 1,000 milligrams per liter at the outcrop of the geologic contact between Pennsylvanian and Mississippian rocks, to greater than 40,000 milligrams per liter in the northwest part of the study area (Gann and others, 1974). The median pH of water samples available from Mississippian rocks is 7.8, the mean concentration of dissolved solids is 2,500 milligrams per liter, and the mean concentration of dissolved iron is 208 micrograms per liter (table 8.0-1).

Rocks of the Ordovician age underlie the entire study area. These rocks are predominantly dolomite. Ground water is hard, and concentrations of dissolved solids increase with depth. Dissolved-solids concentrations in ground water from rocks of Ordovician age increase rapidly from about 1,000 milligrams per liter at the outcrop of the geologic contact between Pennsylvanian and Mississippian rocks, to greater than 40,000 milligrams per liter in the northwest part of the study area (Gann and others, 1974). The median pH of water samples available from wells in Ordovician rocks is 7.6, the mean concentration of dissolved solids is 1,119 milligrams per liter, and the mean concentration of dissolved iron is 70 micrograms per liter (table 8.0-1).

Table 8.0-1 Statistical summary of selected water-quality data for ground-water sites available in the National Water Data Storage and Retrieval System (WATSTORE).

(pH in standard units, dissolved solids in milligrams per liter, and dissolved iron in micrograms per liter)

| Geologic system | Property or constituent | Number of samples | Mean | Median | Maximum | Minimum |
|---|---|---|---|---|---|---|
| Quaternary | pH | 34 | -- | 7.0 | 8.0 | 6.2 |
| Pennsylvanian | pH | 93 | -- | 7.4 | 8.6 | 6.0 |
| Mississippian | pH | 24 | -- | 7.8 | 8.4 | 6.7 |
| Ordovician | pH | 101 | -- | 7.6 | 8.8 | 7.1 |
| Quaternary | Dissolved solids | 41 | 606 | 392 | 4,556 | 136 |
| Pennsylvanian | Dissolved solids | 221 | 6,466 | 1,339 | 39,790 | 43 |
| Mississippian | Dissolved solids | 31 | 2,500 | 1,110 | 19,600 | 269 |
| Ordovician | Dissolved solids | 171 | 1,119 | 833 | 18,260 | 227 |
| Quaternary | Dissolved iron | 9 | 94 | 40 | 350 | 10 |
| Pennsylvanian | Dissolved iron | 37 | 476 | 80 | 5,900 | 10 |
| Mississippian | Dissolved iron | 18 | 208 | 64 | 1,800 | 10 |
| Ordovician | Dissolved iron | 23 | 70 | 40 | 280 | 10 |

# 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.

More detailed explanations of these three activities are given in sections 9.2, 9.3, and 9.4.

# NAWDEX Simplifies Access to Water Data

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

NAWDEX ASSISTANCE CENTER
KANSAS
U.S. Geological Survey
Water Resources Division
1950 Constant Avenue - Campus West
University of Kansas
Lawrence, KS 66045
Telephone: (913) 864-4321
FTS 752-2300, 2301, 2302
Hours: 8:00 - 4:30 CST

MISSOURI
U.S. Geological Survey
Water Resources Division
1400 Independence Road
Mail Stop 200
Rolla, MO 65401
Telephone: (314) 341-0824
FTS 277-0824
Hours: 7:30 - 4:00 CST

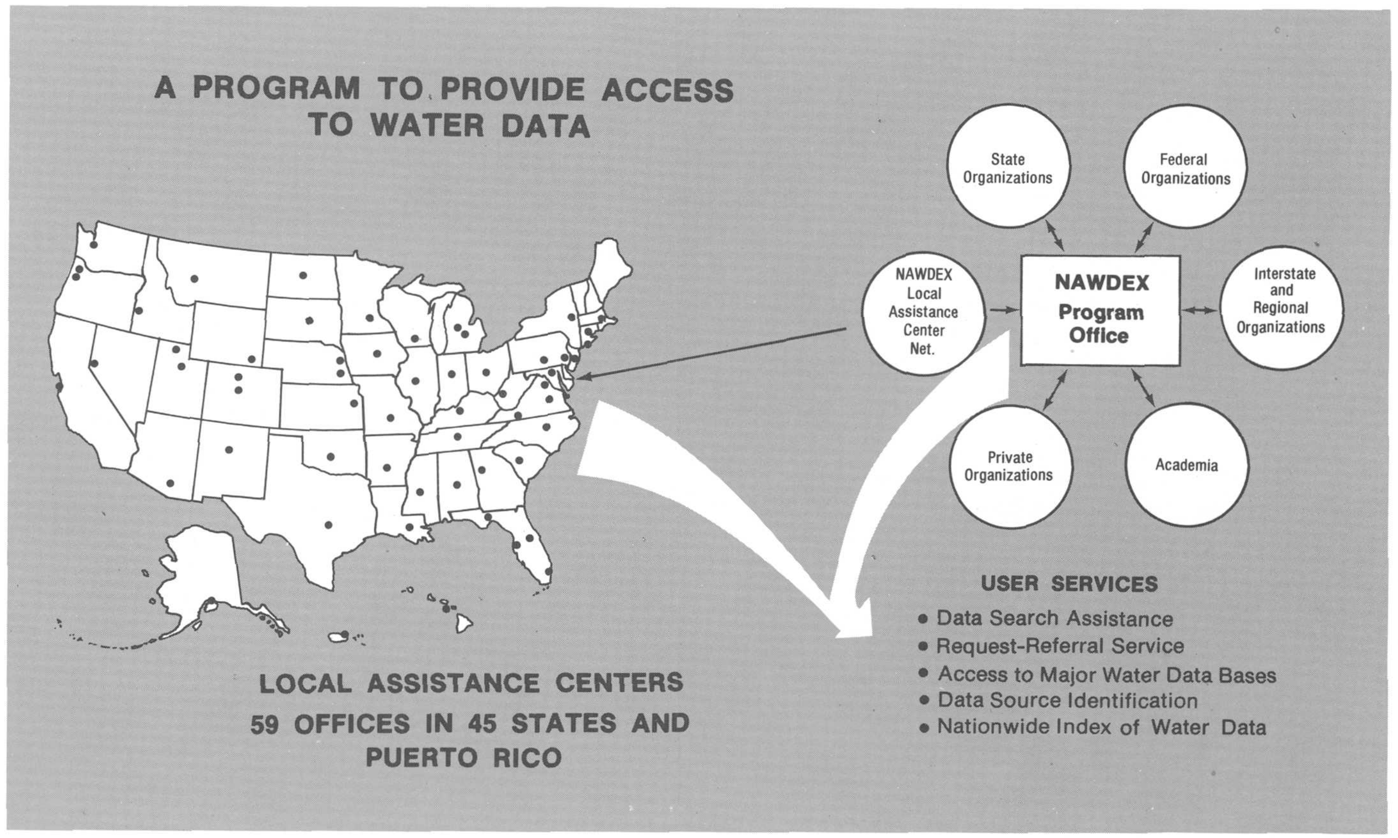



Figure 9.2-1 Access to water data.

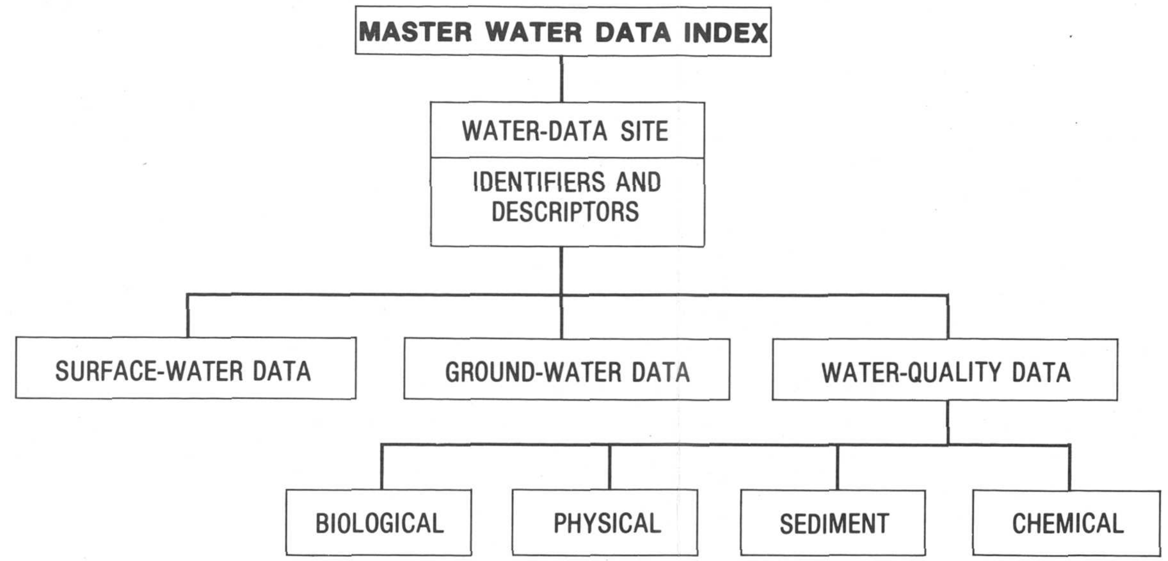



Figure 9.2-2 Master water-data index.

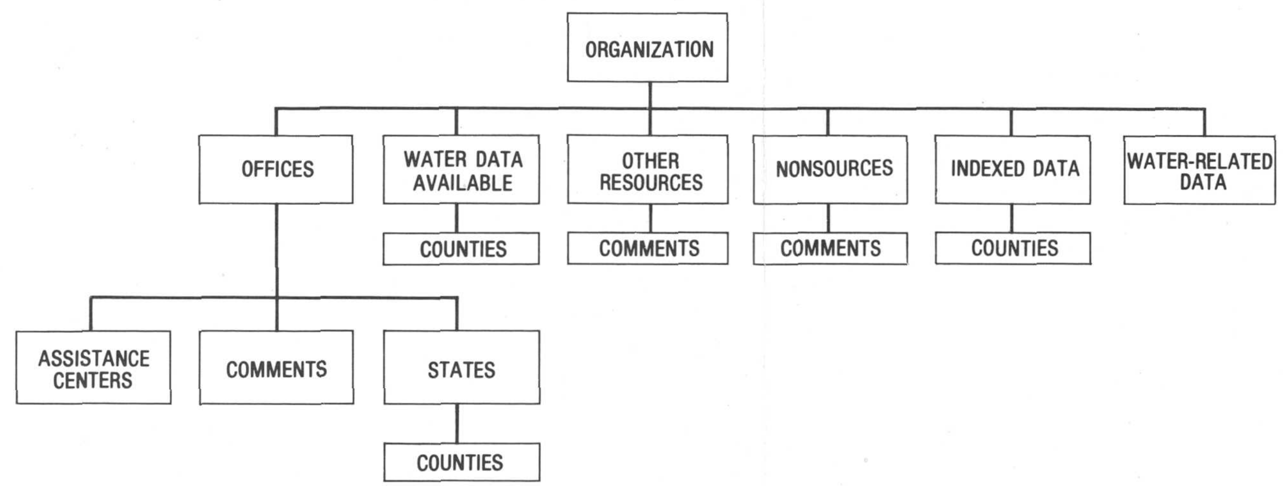



Figure 9.2-3 Water-data sources directory.

# WATSTORE Automated Data System

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

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

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

KANSAS
U.S. Geological Survey
Water Resources Division
1950 Constant Avenue - Campus West
University of Kansas
Lawrence, KS 66045

Missouri
U.S. Geological Survey
Water Resources Division
1400 Independence Road
Mail Stop 200
Rolla, MO 65401

The Geological Survey currently (1983) 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 (1983).

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

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

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

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

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

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

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

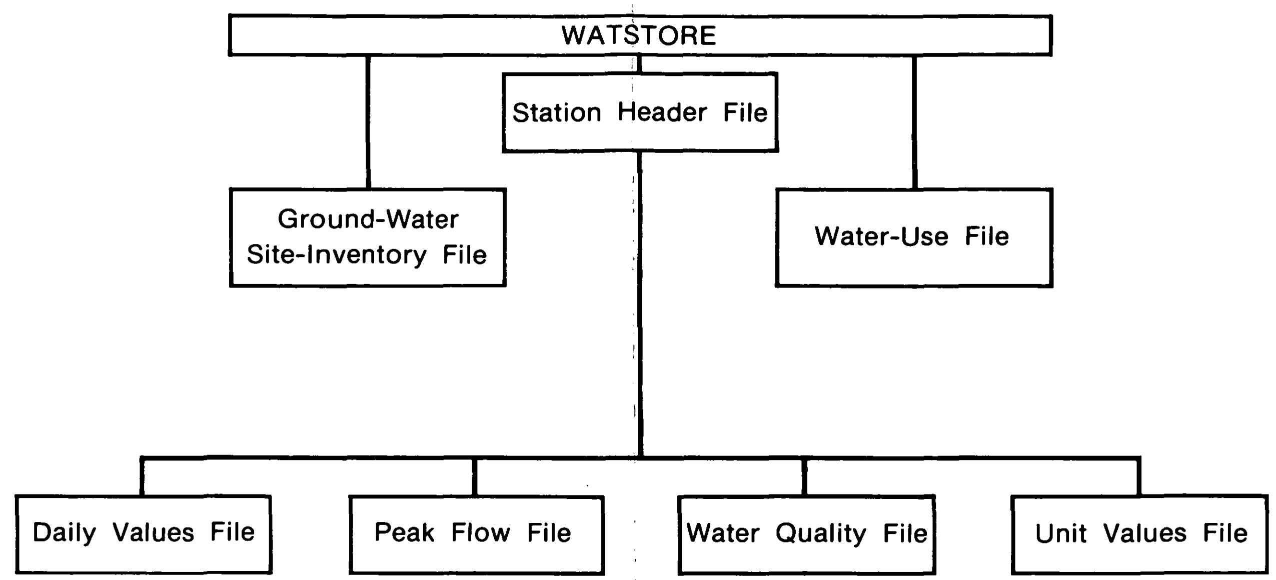



**Figure 9.3-1 Index file stored data.**

# Water Data Indexed for Coal Provinces

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

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

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

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

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

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

Office of Surface Mining
U.S. Department of the Interior
818 Grande Avenue, Scarritt Building
Kansas City, MO 64106

Telephone: (816) 374-3920
FTS 758-5162

KANSAS
U.S. Geological Survey
Water Resources Division
1950 Constant Avenue - Campus West
University of Kansas
Lawrence, KS 66045
Telephone: (913) 864-4321
FTS 752-2300, 2301, 2302
Hours: 8:00 - 4:30 CST

MISSOURI
U.S. Geological Survey
Water Resources Division
1400 Independence Road
Mail Stop 200
Rolla, MO 65401
Telephone: (314) 341-0824
FTS 277-0824
Hours: 7:30 - 4:00 CST

