KANSAS
Floods and Droughts

Located in the central plains, Kansas is affected by the same weather patterns that affect adjoining States. These patterns are dominated by major weather systems that move from west to east across the State. The flow of moisture is seasonal. During winter, moisture originates over the Pacific Ocean and precipitates over the Rocky Mountains; the remaining moisture moves into the State from the northwest and west. Kansas tends to receive less precipitation during winter than summer. During summer, southerly winds move moisture originating over the Gulf of Mexico into the State. Occasionally, remnants of tropical cyclones, including hurricanes originating in the Gulf, move into the State and produce considerable quantities of precipitation.

The nature of these moisture-delivery systems results in numerous, severe floods and long, severe droughts. Since the flood of 1844, the most severe and widespread flood was in July 1951. The 1951 flood, which affected almost one-half of the State, resulted from an intense storm in early July that was preceded by greater than normal rainfall during May and June. Peak discharges in the Kansas, Marais des Cygnes, and Neosho Rivers generally had recurrence intervals greater than 100 years, were greater than any previous discharges, and have not been equaled since. Other significant floods occurred on the Republican River in 1935, the Arkansas River in 1965, the Solomon River in 1973, and the Verdigris River basin in 1976. Although the storm near Great Bend in 1981 did not affect a large area, its intensity caused severe flooding and considerable damage.

Five severe droughts—determined by analysis of streamflow data—have occurred in Kansas since 1900. All affected the entire State. The most severe droughts were during 1929–41 and 1952–57.

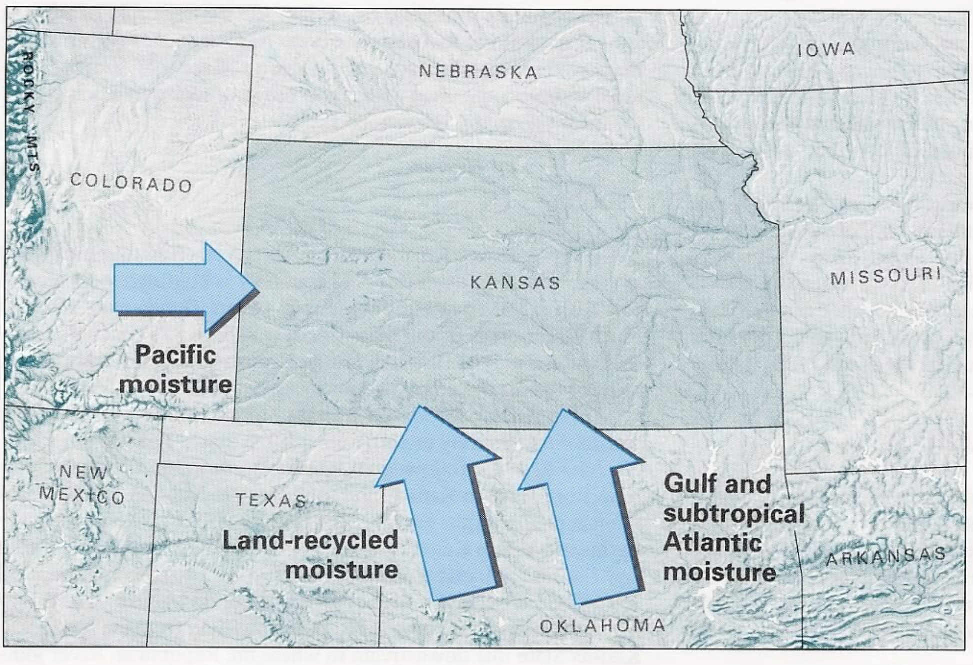


Figure 1. Principal sources and patterns of delivery of moisture into Kansas. Size of arrow implies relative contribution of moisture from source shown. (Source: Data from Douglas R. Clark and Andrea Lage, Wisconsin Geological and Natural History Survey.)