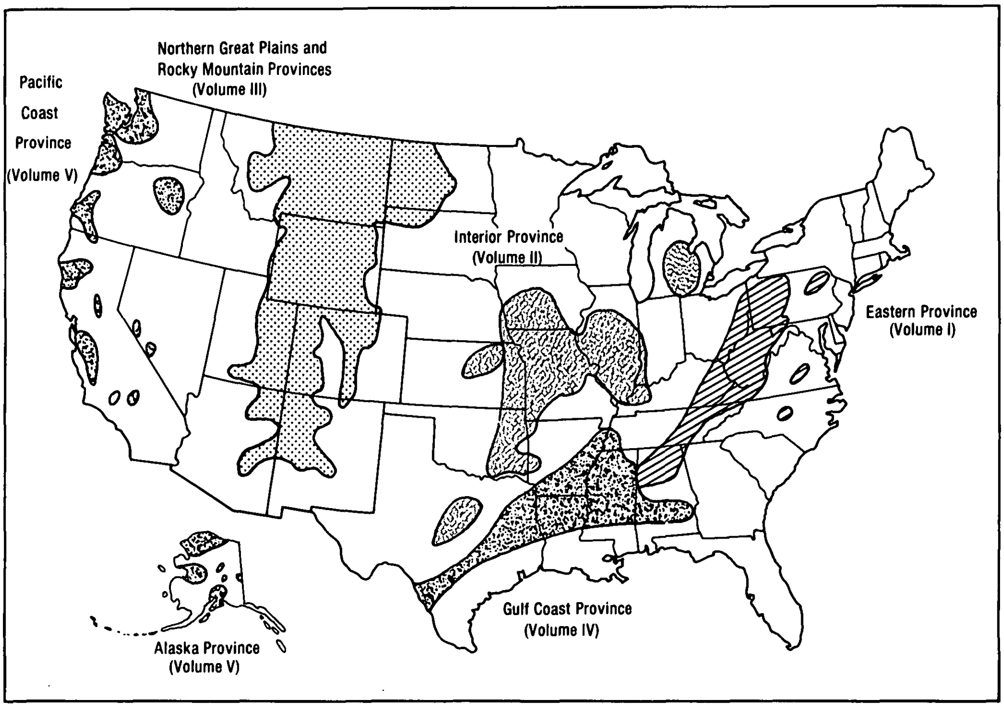



**Figure 9.4-1 Index volumes and related provinces.**

## 10.0 SUPPLEMENTAL INFORMATION FOR AREA 39

*10.1 Surface-Water Stations*

[D = continuous-record streamflow-gaging station; L = low-flow station; C = crest-stage station; QW = quality-of-water station; QW-S = quality-of-water station where sediment data are available; R = reservoir station]

| Map number (fig. 4.0-1) | U.S.G.S. station number | Station name and County where located | Station location Latitude ° ' " | Station location Longitude ° ' " | Drainage area, in square miles | Type of record | Water year of record |
|---|---|---|---|---|---|---|---|
| 1 | 06893000 | Missouri River at Kansas City, Mo., Jackson County[1] | 39 06 43 | 094 35 16 | 485,200 | D | 1898- |
| 2 | 06893080 | Blue River near Stanley, Kans., Johnson County | 38 48 45 | 094 40 31 | 46.0 | C<br>D<br>QW | 1970-74<br>1974-<br>1974- |
| 3 | 06893200 | Blue River at Kansas City, Mo., Jackson County | 38 52 37 | 094 35 12 | --- | L | 1962-65, 1967 |
| 4 | 06893250 | Indian Creek near Overland Park, Kans., Johnson County | 38 54 55 | 094 43 24 | 14.8 | C | 1970-76 |
| 5 | 06893300 | Indian Creek at Overland Park, Kans., Johnson County | 38 56 30 | 094 40 10 | 26.6 | D<br>QW | 1963-<br>1975- |
| 6 | 06893350 | Tomahawk Creek near Overland Park, Kans., Johnson County | 38 54 47 | 094 37 54 | 23.9 | C<br>D<br>QW | 1970-74<br>1975-<br>1975- |
| 7 | 06893500 | Blue River near Kansas City, Mo., Jackson County[2] | 38 57 26 | 094 33 31 | 188 | | 1940- |
| 8 | 06893520 | Blue River near Gregory Blvd., at Kansas City, Mo., Jackson County[2] | 38 59 58 | 094 31 39 | 203 | D, QW-S | 1981-82 |
| 9 | 06893564 | Brush Creek at Elmwood Avenue at Kansas City, Mo., Jackson County | 39 02 13 | 094 31 52 | 29.1 | D, QW-S | 1981-82 |
| 10 | 06893566 | Blue River at Coalmine Road at Kansas City, Mo., Jackson County[2] | 39 02 40 | 094 30 45 | 243 | D, QW-S | 1981-82 |
| 11 | 06893570 | Round Grove Creek at Raytown Road at Kansas City, Mo., Jackson County | 39 02 29 | 094 28 59 | 5.87 | D | 1976- |
| 12 | 06893590 | Blue River at Twelfth Street in Kansas City, Mo., Jackson County[2] | 39 05 48 | 094 43 32 | 264 | D | 1981- |
| 13 | 06893592 | Blue River near St. John Avenue at Kansas City, Mo., Jackson County[2] | 39 06 52 | 094 29 56 | 269 | D, QW-S | 1981-82 |
| 14 | 06893600 | Rock Creek at Independence, Mo., Jackson County | 39 04 37 | 094 27 03 | 5.20 | D | 1968-74 |
| 15 | 06893790 | Little Blue River at Longview Road in Kansas City, Mo., Jackson County | 38 54 49 | 094 27 57 | 47.4 | D | 1966-74 |
| 16 | 06893793 | Little Blue River below Longview Damsite in Kansas City, Mo., Jackson County | 38 55 52 | 094 28 12 | 50.7 | D | 1966- |
| 17 | 06893800 | Little Blue River at Kansas City, Mo., Jackson County | 38 57 51 | 094 25 35 | --- | L | 1962, 1964, 1967 |
| 18 | 06893890 | East Fork Little Blue River near Blue Springs, Mo., Jackson County[3] | 39 01 32 | 094 20 37 | 34.4 | D | 1975- |
| 19 | 06893900 | Little Blue River near Blue Springs, Mo., Jackson County | 39 01 52 | 094 21 22 | --- | L | 1962-65, 1967, 1970, 1972-73 |
| 20 | 06894000 | Little Blue River near Lake City, Mo., Jackson County | 39 06 02 | 094 18 01 | 184 | D | 1948- |
| 21 | 06894100 | Missouri River at Sibley, Mo., Jackson County[1] | 39 10 46 | 094 11 03 | --- | QW | 1972-75 |
| 22 | 06894680 | Sni-a-bar Creek near Tarsney, Mo., Jackson County | 38 56 28 | 094 10 05 | 29.1 | D | 1970-79 |
| 23 | 06894700 | Sni-a-bar Creek at Grain Valley, Mo., Jackson County | 39 00 48 | 094 11 11 | --- | L | 1962, 1964-65, 1967, 1970-71 |
| 24 | 06894800 | Sni-a-bar Creek near Wellington, Mo., Lafayette County | 39 06 38 | 093 39 00 | --- | L | 1962, 1964-65, 1967 1970, 1972 |
| 25 | 06895500 | Missouri River at Waverly, Mo. Lafayette County[1] | 39 12 50 | 093 30 50 | 487,200 | D | 1928- |
| 26 | 06907500 | South Fork Blackwater River near Elm, Mo., Johnson County | 38 49 08 | 094 02 08 | 16.6 | D | 1954-79 |
| 27 | 06907550 | Blackwater River near Warrensburg, Mo., Johnson County | 38 48 27 | 093 44 34 | --- | L | 1942-43, 1946, 1952-53, 1962-64 |
| 28 | 06907600 | Post Oak Creek at Warrensburg, Mo., Johnson County | 38 46 33 | 093 45 47 | --- | L | 1942-43, 1946, 1953, 1962-64 |
| 29 | 06907650 | Clear Creek near Valley City, Mo., Johnson County | 38 50 40 | 093 37 19 | --- | L | 1972 |
| 30 | 06907700 | Blackwater River at Valley City, Mo., Johnson County | 38 52 12 | 093 37 19 | 547 | D | 1959-73 |
| 31 | 06907800 | Davis Creek at Sweet Springs, Mo. Saline County | 38 58 02 | 093 25 20 | --- | L | 1942-43, 1945-46, 1953, 1962, 1964 |

| Map number (fig. 4.0-1) | U.S.G.S. station number | Station name and County where located | Station location Latitude ° ' " | Longitude ° ' " | Drainage area, in square miles | Type of record | Water year of record |
|---|---|---|---|---|---|---|---|
| 32 | 06907900 | Blackwater River at Sweet Springs, Mo., Saline County | 38 57 27 | 093 25 10 | --- | L | 1942-43, 1946, 1952-53, 1962-65, 1967 |
| 33 | 06908000 | Blackwater River at Blue Lick, Mo., Saline County | 38 59 25 | 093 12 14 | 1,120 | D | 1922-33, 1938- |
| 34 | 06908300 | Trent Branch near Waverly, Mo. Lafayette County | 39 12 06 | 093 34 46 | 0.97 | C | 1955-79 |
| 35 | 06908420 | Salt Fork Blackwater River near Marshall, Mo., Saline County | 39 10 25 | 093 13 08 | --- | L | 1967, 1969-71 |
| 36 | 06908500 | Shiloh Branch near Marshall, Mo., Saline County | 39 07 00 | 093 05 50 | 2.87 | D<br>C | 1952-65<br>1966- |
| 37 | 06910800 | Marais des Cygnes River near Reading, Kans., Lyon County | 38 34 00 | 095 57 50 | 177 | D<br>QW-S | 1969-<br>1969- |
| 38 | 06910900 | Marais des Cygnes River at Reading, Kans., Osage County | 38 31 00 | 095 56 00 | 215 | L | 1954-68 |
| 39 | 06910997 | Melvern Lake near Melvern, Kans., | 38 30 34 | 095 42 36 | 349 | R | 1972- |
| 40 | 06911000 | Marais des Cygnes River at Melvern, Kans. Osage County[4] | 38 30 54 | 095 41 29 | 351 | D<br>QW | 1939-74<br>1963-74 |
| 41 | 06911500 | Salt Creek near Lyndon, Kans., Osage County | 38 36 32 | 095 38 17 | 111 | D<br>QW | 1939-<br>1973- |
| 42 | 06911900 | Dragoon Creek near Burlingame, Kans., Osage County | 38 42 30 | 095 50 20 | 114 | D<br>QW-S | 1960-<br>1973- |
| 43 | 06912000 | Switzler Creek at Burlingame, Kans., Osage County[5] | 38 45 13 | 095 49 43 | 26.3 | D | 1954-61 |
| 44 | 06912300 | Dragoon Creek Tributary near Lyndon, Kans., Osage County | 38 41 33 | 095 41 06 | 3.76 | C | 1957- |
| 45 | 06912490 | Pomona Lake near Quenemo, Kans., Osage County | 38 38 51 | 095 33 50 | 322 | R | 1964- |
| 46 | 06912500 | Hundred and Ten Mile Creek near Quenemo, Kans., Osage County[6] | 38 38 41 | 095 33 34 | 322 | D<br>QW-S | 1939-<br>1973- |
| 47 | 06913000 | Marais des Cygnes River near Pomona, Kans., Franklin County[7] | 38 35 03 | 095 27 12 | 1040 | D<br>QW | 1922-38, 1969-<br>1974- |
| 48 | 06913500 | Marais des Cygnes River near Ottawa, Kans., Franklin County[7] | 38 37 00 | 095 15 25 | 1250 | D<br>QW-S | 1902-05, 1919-<br>1961- |
| 49 | 06913600 | Rock Creek near Ottawa, Kans., Franklin County | 38 33 15 | 095 16 02 | 10.2 | C | 1957-77 |
| 50 | 06913700 | Middle Creek near Princeton, Kans., Franklin County | 38 28 39 | 095 15 08 | 52.0 | C | 1957- |
| 51 | 06914000 | Pottawatomie Creek near Garnett, Kans., Anderson County | 38 20 01 | 095 14 55 | 334 | D<br>QW-S | 1939-<br>1964-70, 1976- |
| 52 | 06914250 | South Fork Pottawatomie Creek Tributary near Garnett, Kans., Anderson County | 38 14 00 | 095 14 52 | 0.35 | C | 1963- |
| 53 | 06914500 | Pottawatomie Creek at Lane, Kans. Franklin County | 38 26 38 | 095 05 02 | 513 | D<br>C | 1929-32<br>1961- |
| 54 | 06914995 | Hillsdale Lake near Hillsdale, Kans., Miami County | 38 39 36 | 094 53 50 | 144 | R | 1982- |
| 55 | 06915000 | Big Bull Creek near Hillsdale, Kans., Miami County[8] | 38 38 12 | 094 53 29 | 147 | D<br>QW-S | 1958-<br>1973- |
| 56 | 06915100 | Big Bull Creek at Paola, Kans., Miami County[8] | 38 34 36 | 094 53 44 | 230 | C | 1970- |
| 57 | 382651094474500 | Marais des Cygnes River near Fontana, Kans., Miami County[9] | 38 26 51 | 094 47 45 | 2,600 | QW-S | 1980-82 |
| 58 | 382423094512100 | Middle Creek near Fontana, Kans., Linn County | 38 42 23 | 094 51 21 | 63.3 | QW | 1980-82 |
| 59 | 382046094430800 | Middle Creek four miles west of La Cygne Lake, Kans., Linn County | 38 20 46 | 094 43 08 | 58.5 | QW | 1980-82 |
| 60 | 06915977 | North Sugar Creek below La Cygne Lake, Kans., Linn County | 38 20 04 | 094 38 21 | 57.8 | D<br>QW-S | 1979-81<br>1979-81 |
| 61 | 381854094372300 | Sediment Pond Number 3, Linn County | 38 18 54 | 094 37 23 | --- | QW-S | 1981 |
| 62 | 381854094373100 | Sediment Pond Number 4, Linn County | 38 18 54 | 094 37 31 | --- | QW-S | 1981 |
| 63 | 381901094372400 | Sediment Pond Number 5, Linn County | 38 19 01 | 094 37 24 | --- | QW-S | 1981 |
| 64 | 381919094380900 | North Sugar Creek tributary 1, below La Cygne Lake, Kans., Linn County | 38 19 19 | 094 38 09 | 2.06 | D<br>QW-S | 1980-82<br>1980-82 |
| 65 | 381916094391200 | North Sugar Creek two miles below La Cygne Lake, Kans., Linn County | 38 19 16 | 094 39 12 | 59.3 | QW-S | 1980-82 |

| Map number (fig. 4.0-1) | U.S.G.S. station number | Station name and County where located | Station location Latitude ° ' " | Longitude ° ' " | Drainage area, in square miles | Type of record | Water year of record |
|---|---|---|---|---|---|---|---|
| 66 | 381802094373100 | Sediment Pond Number 2, Linn County | 38 18 02 | 094 37 31 | --- | QW-S | 1981 |
| 67 | 381802094373900 | Sediment Pond Number 1, Linn County | 38 18 02 | 094 37 39 | --- | QW-S | 1981 |
| 68 | 381807094382400 | North Sugar Creek tributary 2, below La Cygne Lake, Kans., Linn County | 38 18 07 | 094 38 24 | 1.91 | D<br>QW-S | 1980-82<br>1980-82 |
| 69 | 381856094403800 | North Sugar Creek tributary 3, below La Cygne Lake, Kans. Linn County | 38 18 56 | 094 40 38 | 1.96 | D<br>QW-S | 1980-82<br>1980-82 |
| 70 | 06915988 | North Sugar Creek near Trading Post, Kans., Linn County | 38 17 27 | 094 42 08 | 73.0 | QW-S | 1979-81 |
| 71 | 06916000 | Marais des Cygnes River at Trading Post, Kans., Linn County | 38 15 | 094 41 | 2880 | D | 1929-58 |
| 72 | 06916500 | Big Sugar Creek at Farlinville, Kans., Linn County | 38 14 07 | 094 51 13 | 198 | D | 1929-32<br>1949-58,<br>1959-70 |
| 73 | 381459094475900 | Big Sugar Creek four miles east of Farlinville, Kans., Linn County | 38 14 59 | 094 47 59 | 306 | QW | 1980-82 |
| 74 | 381354094463700 | Little Sugar Creek five miles east of Farlinville, Kans. Linn County | 38 13 54 | 094 46 37 | 73.6 | QW | 1980-82 |
| 75 | 381155094424500 | Muddy Creek near Pleasanton, Kans., Linn County | 38 11 55 | 094 42 45 | 6.49 | QW | 1980 |
| 76 | 381334094415600 | Muddy Creek tributary two miles southwest of Trading Post, Kans., Linn County | 38 13 34 | 094 41 56 | 4.72 | QW | 1980 |
| 77 | 06916600 | Marais des Cygnes River near Kansas-Missouri State Line, Kans., Linn County[9] | 38 13 21 | 094 40 04 | 3230 | D<br>QW-S | 1958-<br>1969- |
| 78 | 381525094392100 | Marais des Cygnes River Tributary two miles northeast of Trading Post, Kans., Linn County | 38 15 25 | 094 39 21 | 2.11 | QW | 1980-82 |
| 79 | 381432094372600 | Marais des Cygnes River Tributary four miles east of Trading Post, Kans., Linn County | 38 14 32 | 094 37 26 | 6.04 | QW | 1980-82 |
| 80 | 06916650 | Marais des Cygnes River near Worland, Mo., Bates County[9] | 38 13 07 | 094 36 45 | 3240 | QW | 1962-63,<br>1973-75,<br>1977-81 |
| 81 | 381109094383900 | Mine Creek near Pleasanton, Kans., Linn County | 38 11 09 | 094 38 39 | 28.7 | QW | 1980-82 |
| 82 | 06916652 | Unnamed Creek at Worland, Mo., Bates County | 38 11 24 | 094 35 08 | 1.42 | QW-S | 1979-81 |
| 83 | 06916653 | Mulberry Creek at Mulberry, Mo., Bates County | 38 17 27 | 094 34 10 | 16.2 | D<br>QW-S | 1980-83<br>1981 |
| 84 | 06916654 | Unnamed tributary to Mulberry Creek near Amoret, Mo., Bates County | 38 16 17 | 094 33 02 | 5.42 | D<br>QW-S | 1980-83<br>1981 |
| 85 | 06916655 | Mulberry Creek near Amoret, Mo., Bates County | 38 15 15 | 094 33 16 | 34.4 | D<br>QW-S | 1980-1983<br>1979-1981 |
| 86 | 06916660 | Walnut Creek near Foster, Mo., Bates County | 38 10 27 | 094 32 18 | 30.6 | QW-S | 1979-81 |
| 87 | 06916664 | Osage River near Rich Hill, Mo., Bates County[9] | 38 08 02 | 094 20 57 | --- | L | 1962-65,<br>1967, 1970 |
| 88 | 06916670 | Miami Creek near Butler, Mo., Bates County | 38 15 22 | 094 19 36 | --- | L | 1943, 1945,<br>1947, 1949,<br>1952, 1954,<br>1962-64,<br>1975, 1980 |
| 89 | 06916700 | Middle Creek near Kincaid, Kans. Anderson County | 38 03 24 | 095 11 15 | 2.02 | C | 1957- |
| 90 | 06916800 | Little Osage River near Xenia, Kans., Bourbon County | 37 58 24 | 094 55 26 | 183 | L | 1954-59 |
| 91 | 380006094524600 | Little Osage River near Mapleton, Kans., Bourbon County | 38 00 06 | 094 52 46 | 204 | QW-S | 1980-82 |
| 92 | 380217094511500 | Lost Creek near Mapleton, Kans., Bourbon County | 38 02 17 | 094 51 15 | 14.3 | QW | 1980-82 |
| 93 | 380143094465200 | Elk Creek near Fulton, Kans., Bourbon County | 38 01 43 | 094 46 52 | 20.3 | QW | 1980-82 |
| 94 | 380150094435000 | West Laberdie Creek near Fulton, Kans., Bourbon County | 38 01 50 | 094 43 50 | 6.96 | QW | 1980-82 |
| 95 | 380150094417000 | East Laberdie Creek near Fulton, Kans., Bourbon County | 38 01 50 | 094 43 17 | 10.1 | QW | 1980-82 |
| 96 | 06917000 | Little Osage River at Fulton, Kans., Bourbon County | 38 01 09 | 094 42 48 | 295 | D<br>QW-S | 1949-<br>1973- |
| 97 | 380401094383900 | Indian Creek tributary three miles east of Prescott, Kans., Linn County | 38 04 01 | 094 38 39 | 2.00 | QW | 1977 |
| 98 | 380309094383100 | East Fork Indian Creek four miles southwest of Prescott, Kans. Linn County | 38 03 09 | 094 38 31 | 8.50 | QW | 1979 |

| Map number (fig. 4.0-1) | U.S.G.S. station number | Station name and County where located | Station location Latitude ° ' " | Longitude ° ' " | Drainage area, in square miles | Type of record | Water year of record |
|---|---|---|---|---|---|---|---|
| 99 | 380223094393600 | Indian Creek four miles southeast of Prescott, Kans., Linn County | 38 02 23 | 094 39 36 | 10.0 | QW | 1977 |
| 100 | 180057094381400 | Indian Creek near Fulton, Kans., Bourbon County | 38 00 57 | 094 38 14 | 21.9 | QW | 1980-82 |
| 101 | 06917030 | Little Osage River at Stotesbury, Mo., Vernon County | 37 58 28 | 094 33 45 | 427 | D<br>L | 1929-32<br>1962-64, 1967-68, 1980 |
| 102 | 06917060 | Little Osage River at Horton, Mo., Vernon County | 37 59 38 | 094 22 05 | --- | L | 1962-65, 1967, 1980 |
| 103 | 06917100 | Marmaton River tributary near Bronson, Kans. Allen County | 37 54 20 | 095 05 43 | 0.88 | C | 1957- |
| 104 | 06917380 | Marmaton River near Marmaton, Kans., Bourbon County | 37 49 03 | 094 47 30 | 292 | D<br>QW | 1971-<br>1973- |
| 105 | 06917400 | Marmaton River tributary near Fort Scott, Kans., Bourbon County | 37 47 26 | 094 47 47 | 2.80 | C | 1957- |
| 106 | 06917500 | Marmaton River near Fort Scott, Kans., Bourbon County | 37 51 47 | 094 40 36 | 408 | D<br>QW-S | 1921-25, 1929-71<br>1962-70 |
| 107 | 06917640 | Drywood Creek near Oskaloosa, Mo., Barton County | 37 38 20 | 094 33 52 | 93.6 | QW-S | 1979-81 |
| 108 | 374139094385500 | West Fork Drywood Creek three miles north of Arcadia, Kans., Bourbon County | 37 41 39 | 094 38 55 | 72.0 | QW | 1976-80 |
| 109 | 373512094383700 | Cox Creek tributary near Mulberry, Kans., Crawford County | 37 35 12 | 094 38 37 | 8.00 | QW | 1976-80 |
| 110 | 373747094380200 | Cox Creek one mile south of Arcadia, Crawford County | 37 37 47 | 094 38 02 | --- | QW-S | 1976-80 |
| 111 | 373754094391000 | Strip pit 2, Crawford County, Kans. | 37 37 54 | 094 39 10 | --- | QW | 1981 |
| 112 | 373833094385400 | Strip pit 1, Crawford County, Kans. | 37 38 33 | 094 38 54 | --- | QW | 1981 |
| 113 | 374109094370400 | Cox Creek two miles north of Arcadia, Kans., Bourbon County | 37 41 09 | 094 37 04 | --- | QW-S | 1976-80 |
| 114 | 06917680 | Drywood Creek near Deerfield, Mo., Vernon County | 37 47 52 | 094 30 53 | 353 | QW-S | 1979-81 |
| 115 | 06918060 | Marmaton River at Nevada, Mo., Vernon County | 37 54 32 | 094 22 25 | --- | L | 1962-65, 1967-68, 1970, 1981 |
| 116 | 06918080 | Osage River near Schell City, Mo., Vernon County[9] | 38 03 20 | 094 08 44 | 5,530 | QW-S<br>L | 1979-<br>1932-33, 1962-65, 1967, 1970 |
| 117 | 06918200 | North Fork Panther Creek Tributary near Appleton City, Mo., Bates County | 38 11 38 | 094 04 53 | 0.08 | C | 1955-79 |
| 118 | 06918210 | Panther Creek near Rockville, Mo., Bates County | 38 05 00 | 094 05 35 | 35.6 | QW-S | 1979-81 |
| 119 | 06918310 | Robinson Branch near Walker, Mo., Vernon County | 37 54 04 | 094 11 37 | 6.50 | QW-S | 1979-81 |
| 120 | 06918320 | Clear Creek near Eldorado Springs, Mo., Vernon County | 37 41 15 | 094 07 15 | --- | L | 1943, 1945-47, 1949, 1952, 1962- 63 |
| 121 | 06918340 | Monegaw Creek near Monegaw Springs, Mo., St. Clair County | 38 01 32 | 093 32 31 | --- | L | 1971, 1980 |
| 122 | 06920500 | Osage River at Osceola, Mo., St. Clair County | 38 03 43 | 093 41 38 | 8,220 | D | 1918-28, 1931-78 |
| 123 | 06920800 | Big Muddy Creek at Lowry City, Mo., St. Clair County | 38 09 29 | 093 43 22 | 0.31 | C<br>D | 1955-72, 1978-79<br>1973-77 |
| 124 | 06921580 | South Grand River near Freeman, Mo., Cass County | 38 36 59 | 094 28 46 | --- | L | 1962, 1964-65, 1967 |
| 125 | 06921590 | South Grand River at Archie, Mo., Cass County | 38 28 44 | 094 20 03 | 356 | D | 1970- |
| 126 | 06921600 | South Grand River at Urich, Mo., Henry County | 38 27 08 | 094 00 13 | 670 | D<br>QW-S | 1961-69<br>1979 |
| 127 | 06921680 | Big Creek at Pleasant Hill, Mo., Cass County | 38 46 14 | 094 16 15 | --- | L | 1962, 1964, 1976 |
| 128 | 06921720 | Big Creek near Blairstown, Mo., Henry County | 38 33 17 | 093 57 54 | 414 | D | 1960-74 |
| 129 | 06921740 | Brushy Creek near Blairstown, Mo., Henry County | 38 31 42 | 094 00 37 | 1.15 | D | 1961-75 |
| 130 | 06921770 | South Grand River near Clinton, Mo., Henry County | 38 21 23 | 093 50 57 | 1,272 | QW-S | 1979 |

| Map number (fig. 4.0-1) | U.S.G.S. station number | Station name and County where located | Station location Latitude ° ' " | Longitude ° ' " | Drainage area, in square miles | Type of record | Water year of record |
|---|---|---|---|---|---|---|---|
| 131 | 06921780 | Deepwater Creek near Montrose, Mo., Henry County | 38 18 00 | 094 01 13 | --- | L | 1955, 1959, 1962, 1964 |
| 132 | 06921800 | Granddaddy Creek near Urich, Mo., Henry County | 38 21 48 | 094 00 47 | 0.92 | C<br>D | 1957-75<br>1976-79 |
| 133 | 06921810 | Bear Creek near Montrose, Mo., Henry County | 38 15 19 | 093 57 16 | 10.8 | QW-S | 1981 |
| 134 | 06921850 | Deepwater Creek near Deepwater, Mo., Henry County | 38 17 19 | 093 46 39 | 237 | QW-S | 1979 |
| 135 | 06922000 | South Grand River near Brownington, Mo., Henry County | 38 15 49 | 093 42 52 | 1,660 | D | 1921-71 |
| 136 | 06922080 | Tebo Creek near Calhoun, Mo., Henry County | 38 26 58 | 093 36 44 | 68.6 | QW-S | 1979-81 |
| 137 | 06922100 | Sand Creek near Calhoun, Mo., Henry County | 38 29 16 | 093 41 47 | 8.60 | QW-S | 1979-81 |
| 138 | 06922140 | Sand Creek at Calhoun, Mo., Henry County | 38 27 49 | 093 38 20 | 41.8 | QW-S | 1979-81 |
| 139 | 06922200 | Tebo Creek at Leesville, Mo., Henry County | 38 22 04 | 093 32 41 | --- | L<br>QW | 1962-65<br>1979- |

Footnotes

[1] Some regulation from many upstream reservoirs since about 1953.
[2] Low flows augmented significantly by commercial plants upstream from streamflow-gaging station.
[3] Flow impounded or detained in Jackson County Lake at times.
[4] Flow regulated by Melvern Lake since 1973.
[5] Flow affected by detention reservoirs and watershed treatment practices.
[6] Flow regulated by Pomona Lake since 1964.
[7] Flow regulated by Melvern and Pomona Lakes.
[8] Flow regulated by Hillsdale Lake since 1982.
[9] Flow slightly affected by Melvern and Pomona Lakes (since 1973 and 1964, respectively), power development, and other small diversions upstream from station.