GENERAL CLIMATOLOGY

The climate of Kansas, a State located in the middle latitudes, is controlled by a global-circulation pattern dominated by major airmasses and associated frontal systems that move slowly eastward across the continent. The paths followed by these airmasses vary seasonally; however, the general path is positioned over the continental United States during the winter and shifts northward during the summer. During the winter, temperature differs significantly across the boundary between warm and cold airmasses; consequently, frontal systems generated along the boundaries are strong, and movement is slow. During the summer, temperature gradients are small; hence, frontal systems are weak, and movement is rapid. Precipitation during winter is of low intensity and often lasts days. However, some rainfall during summer results from thunderstorm activity that is not associated with fronts. Thunderstorms can produce intense rainfall of short duration, accompanied by lightning, strong gusty winds, and occasionally hail and tornadoes.

The sources of moisture for Kansas are primarily the Gulf of Mexico and the subtropical Atlantic Ocean and secondarily the Pacific Ocean. The quantity and timing of the precipitation are, in part, a function of the State's distance from these moisture sources. The Rocky Mountains to the west form a barrier to the eastward flow of moisture from the Pacific, and considerable moisture is released over the mountains. The airmasses contain little moisture when they reach Kansas. As a result, the winters are relatively dry.

During spring and summer, the path of airmasses shifts northward, and a high-pressure system over the Atlantic Ocean allows southerly winds to carry large quantities of moisture from the Gulf of Mexico into Kansas. As the summer progresses, the Earth's surface warms, and the atmosphere becomes unstable; this instability commonly results in convective thunderstorms. These storms are localized and of short duration, but they can produce 1–5 inches of rain in a few hours. Dry periods of several weeks' duration commonly follow periods of intense rainfall. These dry periods are frequent during the midsummer growing season.

In addition to the oceans, important moisture sources include local and upwind land surfaces, as well as lakes and reservoirs, from which moisture evaporates into the atmosphere. Typically, as a moisture-laden ocean airmass moves inland, it is modified to include some water that has been recycled one or more times through the land-vegetation-air interface. The general directions of movement and the relative quantities of moisture that enter the State are shown in figure 1.

Because the Gulf of Mexico is the principal source of moisture for most of Kansas, the part of the State nearest the gulf receives the most precipitation. Southeastern Kansas receives about 40 inches of precipitation annually, whereas areas along the western border of the State receive 15 inches or less. About 75 percent of the annual precipitation occurs from April to September.

Although summer thunderstorms produce most of the precipitation in Kansas, the quantity is variable, both spatially and temporally. Total precipitation is not a good indicator of moisture available for growing crops. The irregularity of precipitation during the growing season can cause 2- to 8-week-long dry periods between intense rainstorms. Sometimes the circulation patterns that produce precipitation are altered so that precipitation is less than normal for several consecutive years. At these times, drought may become regional.