## 10.2 Statistical Summaries of Water-Quality Data for Surface-Water Stations

[Letter (C) designates station on stream draining coal-mined area; letter (U) designates station on stream draining unmined area. Specific conductance in micromhos per centimeter at 25# C (umhos) , chemical constituents in milligrams per liter (mg/L) or micrograms per liter (ug/L) . Values for total iron and total manganese based on determinations of total-recoverable concentrations.]

| Station number | Station name | Property or constituent | Number of samples | Mean | Median | Maximum | Minimum |
|---|---|---|---|---|---|---|---|
| 2 (U) | Blue River near Stanley, Ks. | pH, units | 30 | -- | 7.7 | 8.2 | 7.3 |
| | | Specific conductance (umhos) | 30 | 469 | 508 | 688 | 220 |
| 5 (U) | Indan Creek at Overland Park, Ks. | pH (units) | 29 | -- | 7.8 | 8.8 | 7.1 |
| | | Specific conductance (umhos) | 30 | 717 | 758 | 1,380 | 240 |
| 6 (U) | Tomahawk Creek near Overland Park, Ks. | pH (units) | 31 | -- | 7.8 | 8.3 | 7.2 |
| | | Specific conductance (umhos) | 31 | 572 | 565 | 1,090 | 210 |
| 21 (U) | Missouri River at Sibley, Mo. | pH (units) | 49 | -- | 8.0 | 8.4 | 7.5 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 49 | 171 | 167 | 218 | 123 |
| | | Specific conductance (umhos) | 49 | 693 | 700 | 850 | 412 |
| | | Dissolved solids (mg/L) | 49 | 442 | 467 | 534 | 254 |
| | | Sulfate (mg/L) | 49 | 150 | 160 | 220 | 70 |
| | | Iron, dissolved (ug/L) | 49 | 70 | 50 | 750 | <10 |
| | | Manganese, dissolved (ug/L) | 49 | 29 | 20 | 90 | <1 |
| 37 (U) | Marais des Cygnes River near Reading, Ks. | pH (units) | 25 | -- | 7.8 | 8.3 | 7.4 |
| | | Specific conductance (umhos) | 28 | 493 | 492 | 690 | 228 |
| | | Sediment, suspended (mg/L) | 1 | 2,110 | -- | -- | -- |
| 40 (C) | Marais des Cygnes River at Melvern, Ks. | pH (units) | 128 | -- | 7.6 | 8.2 | 6.9 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 129 | 195 | 200 | 360 | 54 |
| | | Specific conductance (umhos) | 129 | 476 | 480 | 760 | 120 |
| | | Dissolved solids (mg/L) | 129 | 302 | 300 | 482 | 96 |
| | | Sulfate (mg/L) | 129 | 52 | 50 | 113 | 8.6 |
| | | Iron, dissolved (ug/L) | 17 | 140 | 80 | 540 | <10 |
| | | Manganese; total (ug/L) | 3 | 20 | <1 | 60 | <1 |
| | | Manganese, dissolved (ug/L) | 14 | 62 | 5 | 360 | <1 |
| 41 (C) | Salt Creek near Lyndon, Ks. | pH (units) | 25 | -- | 7.9 | 9.2 | 7.2 |
| | | Specific conductance (umhos) | 28 | 458 | 472 | 655 | 175 |
| 42 (U) | Dragoon Creek near Burlingame, Ks. | pH (units) | 21 | -- | 7.9 | 9.2 | 7.4 |
| | | Specific conductance (umhos) | 32 | 456 | 438 | 770 | 200 |
| | | Sediment, suspended (mg/L) | 33 | 314 | 84 | 4,040 | 10 |
| 46 (C) | Hundred and Ten Mile Creek near Quenemo, Ks. | pH (units) | 34 | -- | 7.9 | 8.4 | 7.4 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 8 | 139 | 140 | 158 | 116 |
| | | Specific conductance (umhos) | 33 | 346 | 352 | 438 | 275 |
| | | Dissolved solids (mg/L) | 8 | 217 | 218 | 244 | 185 |
| | | Sulfate (mg/L) | 8 | 40 | 38 | 50 | 28 |
| | | Iron, dissolved (ug/L) | 6 | 150 | 40 | 740 | <10 |
| | | Manganese, total (ug/L) | 4 | 12 | 5 | 40 | <1 |
| | | Manganese, dissolved (ug/L) | 2 | <1 | <1 | <1 | <1 |
| | | Sediment, suspended (mg/L) | 40 | 3,920 | 2,980 | 13,180 | 240 |
| 47 (C) | Marais des Cygnes River near Pomona, Ks. | pH (units) | 25 | -- | 7.6 | 8.1 | 6.6 |
| | | Specific conductance (umhos) | 23 | 423 | 415 | 571 | 270 |
| 48 (C) | Marais des Cygnes River near Ottawa, Ks. | pH (units) | 218 | -- | 7.6 | 8.6 | 6.7 |
| | | Alkalinity, as CaCO3 (mg/L) | 352 | 165 | 163 | 308 | 24 |
| | | Specific conductance (umhos) | 393 | 448 | 440 | 850 | 80 |
| | | Dissolved solids (mg/L) | 341 | 288 | 288 | 542 | 98 |
| | | Sulfate (mg/L) | 366 | 45 | 43 | 103 | 2.6 |
| | | Iron, total (ug/L) | 14 | 1,900 | 60 | 19,000 | 10 |
| | | Iron, dissolved (ug/L) | 41 | 130 | 90 | 680 | 10 |
| | | Manganese, total (ug/L) | 16 | 58 | <1 | 320 | <1 |
| | | Manganese, dissolved (ug/L) | 39 | 24 | <1 | 180 | <1 |
| | | Sediment, suspended (mg/L) | 4 | 722 | 694 | 1,030 | 469 |
| 51 (U) | Pottawatomie Creek near Garnett, Ks. | pH (units) | 101 | -- | 7.6 | 8.5 | 6.9 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 85 | 175 | 182 | 328 | 36 |
| | | Specific conductance (umhos) | 130 | 370 | 390 | 670 | 75 |
| | | Dissolved solids (mg/L) | 85 | 245 | 252 | 410 | 59 |
| | | Sulfate (mg/L) | 84 | 24 | 21 | 72 | 2.5 |
| | | Iron, total (ug/L) | 1 | 5,100 | -- | -- | -- |
| | | Iron, dissolved (ug/L) | 10 | 60 | 60 | 100 | 20 |
| | | Manganese, total (ug/L) | 4 | 58 | 25 | 180 | <1 |
| | | Manganese, dissolved (ug/L) | 7 | 56 | 40 | 190 | <1 |
| | | Sediment, suspended (mg/L) | 55 | 296 | 113 | 2,600 | 8 |

| Station number | Station name | Property or constituent | Number of samples | Mean | Median | Maximum | Minimum |
|---|---|---|---|---|---|---|---|
| 55 (U) | Big Bull Creek near Hillsdale, Ks. | pH (units) | 24 | -- | 7.8 | 8.7 | 6.8 |
| | | Specific conductance (umhos) | 26 | 397 | 393 | 671 | 185 |
| | | Sediment, suspended (mg/L) | 17 | 2,530 | 1,730 | 6,730 | 540 |
| 57 (C) | Marais des Cygnes River near Fontana, Ks. | pH (units) | 10 | -- | 8.0 | 8.6 | 7.3 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 10 | 165 | 165 | 220 | 120 |
| | | Specific conductance (umhos) | 10 | 416 | 419 | 495 | 334 |
| | | Dissolved solids (mg/L) | 10 | 254 | 254 | 304 | 203 |
| | | Sulfate (mg/L) | 10 | 41 | 38 | 75 | 24 |
| | | Iron, total (ug/L) | 1 | 1,900 | -- | -- | -- |
| | | Iron, dissolved (ug/L) | 8 | 20 | 20 | 50 | 10 |
| | | Manganese, total (ug/L) | 1 | 100 | -- | -- | -- |
| | | Manganese, dissolved (ug/L) | 9 | 36 | 30 | 70 | 10 |
| | | Sediment, suspended (mg/L) | 5 | 59 | 74 | 93 | 13 |
| 58 (U) | Middle Creek near Fontana, Ks. | pH (units) | 2 | -- | 7.4 | 7.4 | 7.4 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 2 | 305 | 305 | 380 | 230 |
| | | Specific conductance (umhos) | 2 | 606 | 606 | 659 | 553 |
| | | Dissolved solids (mg/L) | 2 | 374 | 374 | 419 | 330 |
| | | Sulfate (mg/L) | 2 | 30 | 30 | 47 | 12 |
| | | Iron, total (ug/L) | 1 | 510 | -- | -- | -- |
| | | Iron, dissolved (ug/L) | 1 | 1,800 | -- | -- | -- |
| | | Manganese, total (ug/L) | 1 | 70 | -- | -- | -- |
| | | Manganese, dissolved (ug/L) | 1 | 5,500 | -- | -- | -- |
| 59 (U) | Middle Creek four miles west of LaCygne Lake, Ks. | pH (units) | 1 | -- | 7.3 | -- | -- |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 1 | 240 | -- | -- | -- |
| | | Specific conductance (umhos) | 1 | 563 | -- | -- | -- |
| | | Dissolved solids (mg/L) | 1 | 326 | -- | -- | -- |
| | | Sulfate (mg/L) | 1 | 50 | -- | -- | -- |
| | | Iron, total (ug/L) | 1 | 770 | -- | -- | -- |
| | | Manganese, total (ug/L) | 1 | 130 | -- | -- | -- |
| 60 (C) | North Sugar Creek below LaCygne Lake, Ks. | pH (units) | 18 | -- | 8.0 | 8.7 | 7.3 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 10 | 109 | 120 | 140 | 72 |
| | | Specific conductance (umhos) | 19 | 939 | 945 | 1,370 | 503 |
| | | Dissolved solids (mg/L) | 10 | 668 | 658 | 776 | 427 |
| | | Sulfate (mg/L) | 10 | 313 | 320 | 400 | 160 |
| | | Iron, total (ug/L) | 4 | 410 | 460 | 490 | 220 |
| | | Iron, dissolved (ug/L) | 8 | 10 | 10 | 20 | 10 |
| | | Manganese, total (ug/L) | 6 | 77 | 75 | 120 | 40 |
| | | Manganese, dissolved (ug/L) | 8 | 52 | 33 | 210 | 3 |
| | | Sediment, suspended (mg/L) | 4 | 18 | 17 | 30 | 8 |
| 64 (C) | North Sugar Creek tributary 1 below LaCygne Lake, Ks. | pH (units) | 25 | -- | 7.5 | 7.8 | 7.0 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 23 | 92 | 86 | 230 | 44 |
| | | Specific conductance (umhos) | 25 | 374 | 267 | 1,770 | 110 |
| | | Dissolved solids (mg/L) | 22 | 213 | 169 | 606 | 67 |
| | | Sulfate (mg/L) | 21 | 56 | 27 | 310 | 1.6 |
| | | Iron, total (ug/L) | 21 | 21,000 | 15,000 | 56,000 | 1,400 |
| | | Iron, dissolved (ug/L) | 19 | 110 | 90 | 280 | <10 |
| | | Manganese, total (ug/L) | 21 | 360 | 270 | 990 | 50 |
| | | Manganese, dissolved (ug/L) | 19 | 24 | 14 | 100 | <1 |
| | | Sediment, suspended (mg/L) | 19 | 1,030 | 726 | 3,740 | 204 |
| 65 (C) | North Sugar Creek 2 miles below LaCygne Lake, Ks. | pH (units) | 9 | -- | 7.6 | 8.1 | 7.1 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 9 | 113 | 92 | 220 | 57 |
| | | Specific conductance (umhos) | 9 | 703 | 660 | 1,100 | 175 |
| | | Dissolved solids (mg/L) | 8 | 479 | 383 | 834 | 123 |
| | | Sulfate (mg/L) | 8 | 209 | 140 | 400 | 38 |
| | | Iron, total (ug/L) | 4 | 15,000 | 10,000 | 38,000 | 1,300 |
| | | Iron, dissolved (ug/L) | 7 | 40 | 20 | 70 | 10 |
| | | Manganese, total (ug/L) | 5 | 460 | 290 | 1,100 | 100 |
| | | Manganese, dissolved (ug/L) | 7 | 350 | 40 | 1,700 | 10 |
| | | Sediment, suspended (mg/L) | 5 | 584 | 167 | 1,360 | 25 |
| 68 (C) | North Sugar Creek tributary 2 below LaCygne Lake, Ks. | pH (units) | 25 | -- | 7.5 | 8.1 | 6.8 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 23 | 82 | 72 | 190 | 30 |
| | | Specific conductance (umhos) | 25 | 399 | 202 | 1,850 | 79 |
| | | Dissolved solids (mg/L) | 23 | 243 | 135 | 1,330 | 56 |
| | | Sulfate (mg/L) | 21 | 81 | 6.5 | 670 | 1.3 |
| | | Iron, total (ug/L) | 22 | 9,400 | 6,800 | 28,000 | 640 |
| | | Iron, dissolved (ug/L) | 20 | 150 | 120 | 530 | <10 |
| | | Manganese, total (ug/L) | 22 | 280 | 160 | 1,900 | 20 |
| | | Manganese, dissolved (ug/L) | 20 | 17 | 10 | 70 | <1 |
| | | Sediment, suspended (mg/L) | 20 | 417 | 276 | 1,330 | 61 |

| Station number | Station name | Property or constituent | Number of samples | Mean | Median | Maximum | Minimum |
|---|---|---|---|---|---|---|---|
| 69 (U) | North Sugar Creek tributary 3 below LaCygne Lake, Ks. | pH (units) | 25 | -- | 7.1 | 7.6 | 6.5 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 23 | 60 | 52 | 108 | 30 |
| | | Specific conductance (umhos) | 25 | 182 | 150 | 415 | 73 |
| | | Dissolved solids (mg/L) | 23 | 135 | 128 | 254 | 55 |
| | | Sulfate (mg/L) | 20 | 16 | 7.6 | 63 | 1.1 |
| | | Iron, total (ug/L) | 22 | 16,000 | 16,000 | 48,000 | 1,000 |
| | | Iron, dissolved (ug/L) | 20 | 280 | 150 | 2,000 | 20 |
| | | Manganese, total (ug/L) | 22 | 320 | 320 | 720 | 40 |
| | | Manganese, dissolved (ug/L) | 20 | 25 | 15 | 90 | <1 |
| | | Sediment, suspended (mg/L) | 22 | 714 | 620 | 1,740 | 26 |
| 70 (C) | North Sugar Creek near Trading Post, Ks. | pH (units) | 22 | -- | 7.2 | 7.9 | 6.3 |
| | | Alkalinity, as CaCO3 (mg/L) | 13 | 100 | 110 | 150 | 29 |
| | | Specific conductance (umhos) | 23 | 656 | 600 | 1,100 | 100 |
| | | Dissolved solids (mg/L) | 12 | 507 | 560 | 764 | 75 |
| | | Sulfate (mg/L) | 12 | 219 | 235 | 400 | 2.1 |
| | | Iron, total (ug/L) | 4 | 8,600 | 2,600 | 28,000 | 1,300 |
| | | Iron, dissolved (ug/L) | 10 | 60 | 20 | 340 | 10 |
| | | Manganese, total (ug/L) | 5 | 370 | 280 | 680 | 140 |
| | | Manganese, dissolved (ug/L) | 10 | 420 | 310 | 1,200 | 10 |
| | | Sediment, suspended (mg/L) | 5 | 298 | 43 | 1,360 | 8 |
| 73 (U) | Big Sugar Creek 4 miles east of Farlinville, Ks. | pH (units) | 3 | -- | 7.5 | 7.7 | 7.4 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 3 | 250 | 260 | 260 | 230 |
| | | Specific conductance (umhos) | 3 | 553 | 550 | 569 | 540 |
| | | Dissolved solids (mg/L) | 3 | 328 | 328 | 336 | 321 |
| | | Sulfate (mg/L) | 3 | 27 | 26 | 46 | 7.9 |
| | | Iron, total (ug/L) | 1 | 870 | -- | -- | -- |
| | | Iron, dissolved (ug/L) | 2 | 30 | 30 | 40 | 20 |
| | | Manganese, total (ug/L) | 1 | 80 | -- | -- | -- |
| | | Manganese, dissolved (ug/L) | 2 | 2,000 | 2,000 | 3,200 | 880 |
| 74 (C) | Little Sugar Creek 5 miles east of Farlinville, Ks. | pH (units) | 1 | -- | 7.5 | -- | -- |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 1 | 240 | -- | -- | -- |
| | | Specific conductance (umhos) | 1 | 495 | -- | -- | -- |
| | | Dissolved solids (mg/L) | 1 | 349 | -- | -- | -- |
| | | Sulfate (mg/L) | 1 | 54 | -- | -- | -- |
| | | Iron, total (ug/L) | 1 | 750 | -- | -- | -- |
| | | Manganese, total (ug/L) | 1 | 100 | -- | -- | -- |
| 77 (C) | Marais des Cygnes River near Kansas-Missouri State line, Ks. | pH (units) | 69 | -- | 7.8 | 8.8 | 6.9 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 33 | 172 | 160 | 290 | 57 |
| | | Specific conductance (umhos) | 74 | 433 | 435 | 1,060 | 150 |
| | | Dissolved solids (mg/L) | 39 | 300 | 278 | 748 | 107 |
| | | Sulfate (mg/L) | 39 | 60 | 39 | 380 | 1.8 |
| | | Iron, total (ug/L) | 2 | 7,100 | 7,100 | 12,000 | 2,200 |
| | | Iron, dissolved (ug/L) | 12 | 40 | 20 | 140 | 10 |
| | | Manganese, total (ug/L) | 3 | 110 | 120 | 210 | 9 |
| | | Manganese, dissolved (ug/L) | 19 | 82 | 35 | 530 | <1 |
| | | Sediment, suspended (mg/L) | 540 | 544 | 344 | 5,150 | 5.0 |
| 78 (U) | Marais des Cygnes River tributary 2 miles northeast of Trading Post, Ks. | pH (units) | 1 | -- | 7.3 | -- | -- |
| | | Alkalinity, as CaCO3 (mg/L) | 1 | 100 | -- | -- | -- |
| | | Specific conductance (umhos) | 1 | 370 | -- | -- | -- |
| | | Dissolved solids (mg/L) | 1 | 252 | -- | -- | -- |
| | | Sulfate (mg/L) | 1 | 75 | -- | -- | -- |
| | | Iron, total (ug/L) | 1 | 1,700 | -- | -- | -- |
| | | Manganese, total (ug/L) | 1 | 90 | -- | -- | -- |
| 79 (C) | Marais des Cygnes River tributary 4 miles east of Trading Post, Ks. | pH (units) | 1 | -- | 7.1 | -- | -- |
| | | Alkalinity, as CaCO3 (mg/L) | 1 | 190 | -- | -- | -- |
| | | Specific conductance (umhos) | 1 | 514 | -- | -- | -- |
| | | Dissolved solids (mg/L) | 1 | 313 | -- | -- | -- |
| | | Sulfate (mg/L) | 1 | 78 | -- | -- | -- |
| | | Iron, total (ug/L) | 1 | 520 | -- | -- | -- |
| | | Manganese, total (ug/L) | 1 | 280 | -- | -- | -- |

| Station number | Station name | Property or constituent | Number of samples | Mean | Median | Maximum | Minimum |
|---|---|---|---|---|---|---|---|
| 80 (C) | Marais des Cygnes River near Worland, Mo. | pH (units) | 79 | -- | 7.9 | 8.5 | 7.0 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 68 | 152 | 151 | 276 | 49 |
| | | Specific conductance (umhos) | 79 | 444 | 428 | 1,400 | 135 |
| | | Dissolved solids (mg/L) | 36 | 256 | 246 | 691 | 138 |
| | | Sulfate (mg/L) | 39 | 46 | 41 | 350 | 15 |
| | | Iron, total (ug/L) | 25 | 3,800 | 3,000 | 15,000 | 10 |
| | | Iron, dissolved (ug/L) | 43 | 60 | 40 | 400 | <10 |
| | | Manganese, total (ug/L) | 24 | 170 | 150 | 360 | 20 |
| | | Manganese, dissolved (ug/L) | 46 | 28 | 20 | 150 | <1 |
| 81 (C) | Mine Creek near Pleasanton, Ks. | pH (units) | 1 | -- | 7.4 | -- | -- |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 1 | 190 | -- | -- | -- |
| | | Specific conductance (umhos) | 1 | 400 | -- | -- | -- |
| | | Dissolved solids (mg/L) | 1 | 287 | -- | -- | -- |
| | | Sulfate (mg/L) | 1 | 55 | -- | -- | -- |
| | | Iron, total (ug/L) | 1 | 800 | -- | -- | -- |
| | | Manganese, total (ug/L) | 1 | 150 | -- | -- | -- |
| 82 (C) | Unnamed Creek at Worland, Mo. | pH (units) | 2 | -- | 3.0 | 3.7 | 2.4 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 2 | 0 | 0 | 0 | 0 |
| | | Specific conductance (umhos) | 2 | 3,150 | 3,150 | 4,980 | 1,320 |
| | | Dissolved solids (mg/L) | 2 | 3,995 | 3,995 | 6,870 | 1,120 |
| | | Sulfate (mg/L) | 2 | 2,710 | 2,710 | 4,660 | 760 |
| | | Iron, total (ug/L) | 2 | 150,000 | 150,000 | 230,000 | 79,000 |
| | | Iron, dissolved (ug/L) | 2 | 140,000 | 140,000 | 200,000 | 71,000 |
| | | Manganese, total (ug/L) | 2 | 5,900 | 5,900 | 10,000 | 1,800 |
| | | Manganese, dissolved (ug/L) | 2 | 6,000 | 6,000 | 10,000 | 1,900 |
| | | Sediment, suspended (mg/L) | 2 | 110 | 110 | 148 | 72 |
| 83 (C) | Mulberry Creek at Mulberry, Mo. | pH (units) | 11 | -- | 8.1 | 8.2 | 7.3 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 11 | 129 | 131 | 189 | 59 |
| | | Specific conductance (umhos) | 11 | 902 | 825 | 1,440 | 238 |
| | | Dissolved solids (mg/L) | 11 | 621 | 569 | 1,080 | 155 |
| | | Sulfate (mg/L) | 11 | 314 | 270 | 580 | 58 |
| | | Iron, total (ug/L) | 11 | 5,000 | 4,900 | 16,000 | 320 |
| | | Iron, dissolved (ug/L) | 11 | 80 | 60 | 290 | 10 |
| | | Manganese, total (ug/L) | 11 | 180 | 180 | 290 | 110 |
| | | Manganese, dissolved (ug/L) | 11 | 74 | 60 | 150 | 30 |
| | | Sediment, suspended (mg/L) | 11 | 168 | 115 | 588 | 6 |
| 84 (U) | Unnamed tributary to Mulberry Creek near Amoret, Mo. | pH (units) | 8 | -- | 7.5 | 8.2 | 7.0 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 8 | 84 | 69 | 189 | 20 |
| | | Specific conductance (umhos) | 8 | 272 | 271 | 556 | 50 |
| | | Dissolved solids (mg/L) | 8 | 194 | 192 | 340 | 83 |
| | | Sulfate (mg/L) | 8 | 29 | 36 | 63 | 3.9 |
| | | Iron, total (ug/L) | 8 | 8,300 | 3,800 | 26,000 | 210 |
| | | Iron, dissolved (ug/L) | 8 | 190 | 160 | 400 | 10 |
| | | Manganese, total (ug/L) | 8 | 210 | 95 | 670 | 40 |
| | | Manganese, dissolved (ug/L) | 8 | 25 | 25 | 40 | 10 |
| | | Sediment, suspended (mg/L) | 7 | 267 | 57 | 1,270 | 6 |
| 85 (C) | Mulberry Creek near Amoret, Mo. | pH (units) | 10 | -- | 7.8 | 8.0 | 7.5 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 10 | 144 | 119 | 330 | 67 |
| | | Specific conductance (umhos) | 10 | 811 | 708 | 1,580 | 314 |
| | | Dissolved solids (mg/L) | 10 | 563 | 476 | 1,210 | 217 |
| | | Sulfate (mg/L) | 10 | 265 | 210 | 570 | 48 |
| | | Iron, total (ug/L) | 10 | 7,600 | 4,500 | 29,000 | 830 |
| | | Iron, dissolved (ug/L) | 10 | 90 | 80 | 170 | 20 |
| | | Manganese, total (ug/L) | 10 | 390 | 320 | 940 | 120 |
| | | Manganese, dissolved (ug/L) | 10 | 170 | 70 | 600 | 30 |
| | | Sediment, suspended (mg/L) | 9 | 369 | 144 | 1,630 | 7 |
| 86 (C) | Walnut Creek near Foster, Mo. | pH (units) | 3 | -- | 7.5 | 7.7 | 7.2 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 3 | 109 | 52 | 230 | 46 |
| | | Specific conductance (umhos) | 3 | 543 | 331 | 1,080 | 219 |
| | | Dissolved solids (mg/L) | 3 | 409 | 218 | 860 | 149 |
| | | Sulfate (mg/L) | 3 | 184 | 100 | 390 | 62 |
| | | Iron, total (ug/L) | 3 | 11,000 | 13,000 | 20,000 | 420 |
| | | Iron, dissolved (ug/L) | 3 | 190 | 210 | 250 | 100 |
| | | Manganese, total (ug/L) | 3 | 840 | 690 | 1,300 | 540 |
| | | Manganese, dissolved (ug/L) | 3 | 470 | 130 | 1,200 | 90 |
| | | Sediment, suspended (mg/L) | 3 | 426 | 519 | 730 | 30 |

| Station number | Station name | Property or constituent | Number of samples | Mean | Median | Maximum | Minimum |
|---|---|---|---|---|---|---|---|
| 91 (U) | Little Osage River near Mapleton, Ks. | pH (units) | 8 | -- | 7.4 | 8.1 | 7.0 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 8 | 206 | 205 | 310 | 100 |
| | | Specific conductance (umhos) | 8 | 406 | 385 | 536 | 265 |
| | | Dissolved solids (mg/L) | 8 | 260 | 260 | 328 | 168 |
| | | Sulfate (mg/L) | 8 | 26 | 20 | 46 | 15 |
| | | Iron, total (ug/L) | 1 | 610 | -- | -- | -- |
| | | Iron, dissolved (ug/L) | 7 | 30 | 20 | 50 | 10 |
| | | Manganese, total (ug/L) | 1 | 60 | -- | -- | -- |
| | | Manganese, dissolved (ug/L) | 7 | 460 | 80 | 2,100 | 40 |
| | | Sediment, suspended (mg/L) | 2 | 62 | 62 | 99 | 26 |
| 92 (U) | Lost Creek near Mapleton, Ks. | pH (units) | 1 | -- | 7.8 | -- | -- |
| | | Alkalinity, as CaCO3 (mg/L) | 1 | 310 | -- | -- | -- |
| | | Specific conductance (umhos) | 1 | 490 | -- | -- | -- |
| | | Dissolved solids (mg/L) | 1 | 309 | -- | -- | -- |
| | | Sulfate (mg/L) | 1 | 51 | -- | -- | -- |
| | | Iron, total (ug/L) | 1 | 260 | -- | -- | -- |
| | | Manganese, total (ug/L) | 1 | 50 | -- | -- | -- |
| 93 (C) | Elk Creek near Fulton, Ks. | pH (units) | 1 | -- | 7.6 | -- | -- |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 1 | 230 | -- | -- | -- |
| | | Specific conductance (umhos) | 1 | 510 | -- | -- | -- |
| | | Dissolved solids (mg/L) | 1 | 324 | -- | -- | -- |
| | | Sulfate (mg/L) | 1 | 54 | -- | -- | -- |
| | | Iron, total (ug/L) | 1 | 400 | -- | -- | -- |
| | | Manganese, total (ug/L) | 1 | 110 | -- | -- | -- |
| 94 (C) | West Laberdie Creek near Fulton, Ks. | pH (units) | 1 | -- | 7.4 | -- | -- |
| | | Alkalinity, as CaCO3 (mg/L) | 1 | 220 | -- | -- | -- |
| | | Specific conductance (umhos) | 1 | 564 | -- | -- | -- |
| | | Dissolved solids (mg/L) | 1 | 324 | -- | -- | -- |
| | | Sulfate (mg/L) | 1 | 59 | -- | -- | -- |
| | | Iron, total (ug/L) | 1 | 330 | -- | -- | -- |
| | | Manganese, total (ug/L) | 1 | 120 | -- | -- | -- |
| 95 (C) | East Laberdie Creek near Fulton, Ks. | pH (units) | 1 | -- | 7.3 | -- | -- |
| | | Alkalinity, as CaCO3 (mg/L) | 1 | 210 | -- | -- | -- |
| | | Specific conductance (umhos) | 1 | 616 | -- | -- | -- |
| | | Dissolved solids (mg/L) | 1 | 368 | -- | -- | -- |
| | | Sulfate (mg/L) | 1 | 81 | -- | -- | -- |
| | | Iron, total (ug/L) | 1 | 330 | -- | -- | -- |
| | | Manganese, total (ug/L) | 1 | 140 | -- | -- | -- |
| 96 (C) | Little Osage River at Fulton, Ks. | pH (units) | 60 | -- | 7.9 | 8.3 | 7.1 |
| | | Alkalinity, as CaCO3 (mg/L) | 49 | 201 | 213 | 292 | 79 |
| | | Specific conductance (umhos) | 64 | 436 | 461 | 640 | 202 |
| | | Dissolved solids (mg/L) | 49 | 274 | 280 | 380 | 132 |
| | | Sulfate (mg/L) | 49 | 31 | 33 | 54 | 8.2 |
| | | Iron, total (ug/L) | 1 | 770 | -- | -- | -- |
| | | Iron, dissolved (ug/L) | 43 | 60 | 30 | 1,100 | <10 |
| | | Manganese, total (ug/L) | 6 | 70 | 65 | 160 | <1 |
| | | Manganese, dissolved (ug/L) | 43 | 120 | 45 | 1,900 | <1 |
| | | Sediment, suspended (mg/L) | 296 | 338 | 80 | 5,060 | 0 |
| 97 (C) | Indian Creek tributary 3 miles east of Prescott, Ks. | pH (units) | 1 | -- | 6.4 | -- | -- |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 1 | 36 | -- | -- | -- |
| | | Specific conductance (umhos) | 1 | 1,600 | -- | -- | -- |
| | | Dissolved solids (mg/L) | 1 | 1,350 | -- | -- | -- |
| | | Sulfate (mg/L) | 1 | 1,000 | -- | -- | -- |
| | | Iron, total (ug/L) | 1 | 940 | -- | -- | -- |
| | | Iron, dissolved (ug/L) | 1 | 520 | -- | -- | -- |
| | | Manganese, total (ug/L) | 1 | 1,200 | -- | -- | -- |
| | | Manganese, dissolved (ug/L) | 1 | 1,200 | -- | -- | -- |