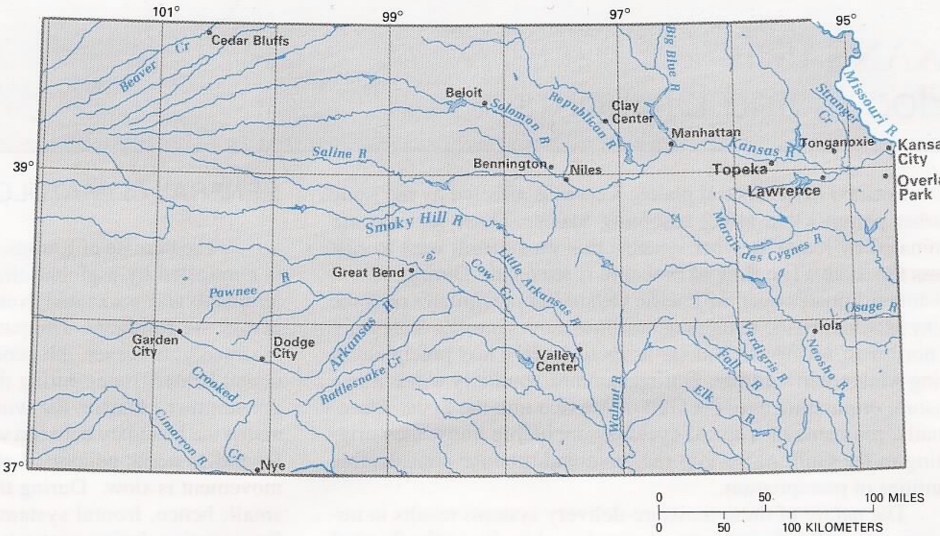


Figure 2. Selected geographic features, Kansas.

Floods in Kansas are caused by several different mechanisms, all dependent on a large flow of moist air from the south. One mechanism is a cool airmass from the north that becomes stationary over southern Kansas or Oklahoma for several days. A frontal system is formed as warm, moist air moving northward from the Gulf of Mexico rises over the cooler, heavier air. Because the frontal system is stationary, rain can fall for several consecutive days. When the moisture supply is large, rainfall totals can be 10–15 inches over large areas.

Another flood-producing mechanism is the slow-moving, intense thunderstorm. These storms can produce local flash floods and result in extensive property damage and loss of life. The floods can be especially destructive in urban areas where drainage systems are not adequate to remove the runoff.

A third mechanism, although not common, is dissipating tropical cyclones, including hurricanes, that move northward from the Gulf of Mexico carrying tremendous quantities of moisture. Occasionally, the remnants of hurricanes merge with frontal systems moving through the State. The combination can produce intense rainfall and severe flooding.

In a semiarid region of variable precipitation, a drought can be difficult to define. Even in the eastern one-third of the State where annual precipitation is much greater, dry periods of several weeks are frequent. Widespread drought affects Kansas when the area is dominated by high atmospheric pressure. The absence of significant vertical air movement within these high-pressure systems does not allow the convection necessary to produce clouds and precipitation.

MAJOR FLOODS AND DROUGHTS

The floods and droughts discussed herein are those that have occurred since 1900 and have had a substantial areal effect. Discussions include only floods with peak discharges having recurrence intervals greater than 25 years and droughts having recurrence intervals greater than 10 years. The most memorable floods and droughts in Kansas since about 1900 are summarized in table 1; rivers and cities are shown in figure 2.

Floods and droughts were evaluated using data collected from a streamflow-gaging-station network. Streamflow data are collected, stored, and reported by water year (a water year is the 12-month period from October 1 through September 30 and is identified by the calendar year in which it ends). Use of data from the streamflow-gaging-station network in Kansas is limited by three factors: (1) the limited number of gaging stations having adequate length of record for the evaluation of extreme events, (2) the regulation of streamflows by reservoir storage, and (3) the effects of farming practices and ground-water withdrawals on streamflows, particularly in the western part of the State.

Six gaging stations were selected to represent the areal diversity of hydrologic conditions in the State. The six graphs depicting floods (fig. 3) indicate the magnitude of the annual maximum instantaneous discharge recorded during each water year for the period of record at each of the six gaging stations. The maps shown in figure 3 indicate the areal extent of the most severe floods recorded during the period of systematic stream gaging in Kansas. The six graphs depicting droughts (fig. 4) indicate the departure of average annual streamflow for each water year from average streamflow for the period of record at each gaging station. Each map shown in figure 4 indicates the areal extent and range of recurrence interval of the most severe droughts since 1900.

FLOODS

At least one Kansas stream has severe flooding during an average year. Although flooding generally is confined to an area of less than 2,500 square miles, several severe floods have affected much larger areas of the State. Flora (1948, p. 279) documented a severe flood in June 1844 that resulted from a large storm and affected most of the north-central and northeastern parts of the State.