## 10.2 Statistical Summaries of Water-Quality Data for Surface-Water Stations

| Station number | Station name | Property or constituent | Number of samples | Mean | Median | Maximum | Minimum |
|---|---|---|---|---|---|---|---|
| 98 (C) | East Fork Indian Creek 4 miles southeast of Prescott, Ks. | pH (units) | 1 | -- | 6.9 | -- | -- |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 1 | 33 | -- | -- | -- |
| | | Specific conductance (umhos) | 1 | 1,380 | -- | -- | -- |
| | | Dissolved solids (mg/L) | 1 | 1,170 | -- | -- | -- |
| | | Sulfate (mg/L) | 1 | 840 | -- | -- | -- |
| | | Iron, total (ug/L) | 1 | 280 | -- | -- | -- |
| | | Iron, dissolved (ug/L) | 1 | 80 | -- | -- | -- |
| | | Manganese, total (ug/L) | 1 | 1,300 | -- | -- | -- |
| | | Manganese, dissolved (ug/L) | 1 | 1,300 | -- | -- | -- |
| 99 (C) | Indian Creek 4 miles southeast of Prescott, Ks. | pH (units) | 1 | -- | 7.4 | -- | -- |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 1 | 180 | -- | -- | -- |
| | | Specific conductance (umhos) | 1 | 660 | -- | -- | -- |
| | | Dissolved solids (mg/L) | 1 | 568 | -- | -- | -- |
| | | Sulfate (mg/L) | 1 | 290 | -- | -- | -- |
| | | Iron, total (ug/L) | 1 | 600 | -- | -- | -- |
| | | Iron, dissolved (ug/L) | 1 | 30 | -- | -- | -- |
| | | Manganese, total (ug/L) | 1 | 250 | -- | -- | -- |
| | | Manganese, dissolved (ug/L) | 1 | 200 | -- | -- | -- |
| 100 (C) | Indian Creek near Fulton, Ks. | pH (units) | 1 | -- | 6.9 | -- | -- |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 1 | 120 | -- | -- | -- |
| | | Specific conductance (umhos) | 1 | 966 | -- | -- | -- |
| | | Dissolved solids (mg/L) | 1 | 678 | -- | -- | -- |
| | | Sulfate (mg/L) | 1 | 360 | -- | -- | -- |
| | | Iron, total (ug/L) | 1 | 1,200 | -- | -- | -- |
| | | Manganese, total (ug/L) | 1 | 890 | -- | -- | -- |
| 104 (U) | Marmaton River near Marmaton, Ks. | pH (units) | 27 | -- | 7.8 | 8.8 | 7.1 |
| | | Specific conductance (umhos) | 29 | 417 | 441 | 558 | 130 |
| 106 (U) | Marmaton River near Fort Scott, Ks. | pH (units) | 147 | -- | 7.7 | 8.5 | 6.9 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 147 | 175 | 178 | 266 | 72 |
| | | Specific conductance (umhos) | 147 | 465 | 460 | 770 | 160 |
| | | Dissolved solids (mg/L) | 147 | 289 | 284 | 492 | 110 |
| | | Sulfate (mg/L) | 147 | 48 | 43 | 132 | 9.3 |
| | | Iron, total (ug/L) | 12 | 260 | 40 | 2,400 | 20 |
| | | Iron, dissolved (ug/L) | 66 | 50 | 50 | 200 | <10 |
| | | Manganese, total (ug/L) | 19 | 59 | 30 | 230 | <1 |
| | | Manganese, dissolved (ug/L) | 63 | 84 | 60 | 440 | <1 |
| | | Sediment, suspended (mg/L) | 31 | 1,324 | 1,170 | 3,110 | 179 |
| 107 (C) | Drywood Creek near Oskaloosa, Mo. | pH (units) | 4 | -- | 7.7 | 7.9 | 7.3 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 4 | 120 | 124 | 180 | 52 |
| | | Specific conductance (umhos) | 4 | 2,050 | 2,130 | 3,240 | 695 |
| | | Dissolved solids (mg/L) | 4 | 2,050 | 2,100 | 3,520 | 477 |
| | | Sulfate (mg/L) | 4 | 1,140 | 995 | 2,300 | 270 |
| | | Iron, total (ug/L) | 4 | 3,300 | 1,900 | 9,000 | 410 |
| | | Iron, dissolved (ug/L) | 4 | 80 | 70 | 140 | 40 |
| | | Manganese, total (ug/L) | 4 | 1,000 | 880 | 1,800 | 450 |
| | | Manganese, dissolved (ug/L) | 4 | 830 | 600 | 1,800 | 330 |
| | | Sediment, suspended (mg/L) | 4 | 137 | 118 | 292 | 22 |
| 108 (C) | West Fork Drywood Creek 3 miles north of Arcadia, Ks. | pH (units) | 14 | -- | 7.6 | 8.0 | 7.2 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 14 | 189 | 189 | 230 | 148 |
| | | Specific conductance (umhos) | 14 | 508 | 486 | 780 | 330 |
| | | Dissolved solids (mg/L) | 13 | 329 | 317 | 486 | 237 |
| | | Sulfate (mg/L) | 14 | 85 | 76 | 170 | 12 |
| | | Iron, total (ug/L) | 14 | 1,000 | 950 | 2,900 | 150 |
| | | Iron, dissolved (ug/L) | 14 | 100 | 10 | 860 | 10 |
| | | Manganese, total (ug/L) | 14 | 530 | 320 | 2,700 | 15 |
| | | Manganese, dissolved (ug/L) | 14 | 480 | 230 | 2,600 | 10 |
| 109 (C) | Cox Creek tributary near Mulberry, Ks. | pH (units) | 10 | -- | 7.3 | 8.4 | 6.7 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 10 | 92 | 85 | 140 | 64 |
| | | Specific conductance (umhos) | 10 | 1,342 | 1,405 | 1,840 | 700 |
| | | Dissolved solids (mg/L) | 10 | 1,019 | 1,073 | 1,490 | 454 |
| | | Sulfate (mg/L) | 10 | 675 | 685 | 1,000 | 260 |
| | | Iron, total (ug/L) | 10 | 340 | 220 | 820 | 60 |
| | | Iron, dissolved (ug/L) | 10 | 20 | 20 | 50 | 10 |
| | | Manganese, total (ug/L) | 10 | 1,600 | 1,300 | 4,600 | 450 |
| | | Manganese, dissolved (ug/L) | 10 | 1,600 | 1,300 | 4,500 | 420 |

| Station number | Station name | Property or constituent | Number of samples | Mean | Median | Maximum | Minimum |
|---|---|---|---|---|---|---|---|
| 110 (C) | Cox Creek 1 mile south of Arcadia, Ks. | pH (units) | 14 | -- | 7.4 | 8.0 | 6.8 |
| | | Alkalinity, as CaCO3 (mg/L) | 14 | 180 | 180 | 271 | 53 |
| | | Specific conductance (umhos) | 14 | 2,608 | 2,685 | 3,800 | 950 |
| | | Dissolved solids (mg/L) | 13 | 2,178 | 2,180 | 3,530 | 633 |
| | | Sulfate (mg/L) | 14 | 1,480 | 1,500 | 2,400 | 400 |
| | | Iron, total (ug/L) | 14 | 1,100 | 600 | 3,400 | 180 |
| | | Iron, dissolved (ug/L) | 14 | 80 | 30 | 340 | 10 |
| | | Manganese, total (ug/L) | 14 | 1,700 | 1,600 | 2,700 | 560 |
| | | Manganese, dissolved (ug/L) | 14 | 1,600 | 1,600 | 2,700 | 560 |
| | | Sediment, suspended (mg/L) | 2 | 77 | 77 | 113 | 42 |
| 113 (C) | Cox Creek 2 miles north of Arcadia, Ks. | pH (units) | 14 | -- | 7.4 | 8.0 | 6.6 |
| | | Alkalinity, as CaCO3 (mg/L) | 14 | 174 | 168 | 262 | 82 |
| | | Specific conductance (umhos) | 14 | 2,607 | 2,715 | 3,800 | 962 |
| | | Dissolved solids (mg/L) | 13 | 2,144 | 2,120 | 3,530 | 729 |
| | | Sulfate (mg/L) | 14 | 1,447 | 1,450 | 2,400 | 450 |
| | | Iron, total (ug/L) | 14 | 800 | 580 | 2,900 | 160 |
| | | Iron, dissolved (ug/L) | 14 | 40 | 20 | 180 | 10 |
| | | Manganese, total (ug/L) | 14 | 1,400 | 1,300 | 2,600 | 350 |
| | | Manganese, dissolved (ug/L) | 14 | 1,300 | 1,300 | 2,400 | 300 |
| | | Sediment, suspended (mg/L) | 1 | 144 | -- | -- | -- |
| 114 (C) | Drywood Creek near Deerfield, Mo. | pH (units) | 4 | -- | 7.8 | 7.9 | 7.6 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 4 | 156 | 158 | 180 | 131 |
| | | Specific conductance (umhos) | 4 | 1,760 | 1,750 | 2,250 | 1,300 |
| | | Dissolved solids (mg/L) | 4 | 1,580 | 1,640 | 1,990 | 1,050 |
| | | Sulfate (mg/L) | 4 | 940 | 950 | 1,300 | 560 |
| | | Iron, total (ug/L) | 4 | 1,900 | 1,800 | 2,800 | 980 |
| | | Iron, dissolved (ug/L) | 3 | 40 | 50 | 50 | 30 |
| | | Manganese, total (ug/L) | 4 | 1,800 | 1,400 | 3,200 | 1,100 |
| | | Manganese, dissolved (ug/L) | 3 | 1,700 | 1,300 | 3,000 | 900 |
| | | Sediment, suspended (mg/L) | 4 | 36 | 33 | 67 | 13 |
| 116 (C) | Osage River near Schell City, Mo. | pH (units) | 35 | -- | 7.9 | 8.6 | 6.9 |
| | | Alkalinity, as CaCO3 (mg/L) | 35 | 142 | 148 | 213 | 69 |
| | | Specific conductance (umhos) | 35 | 506 | 455 | 1,290 | 221 |
| | | Dissolved solids (mg/L) | 35 | 333 | 297 | 861 | 146 |
| | | Sulfate (mg/L) | 35 | 98 | 74 | 350 | 29 |
| | | Iron, total (ug/L) | 14 | 2,400 | 1,800 | 8,700 | 370 |
| | | Iron, dissolved (ug/L) | 17 | 50 | 20 | 210 | 10 |
| | | Manganese, total (ug/L) | 14 | 270 | 220 | 590 | 120 |
| | | Manganese, dissolved (ug/L) | 17 | 91 | 50 | 290 | 3 |
| | | Sediment, suspended (mg/L) | 31 | 396 | 125 | 4,400 | 11 |
| 118 (U) | Panther Creek near Rockville, Mo. | pH (units) | 2 | -- | 7.2 | 7.4 | 7.0 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 2 | 106 | 106 | 140 | 72 |
| | | Specific conductance (umhos) | 2 | 291 | 291 | 332 | 250 |
| | | Dissolved solids (mg/L) | 2 | 198 | 198 | 236 | 159 |
| | | Sulfate (mg/L) | 2 | 46 | 46 | 52 | 39 |
| | | Iron, total (ug/L) | 2 | 6,000 | 6,000 | 7,300 | 4,600 |
| | | Iron, dissolved (ug/L) | 2 | 320 | 320 | 330 | 300 |
| | | Manganese, total (ug/L) | 2 | 1,600 | 1,600 | 2,500 | 610 |
| | | Manganese, dissolved (ug/L) | 2 | 1,400 | 1,400 | 2,400 | 510 |
| | | Sediment, suspended (mg/L) | 2 | 140 | 140 | 191 | 89 |
| 119 (C) | Robinson Branch near Walker, Mo. | pH (units) | 2 | -- | 3.8 | 4.0 | 3.6 |
| | | Alkalinity, as CaCO3 (mg/L) | 2 | 0 | 0 | 0 | 0 |
| | | Specific conductance (umhos) | 2 | 952 | 952 | 1,270 | 633 |
| | | Dissolved solids (mg/L) | 2 | 696 | 696 | 996 | 396 |
| | | Sulfate (mg/L) | 2 | 480 | 480 | 690 | 270 |
| | | Iron, total (ug/L) | 2 | 15,000 | 15,000 | 27,000 | 2,200 |
| | | Iron, dissolved (ug/L) | 2 | 3,400 | 3,400 | 5,200 | 1,600 |
| | | Manganese, total (ug/L) | 2 | 3,200 | 3,200 | 5,300 | 1,100 |
| | | Manganese, dissolved (ug/L) | 2 | 3,200 | 3,200 | 5,400 | 1,100 |
| | | Sediment, suspended (mg/L) | 2 | 228 | 228 | 437 | 20 |
| 126 (U) | South Grand River at Urich, Mo. | pH (units) | 1 | -- | 7.7 | -- | -- |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 1 | 140 | -- | -- | -- |
| | | Specific conductance (umhos) | 1 | 350 | -- | -- | -- |
| | | Dissolved solids (mg/L) | 1 | 218 | -- | -- | -- |
| | | Sulfate (mg/L) | 1 | 29 | -- | -- | -- |
| | | Iron, total (ug/L) | 1 | 1,500 | -- | -- | -- |
| | | Iron, dissolved (ug/L) | 1 | 30 | -- | -- | -- |
| | | Manganese, total (ug/L) | 1 | 680 | -- | -- | -- |
| | | Manganese, dissolved (ug/L) | 1 | 590 | -- | -- | -- |
| | | Sediment, suspended (mg/L) | 1 | 57 | -- | -- | -- |

| Station number | Station name | Property or constituent | Number of samples | Mean | Median | Maximum | Minimum |
|---|---|---|---|---|---|---|---|
| 130 (C) | South Grand River near Clinton, Mo. | pH (units) | 1 | -- | 7.8 | -- | -- |
| | | Alkalinity, as CaCO3 (mg/L) | 1 | 130 | -- | -- | -- |
| | | Specific conductance (umhos) | 1 | 465 | -- | -- | -- |
| | | Dissolved solids (mg/L) | 1 | 318 | -- | -- | -- |
| | | Sulfate (mg/L) | 1 | 110 | -- | -- | -- |
| | | Iron, total (ug/L) | 1 | 490 | -- | -- | -- |
| | | Iron, dissolved (ug/L) | 1 | 30 | -- | -- | -- |
| | | Manganese, total (ug/L) | 1 | 210 | -- | -- | -- |
| | | Manganese, dissolved (ug/L) | 1 | 200 | -- | -- | -- |
| | | Sediment, suspended (mg/L) | 1 | 33 | -- | -- | -- |
| 133 (C) | Bear Creek near Montrose, Mo. | pH (units) | 1 | -- | 7.4 | -- | -- |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 1 | 75 | -- | -- | -- |
| | | Specific conductance (umhos) | 1 | 700 | -- | -- | -- |
| | | Dissolved solids (mg/L) | 1 | 477 | -- | -- | -- |
| | | Sulfate (mg/L) | 1 | 220 | -- | -- | -- |
| | | Iron, total (ug/L) | 1 | 45,000 | -- | -- | -- |
| | | Iron, dissolved (ug/L) | 1 | 190 | -- | -- | -- |
| | | Manganese, total (ug/L) | 1 | 280 | -- | -- | -- |
| | | Manganese, dissolved (ug/L) | 1 | 200 | -- | -- | -- |
| | | Sediment, suspended (mg/L) | 1 | 79 | -- | -- | -- |
| 134 (C) | Deepwater Creek near Deepwater, Mo. | pH (units) | 1 | -- | 7.5 | -- | -- |
| | | Alkalinity, as CaCO3 (mg/L) | 1 | 79 | -- | -- | -- |
| | | Specific conductance (umhos) | 1 | 515 | -- | -- | -- |
| | | Dissolved solids (mg/L) | 1 | 349 | -- | -- | -- |
| | | Sulfate (mg/L) | 1 | 140 | -- | -- | -- |
| | | Iron, total (ug/L) | 1 | 580 | -- | -- | -- |
| | | Iron, dissolved (ug/L) | 1 | 50 | -- | -- | -- |
| | | Manganese, total (ug/L) | 1 | 260 | -- | -- | -- |
| | | Manganese, dissolved (ug/L) | 1 | 220 | -- | -- | -- |
| | | Sediment, suspended (mg/L) | 1 | 14 | -- | -- | -- |
| 136 (C) | Tebo Creek near Calhoun, Mo. | pH (units) | 3 | -- | 7.0 | 7.3 | 6.9 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 3 | 57 | 66 | 75 | 30 |
| | | Specific conductance (umhos) | 3 | 1,320 | 1,320 | 1,500 | 1,150 |
| | | Dissolved solids (mg/L) | 3 | 1,030 | 1,020 | 1,100 | 979 |
| | | Sulfate (mg/L) | 3 | 650 | 620 | 720 | 610 |
| | | Iron, total (ug/L) | 3 | 670 | 640 | 730 | 630 |
| | | Iron, dissolved (ug/L) | 3 | 80 | 90 | 100 | 60 |
| | | Manganese, total (ug/L) | 3 | 5,400 | 1,800 | 13,000 | 1,500 |
| | | Manganese, dissolved (ug/L) | 3 | 4,400 | 1,800 | 10,000 | 1,500 |
| | | Sediment, suspended (mg/L) | 3 | 57 | 24 | 124 | 23 |
| 137 (U) | Sand Creek near Calhoun, Mo. | pH (units) | 2 | -- | 7.6 | 7.8 | 7.5 |
| | | Alkalinity, as CaCO3 (mg/L) | 2 | 134 | 134 | 160 | 107 |
| | | Specific conductance (umhos) | 2 | 420 | 420 | 517 | 324 |
| | | Dissolved solids (mg/L) | 2 | 280 | 280 | 348 | 213 |
| | | Sulfate (mg/L) | 2 | 54 | 54 | 100 | 8 |
| | | Iron, total (ug/L) | 2 | 560 | 560 | 800 | 330 |
| | | Iron, dissolved (ug/L) | 2 | 110 | 110 | 180 | 40 |
| | | Manganese, total (ug/L) | 2 | 160 | 160 | 200 | 130 |
| | | Manganese, dissolved (ug/L) | 2 | 120 | 120 | 170 | 80 |
| | | Sediment, suspended (mg/L) | 2 | 71 | 71 | 129 | 13 |
| 138 (C) | Sand Creek at Calhoun, Mo. | pH (units) | 2 | -- | 7.5 | 7.7 | 7.3 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 2 | 134 | 134 | 160 | 107 |
| | | Specific conductance (umhos) | 2 | 736 | 736 | 747 | 725 |
| | | Dissolved solids (mg/L) | 2 | 532 | 532 | 539 | 526 |
| | | Sulfate (mg/L) | 2 | 255 | 255 | 270 | 240 |
| | | Iron, total (ug/L) | 2 | 2,200 | 2,200 | 3,000 | 1,500 |
| | | Iron, dissolved (ug/L) | 2 | 30 | 30 | 40 | 20 |
| | | Manganese, total (ug/L) | 2 | 740 | 740 | 750 | 740 |
| | | Manganese, dissolved (ug/L) | 2 | 380 | 380 | 460 | 310 |
| | | Sediment, suspended (mg/L) | 2 | 33 | 33 | 56 | 10 |
| 139 (C) | Tebo Creek at Leesville, Mo. | pH (units) | 69 | -- | 7.6 | 8.4 | 6.9 |
| | | Alkalinity, as $CaCO_3$ (mg/L) | 69 | 89 | 89 | 154 | 23 |
| | | Specific conductance (umhos) | 67 | 537 | 394 | 1,900 | 112 |
| | | Dissolved solids (mg/L) | 64 | 376 | 252 | 1,470 | 83 |
| | | Sulfate (mg/L) | 65 | 178 | 92 | 850 | 38 |
| | | Iron, total (ug/L) | 24 | 2,000 | 760 | 25,000 | 110 |
| | | Manganese, total (ug/L) | 23 | 550 | 340 | 2,300 | 90 |

KANSAS

| County | Site-identification number (WATSTORE) | Location (township-range-section) | Geologic system |
|---|---|---|---|
| Allen | 375434095111301 | 24S.-20E.-35 | Pennsylvanian |
| Anderson | 382025095125101 | 20S.-20E.-05 | Quaternary |
| | 381455095265901 | 21S.-18E.-05 | " |
| | 381455095265902 | 21S.-18E.-05 | " |
| | 381657095170401 | 20S.-19E.-26 | Pennsylvanian |
| Bourbon | 380127095003501 | 23S.-22E.-29 | Pennsylvanian |
| | 375910094530601 | 24S.-23E.-04 | " |
| | 374537094485201 | 26S.-24E.-29 | " |
| | 374405094385801 | 26S.-25E.-35 | " |
| Coffey | 382417095415201 | 19S.-15E.-13 | Pennsylvanian |
| Crawford | 373836094390601 | 28S.-25E.-03 | Pennsylvanian |
| Douglas | 384658095200301 | 14S.-19E.-32 | Pennsylvanian |
| Franklin | 384232095240001 | 15S.-18E.-34 | Pennsylvanian |
| | 383304095260201 | 17S.-18E.-21 | " |
| | 383008095261001 | 18S.-18E.-08 | " |
| Linn | 382040094442801 | 20S.-24E.-03 | Quaternary |
| | 382235095035201 | 19S.-21E.-23 | Pennsylvanian |
| | 381534095000701 | 20S.-22E.-32 | " |
| | 381534095000702 | 20S.-22E.-32 | " |
| | 380739094442401 | 22S.-24E.-14 | " |
| | 380335094414701 | 23S.-25E.-07 | " |
| | 380316094415501 | 23S.-25E.-07 | " |
| Lyon | 383839095594101 | 16S.-13E.-20 | Quaternary |
| Miami | 384231095024201 | 15S.-21E.-35 | Pennsylvanian |
| | 383735094490001 | 16S.-23E.-25 | " |
| | 382601094455701 | 18S.-24E.-33 | " |
| | 382415094403701 | 19S.-25E.-07 | " |
| Osage | 384332095514601 | 15S.-14E.-21 | Quaternary |
| | 384653095471301 | 15S.-15E.-06 | Pennsylvanian |
| | 384305095463901 | 15S.-15E.-29 | " |
| | 383120095382901 | 17S.-16E.-33 | " |

MISSOURI

| County | Site-identification number (WATSTORE) | Location (township-range-section) | Geologic system |
|---|---|---|---|
| Barton | 373300094311501 | 32N.-33W.-02 | Ordovician |
| | 373300094311502 | 32N.-33W.-02 | " |
| Bates | 380530094345001 | 38N.-33W.-08 | Pennsylvanian |
| | 380813094062501 | 39N.-29W.-22 | " |
| | 381340094223001 | 40N.-29W.-32 | " |
| | 382200094084001 | 41N.-29W.-08 | " |
| | 380318094095201 | 38N.-29W.-18 | Mississippian |
| | 380552094121301 | 38N.-30W.-03 | " |
| | 380431094223301 | 38N.-31W.-18 | " |
| | 380405094215001 | 38N.-31W.-20 | " |
| | 380418094270801 | 38N.-32W.-16 | " |
| | 380745094285901 | 39N.-32W.-31 | " |
| | 381003094305201 | 39N.-33W.-15 | " |
| | 382112094271401 | 41N.-32W.-15 | " |
| | 380540094213001 | 38N.-31W.-08 | Ordovician |
| | 380716094083201 | 39N.-29W.-29 | " |
| Cass | 382940094041001 | 43N.-29W.-25 | Pennsylvanian |
| | 382955094151001 | 43N.-30W.-29 | " |
| | 383010094222501 | 43N.-31W.-20 | " |
| | 384230094294501 | 44N.-32W.-19 | " |
| | 384000094140001 | 45N.-30W.-34 | " |
| | 384300094273001 | 45N.-32W.-15 | " |
| | 385000094194501 | 46N.-31W.-03 | " |
| | 384900094190001 | 46N.-31W.-11 | " |
| | 384840094290001 | 46N.-32W.-17 | " |
| | 385010094320001 | 46N.-33W.-02 | " |
| | 385000094330001 | 46N.-33W.-03 | " |
| | 385000094213001 | 46N.-33W.-04 | " |
| | 384915094314501 | 46N.-33W.-11 | " |
| | 384830094321001 | 46N.-33W.-14 | " |
| | 384855094320501 | 46N.-33W.-14 | " |
| | 384850094341001 | 46N.-33W.-16 | " |
| Cedar | 375150094014001 | 36N.-28W.-28 | Mississippian |
| | 375140094040001 | 36N.-28W.-30 | " |
| | 375250094012001 | 36N.-28W.-21 | Ordovician |
| | 375200094010001 | 36N.-28W.-28 | " |
| | 375150094014101 | 36N.-28W.-28 | " |
| Henry | 381430093430001 | 40N.-25W.-20 | Pennsylvanian |
| | 381520093590001 | 40N.-28W.-14 | " |
| | 381500093590001 | 40N.-28W.-23 | " |
| | 381330093585001 | 40N.-28W.-36 | " |
| | 382410093415001 | 42N.-25W.-28 | " |
| | 382750094001001 | 42N.-28W.-03 | " |
| | 383340093573001 | 44N.-28W.-36 | " |
| | 381530093470001 | 40N.-26W.-14 | Ordovician |
| | 381910093362001 | 41N.-24W.-20 | " |
| | 382240093460001 | 41N.-26W.-02 | " |
| | 382220093464001 | 41N.-26W.-03 | " |
| | 382130093473701 | 41N.-26W.-10 | " |
| | 382000093472001 | 41N.-26W.-22 | " |
| | 383220093310001 | 43N.-24W.-01 | " |
| | 383220093310002 | 43N.-24W.-01 | " |
| | 382750093372001 | 43N.-24W.-31 | " |

| County | Site-identification number (WATSTORE) | Location (township-range-section) | Geologic system |
|---|---|---|---|
| Jackson | 390240094080001 | 49N.-29W.-20 | Quaternary |
| | 390834094072501 | 50N.-29W.-17 | " |
| | 390700094143001 | 50N.-30W.-29 | " |
| | 390700094144001 | 50N.-30W.-29 | " |
| | 390700094154001 | 50N.-30W.-30 | " |
| | 390610094144001 | 50N.-30W.-32 | " |
| | 391040094174501 | 50N.-31W.-02 | " |
| | 390600094170001 | 50N.-31W.-36 | " |
| | 390605094164501 | 50N.-31W.-36 | " |
| | 390635094153001 | 50N.-32W.-36 | " |
| | 390829094314401 | 50N.-33W.-23 | " |
| | 391249094170501 | 51N.-31W.-23 | " |
| | 385210094083001 | 47N.-29W.-20 | Pennsylvanian |
| | 385220094080001 | 47N.-29W.-21 | " |
| | 385300094130001 | 47N.-30W.-15 | " |
| | 385210094120001 | 47N.-30W.-23 | " |
| | 385200094122001 | 47N.-30W.-23 | " |
| | 385200094122101 | 47N.-30W.-23 | " |
| | 385205094103501 | 47N.-30W.-24 | " |
| | 385130094163001 | 47N.-30W.-30 | " |
| | 385500094220001 | 47N.-31W.-05 | " |
| | 385500094220101 | 47N.-31W.-05 | " |
| | 385525094222001 | 47N.-31W.-05 | " |
| | 385500094230001 | 47N.-31W.-06 | " |
| | 385500094242401 | 47N.-31W.-06 | " |
| | 385420094223001 | 47N.-31W.-08 | " |
| | 385400094210001 | 47N.-31W.-09 | " |
| | 385040094200001 | 47N.-31W.-34 | " |
| | 385520094283001 | 47N.-32W.-05 | " |
| | 385520094240001 | 47N.-32W.-01 | " |
| | 385440094235001 | 47N.-32W.-01 | " |
| | 385500094271001 | 47N.-32W.-04 | " |
| | 385300094280001 | 47N.-32W.-16 | " |
| | 385540094353001 | 47N.-33W.-05 | " |
| | 385530094360001 | 47N.-33W.-06 | " |
| | 385530094362001 | 47N.-33W.-06 | " |
| | 385510094355001 | 47N.-33W.-06 | " |
| | 385420094360001 | 47N.-33W.-07 | " |
| | 385430094341001 | 47N.-33W.-09 | " |
| | 385410094330001 | 47N.-33W.-10 | " |
| | 385340094341501 | 47N.-33W.-16 | " |
| | 385300094350001 | 47N.-33W.-20 | " |
| | 385240094315001 | 47N.-33W.-23 | " |
| | 385145094351001 | 47N.-33W.-29 | " |
| | 385110094354001 | 47N.-33W.-32 | " |
| | 385100094314501 | 47N.-33W.-35 | " |
| | 385941094082001 | 48N.-29W.-05 | " |
| | 385640094111001 | 48N.-30W.-25 | " |
| | 385645094161501 | 48N.-30W.-30 | " |
| | 390015094224501 | 48N.-31W.-06 | " |
| | 390000094222501 | 48N.-31W.-06 | " |
| | 385940094220001 | 48N.-31W.-08 | " |
| | 385945094183001 | 48N.-31W.-11 | " |
| | 385810094172001 | 48N.-31W.-13 | " |
| | 385730094230001 | 48N.-31W.-19 | " |
| | 385755094184501 | 48N.-31W.-23 | " |