Numerous floods on Kansas streams have resulted from storms either entirely or partly outside the State. The floods of May 28–June 6, 1935, followed an intense storm in northeastern Colorado, northwestern Kansas, and southwestern Nebraska. Additional intense precipitation fell over the Smoky Hill and Solomon River basins in western Kansas and the Big Blue River basin in Nebraska and Kansas (Follansbee and Spiegel, 1937). The storm also caused record peak discharges on the Pawnee River on May 28. The flooding was most severe along the Republican River from the Nebraska-Kansas State line downstream to where the Republican River joins the Kansas River. Peak discharges on the Republican River were the largest since the flood of 1844. Moderate flooding continued downstream along the Kansas River as flows from the Smoky Hill and Big Blue Rivers contributed to the flow of the Republican River. Historical information indicates that the maximum discharges along the Kansas River in 1935 were less than those in 1903. Ten people were killed, and the flood damaged or destroyed 400,000 acres of farmland, destroyed 12,000 head of livestock, damaged 3,000 homes and other buildings, and caused considerable damage to transportation facilities.

The flood of July 10–13, 1951, extended over about one-half of the State, including the north-central, northeastern, east-central, and southeastern parts, and along the Missouri and Osage Rivers in western Missouri (U.S. Geological Survey, 1952, p. 39–40). The flood was caused by storms that originated at the convergence of warm, moist, tropical air from the Gulf of Mexico and a frontal system that was centered in east-central Kansas. The resulting precipitation, which for the 4 days ranged from 6 to 17.5 inches, fell during three periods about 24 hours apart starting during the evening of July 9. Precipitation totals for May and June had been much greater than normal, and precipitation during the first 8 days of July had been light to moderate. Because the soil was saturated, virtually all precipitation that fell during July 10–13 was available for runoff. Peak discharges of the streamflow generated by the storm generally were greater than any discharge since the flood of 1844. On the main stems of the Solomon, Kansas, Marais des Cygnes, and Neosho Rivers, peak discharge recurrence intervals generally were greater than 100 years. Flooding also was severe along the major tributaries of these basins, where peak discharge recurrence intervals commonly exceeded 100 years (fig. 3, sites 2, 3, and 6). Agricultural and urban areas were inundated, and total damage was $800 million (U.S. Geological Survey, 1952, p. 39–40). Damage was greatest in populated areas along the main stem of the Kansas River at Manhattan, Topeka, Lawrence, and Kansas City. However, virtually no community located on major tributaries escaped without at least moderate damage. Rural damage included agricultural losses and damage to or destruction of utilities and transportation facilities. In Kansas, about 900 people were injured, and 15 were killed as a result of the flood.

Severe flooding occurred along the Arkansas River upstream from Great Bend during June 17–25, 1965, as a result of storms in the foothills and plains east of the Rocky Mountains in Colorado and New Mexico (Snipes and others, 1974, p. D4). Because the main storm did not affect Kansas, local flooding was minimal, but the Arkansas River overflowed from the western State line downstream to Great Bend. Flow in the Arkansas River peaked near the Colorado-Kansas State line on June 17. The peak discharges recorded at all gaging stations on the Arkansas River at and upstream from Great Bend were larger than any previously recorded and had recurrence intervals greater than 50 years. As the crest of the flood progressed downstream to its junction with the Little Arkansas River on June 25, the peak discharge had decreased to a magnitude having a recurrence interval less than 10 years. Although inundation of the flood plain caused considerable damage to urban areas, such as Garden City and Dodge City, most of the estimated $16 million in damage was to cropland (Snipes and others, 1974, table 2, p. D28).

In 1973, a series of severe floods occurred on streams throughout the central and east-central parts of the State during 3 weeks from late September to mid-October. Abundant precipitation preceded the floods of September 26–28 (water year 1973), when as much as 11 inches fell during the 4 days of September 25–28. Several locations reported precipitation in excess of 7 inches on September 26. The flooding was most severe in Rattlesnake and Cow Creeks in the south-central part of the State and in the Smoky Hill River, its tributaries, and tributaries of the Republican River in the north-central part. Light to moderate precipitation continued until October 10 when additional rainfall—as much as 5 inches in 3 days—began in the central, north-central, and east-central parts of the State. Severe flooding occurred during October 11–13 (water year 1974) in the downstream reaches of the Smoky Hill, Solomon (fig. 3, site 2), and Saline Rivers in the north-central part of the State, along the upstream reach of the Little Arkansas River in the central part, and along the Marais des Cygnes River near the Kansas-Missouri State line.