*10.3 Ground-Water Quality Sites Available in the National Water Data Storage and Retrieval System (WATSTORE)*

| County | Site-identification number (WATSTORE) | Location (township-range-section) | Geologic system |
|---|---|---|---|
| Jackson | 385525094213001 | 48N.-31W.-32 | Pennsylvanian |
| | 390030094293001 | 48N.-32W.-06 | " |
| | 385915094273501 | 48N.-32W.-09 | " |
| | 385838094265501 | 48N.-32W.-16 | " |
| | 385845094293001 | 48N.-32W.-18 | " |
| | 385745094263001 | 48N.-32W.-22 | " |
| | 385712094244001 | 48N.-32W.-26 | " |
| | 385642094250001 | 48N.-32W.-26 | " |
| | 385645094250001 | 48N.-32W.-26 | " |
| | 385710094291001 | 48N.-32W.-30 | " |
| | 390000094350001 | 48N.-33W.-08 | " |
| | 385940094353001 | 48N.-33W.-08 | " |
| | 385900094350001 | 48N.-33W.-17 | " |
| | 385800094320001 | 48N.-33W.-23 | " |
| | 385710094330001 | 48N.-33W.-27 | " |
| | 385720094343001 | 48N.-33W.-28 | " |
| | 385700094353001 | 48N.-33W.-29 | " |
| | 385615094360001 | 48N.-33W.-31 | " |
| | 385635094302501 | 48N.-33W.-36 | " |
| | 390240094350001 | 49N.-23W.-29 | " |
| | 390355094091001 | 49N.-29W.-07 | " |
| | 390100094082001 | 49N.-29W.-32 | " |
| | 390450094115001 | 49N.-30W.-02 | " |
| | 390100094170001 | 49N.-30W.-20 | " |
| | 390035094160001 | 49N.-30W.-31 | " |
| | 390115094120001 | 49N.-30W.-35 | " |
| | 390240094183001 | 49N.-31W.-23 | " |
| | 390155094192001 | 49N.-31W.-27 | " |
| | 390200094191501 | 49N.-31W.-27 | " |
| | 390120094200001 | 49N.-31W.-33 | " |
| | 390600094273501 | 49N.-32W.-05 | " |
| | 390455094290501 | 49N.-32W.-07 | " |
| | 390440094254001 | 49N.-32W.-10 | " |
| | 390430094244001 | 49N.-32W.-11 | " |
| | 390345094271501 | 49N.-32W.-16 | " |
| | 390400094281501 | 49N.-32W.-17 | " |
| | 390350094282001 | 49N.-32W.-17 | " |
| | 390400094252001 | 49N.-32W.-17 | " |
| | 390400094282501 | 49N.-32W.-17 | " |
| | 390340094280001 | 49N.-32W.-17 | " |
| | 390400094293101 | 49N.-32W.-18 | " |
| | 390400094293001 | 49N.-32W.-18 | " |
| | 390125094282501 | 49N.-32W.-21 | " |
| | 390150094254501 | 49N.-32W.-27 | " |
| | 390210094282001 | 49N.-32W.-29 | " |
| | 390230094292001 | 49N.-32W.-30 | " |
| | 390116094255401 | 49N.-32W.-34 | " |
| | 390220094324001 | 49N.-33W.-27 | " |
| | 390545094323001 | 49N.-33W.-03 | " |
| | 390300094302001 | 49N.-33W.-24 | " |
| | 390145094304001 | 49N.-33W.-36 | " |
| | 390140094302501 | 49N.-33W.-36 | " |
| | 390920094114001 | 50N.-30W.-11 | " |
| | 390800094154501 | 50N.-30W.-19 | " |
| | 390800094114001 | 50N.-30W.-23 | " |
| | 390545094120501 | 50N.-30W.-34 | " |
| | 390925094175001 | 50N.-31W.-11 | " |
| | 390940094175001 | 50N.-31W.-11 | " |

| County | Site-identification number (WATSTORE) | Location (township-range-section) | Geologic system |
|---|---|---|---|
| Jackson | 390930094174501 | 50N.-31W.-11 | Pennsylvanian |
| | 391000094180001 | 50N.-31W.-11 | " |
| | 390805094153001 | 50N.-31W.-19 | " |
| | 390800094200001 | 50N.-31W.-21 | " |
| | 390700094170001 | 50N.-31W.-25 | " |
| | 390720094130001 | 50N.-31W.-29 | " |
| | 390620094222001 | 50N.-31W.-31 | " |
| | 390620094190001 | 50N.-31W.-34 | " |
| | 390710094233001 | 50N.-32W.-25 | " |
| | 390720094253001 | 50N.-32W.-27 | " |
| | 390635094253001 | 50N.-32W.-34 | " |
| | 385420094344201 | 47N.-33W.-09 | Mississippian |
| | 385808094180001 | 48N.-31W.-14 | " |
| | 390500094300001 | 49N.-32W.-07 | " |
| Johnson | 383550093510001 | 44N.-27W.-13 | Pennsylvanian |
| | 384415093424001 | 45N.-26W.-12 | " |
| | 384327093564001 | 45N.-27W.-06 | " |
| | 384225093542001 | 45N.-27W.-16 | " |
| | 384050093563501 | 45N.-27W.-19 | " |
| | 384015093523001 | 45N.-27W.-26 | " |
| | 384340094033001 | 45N.-28W.-06 | " |
| | 384420094041501 | 45N.-29W.-01 | " |
| | 384420094041601 | 45N.-29W.-01 | " |
| | 384320094070001 | 45N.-29W.-10 | " |
| | 384150094044501 | 45N.-29W.-24 | " |
| | 384740093425001 | 46N.-25W.-07 | " |
| | 384430093503001 | 46N.-27W.-36 | " |
| | 384640094010001 | 46N.-28W.-21 | " |
| | 384650093592501 | 46N.-28W.-23 | " |
| | 385015094040001 | 47N.-29W.-36 | " |
| | 384900093534501 | 46N.-27W.-04 | Mississippian |
| | 383810093364001 | 44N.-24W.-06 | Ordovician |
| | 384306093341501 | 45N.-24W.-04 | " |
| | 383908093453201 | 45N.-26W.-35 | " |
| | 384308093592001 | 45N.-28W.-11 | " |
| | 384635093355001 | 46N.-24W.-18 | " |
| | 384540093333501 | 46N.-24W.-21 | " |
| | 384545093333501 | 46N.-24W.-21 | " |
| | 384535093333001 | 46N.-24W.-21 | " |
| | 384550093332001 | 46N.-24W.-22 | " |
| | 384450093360501 | 46N.-24W.-30 | " |
| | 384404093345201 | 46N.-24W.-32 | " |
| | 384418093340601 | 46N.-24W.-33 | " |
| | 384407093343001 | 46N.-25W.-33 | " |
| | 384407093341101 | 46N.-24W.-33 | " |
| | 384359093340501 | 46N.-24W.-33 | " |
| | 384349093340701 | 46N.-24W.-33 | " |
| | 384450093371001 | 46N.-25W.-25 | " |
| | 384415093370001 | 46N.-25W.-36 | " |
| | 384615093451501 | 46N.-26W.-23 | " |
| | 384600093440001 | 46N.-26W.-24 | " |
| | 384430093442001 | 46N.-26W.-36 | " |

*10.3 Ground-Water Quality Sites Available in the National Water Data Storage and Retrieval System (WATSTORE)*

| County | Site-identification number (WATSTORE) | Location (township-range-section) | Geologic system |
|---|---|---|---|
| Lafayette | 391020094002001 | 50N.-28W.-04 | Quaternary |
| | 390805093590001 | 50N.-28W.-15 | " |
| | 390811093584101 | 50N.-28W.-15 | " |
| | 391225093305001 | 51N.-24W.-14 | " |
| | 391230093304001 | 51N.-24W.-14 | " |
| | 391225093304001 | 51N.-24W.-14 | " |
| | 391215093301501 | 51N.-24W.-23 | " |
| | 391200093300001 | 51N.-24W.-24 | " |
| | 391331093373201 | 51N.-25W.-11 | " |
| | 391142093474001 | 51N.-26W.-29 | " |
| | 391124094010301 | 51N.-28W.-32 | " |
| | 385815093533301 | 48N.-27W.-09 | Pennsylvanian |
| | 385520094020001 | 48N.-28W.-32 | " |
| | 390255093502001 | 49N.-27W.-13 | " |
| | 385700093375001 | 48N.-25W.-14 | Mississippian |
| | 385855093340501 | 48N.-24W.-04 | Ordovician |
| | 385900093342501 | 48N.-24W.-05 | " |
| | 385850093341501 | 48N.-24W.-05 | " |
| | 390020093325001 | 49N.-24W.-27 | " |
| | 390555093324501 | 50N.-24W.-28 | " |
| | 390500093300001 | 50N.-24W.-36 | " |
| Pettis | 385350093214001 | 48N.-22W.-32 | Ordovician |
| | 385348093214501 | 48N.-22W.-32 | " |
| Saline | 390740093070001 | 50N.-20W.-09 | Quaternary |
| | 390728093115001 | 50N.-21W.-10 | " |
| | 390751093110001 | 50N.-21W.-11 | " |
| | 390748093110801 | 50N.-21W.-11 | " |
| | 390750093114001 | 50N.-21W.-11 | " |
| | 390750093105501 | 50N.-21W.-11 | " |
| | 390748093110001 | 50N.-21W.-11 | " |
| | 390750093105801 | 50N.-21W.-11 | " |
| | 390710093120001 | 50N.-21W.-15 | " |
| | 390930093120001 | 51N.-21W.-34 | " |
| | 390705093281601 | 51N.-23W.-31 | " |
| | 391710093064501 | 52N.-20W.-17 | " |
| | 390710093004001 | 50N.-19W.-08 | Mississippian |
| | 390550093103001 | 50N.-21W.-24 | " |
| | 391145093072001 | 51N.-20W.-17 | " |
| | 385820093250001 | 48N.-23W.-02 | Ordovician |
| | 390055093005001 | 49N.-19W.-17 | " |
| | 390000093013001 | 49N.-19W.-29 | " |
| | 385950093014501 | 49N.-19W.-29 | " |
| | 390130093053001 | 49N.-20W.-15 | " |
| | 390130093080001 | 49N.-20W.-17 | " |
| | 390140093120001 | 49N.-21W.-15 | " |
| | 390215093193501 | 49N.-22W.-16 | " |
| | 390410093233001 | 49N.-23W.-01 | " |
| | 390405093262101 | 49N.-23W.-04 | " |
| | 390600093074501 | 50N.-20W.-14 | " |
| | 390435093091501 | 50N.-20W.-31 | " |
| | 390730093113501 | 50N.-21W.-11 | " |
| | 390515093213001 | 50N.-22W.-29 | " |
| | 390815093250001 | 50N.-23W.-10 | " |
| | 391315093033001 | 51N.-20W.-04 | " |
| | 391320093033001 | 51N.-20W.-11 | " |
| | 391000093042001 | 51N.-20W.-17 | " |

| County | Site-identification number (WATSTORE) | Location (township-range-section) | Geologic system |
|---|---|---|---|
| Saline | 391240093115001 | 51N.-21W.-10 | Ordovician |
| | 391300093110001 | 51N.-21W.-11 | " |
| | 391145093211001 | 51N.-22W.-19 | " |
| | 391545093071501 | 52N.-20W.-29 | " |
| | 391510093070001 | 52N.-20W.-32 | " |
| | 391500093052501 | 52N.-20W.-34 | " |
| | 391500093040001 | 52N.-20W.-35 | " |
| | 391645093104501 | 52N.-21W.-23 | " |
| St. Clair | 381220094020001 | 39N.-28W.-06 | Pennsylvanian |
| | 380800093595001 | 39N.-28W.-22 | " |
| Vernon | 374443094083001 | 34N.-29W.-06 | Mississippian |
| | 374000094103801 | 34N.-30W.-25 | " |
| | 374255094172801 | 34N.-31W.-11 | " |
| | 374631094160901 | 35N.-30W.-32 | " |
| | 374804094224101 | 35N.-31W.-20 | " |
| | 374914094285801 | 35N.-32W.-17 | " |
| | 375320094090001 | 36N.-29W.-17 | " |
| | 375118094181701 | 36N.-31W.-36 | " |
| | 375752094113301 | 37N.-30W.-23 | " |
| | 380310094275001 | 38N.-32W.-29 | " |
| | 374040094173001 | 34N.-31W.-23 | Ordovician |
| | 373930094174001 | 34N.-31W.-35 | " |
| | 373910094180001 | 34N.-31W.-35 | " |
| | 373925094173501 | 34N.-31W.-35 | " |
| | 374557094271201 | 34N.-32W.-05 | " |
| | 374130094274001 | 34N.-32W.-20 | " |
| | 374738094100901 | 35N.-29W.-19 | " |
| | 375100094223001 | 35N.-31W.-05 | " |
| | 374930094174001 | 35N.-31W.-13 | " |
| | 375429094094501 | 36N.-29W.-07 | " |
| | 375500094075301 | 36N.-29W.-09 | " |
| | 375357094135001 | 36N.-30W.-15 | " |
| | 375330094204001 | 36N.-31W.-21 | " |
| | 375140094214001 | 36N.-31W.-33 | " |
| | 375604094240201 | 36N.-32W.-01 | " |
| | 375602094243201 | 36N.-32W.-01 | " |
| | 375558094264601 | 36N.-32W.-03 | " |
| | 375548094275001 | 36N.-32W.-04 | " |
| | 375500094293601 | 36N.-32W.-07 | " |
| | 375312094274301 | 36N.-32W.-22 | " |
| | 375243094294401 | 36N.-32W.-30 | " |
| | 380020094034001 | 37N.-29W.-01 | " |
| | 375914094060501 | 37N.-29W.-08 | " |
| | 375914094214501 | 37N.-31W.-17 | " |
| | 375840094195001 | 37N.-31W.-22 | " |
| | 375653094173001 | 37N.-31W.-36 | " |
| | 375943094255601 | 37N.-32W.-15 | " |
| | 375944094272601 | 37N.-32W.-16 | " |
| | 375703094291701 | 37N.-32W.-31 | " |
| | 375637094295501 | 37N.-32W.-31 | " |
| | 375708094285001 | 37N.-32W.-32 | " |
| | 375620094254001 | 37N.-32W.-35 | " |
| | 380110094065001 | 38N.-29W.-33 | " |

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