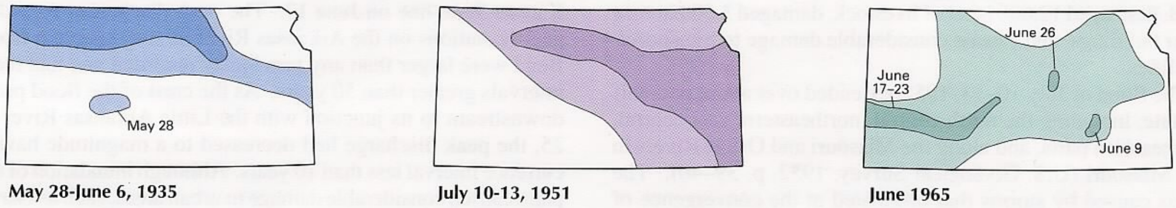
Flooding was severe in the downstream reaches of the Verdigris River basin during July 2–4, 1976, as a result of an intense storm over the southeastern part of the State. The storm produced 24-hour precipitation that totaled about 6–13 inches and 2-day precipitation of as much as 16 inches. Generally, precipitation ended during the late afternoon on July 3; however, runoff continued to cause flooding on July 4. The most severe flooding was confined to the main stem and tributaries of the Elk River and tributaries of the

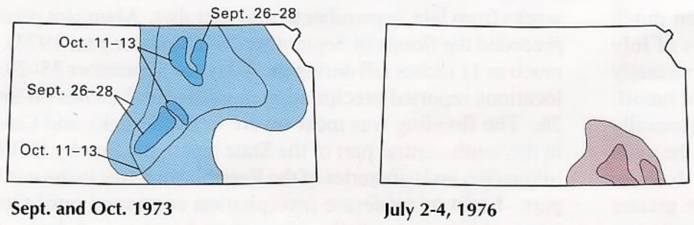
Table 1. Chronology of major and other memorable floods and droughts in Kansas, 1844–1988

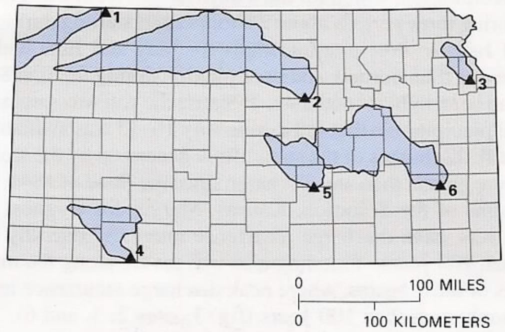
[Recurrence interval: The average interval of time within which streamflow will be greater than a particular value for floods or less than a particular value for droughts. Symbol: >, greater than. Sources: Recurrence intervals calculated from U.S. Geological Survey data; other information from U.S. Geological Survey, State and local reports, and newspapers]

Flood or drought	Date	Area affected (fig. 2)	Recurrence interval (years)	Remarks
Flood	June 1844	Kansas and Marais des Cygnes River basins.	Unknown	Called the "Big Water" in Indian legend. Recurrence interval probably much greater than 100 years.
Flood	May–June 1903	Republican and Kansas River basins.	>50	Discharges greater than any flood since 1844.
Drought	1929–41	Statewide	>25	Regional.
Flood	May 28–June 6, 1935	Republican River basin	25 to >50	Storms in northeastern Colorado, northwestern Kansas, and southwestern Nebraska. Lives lost, 10.
Flood	July 10–13, 1951	Solomon, Kansas, Marais des Cygnes, and Neosho River basins.	25 to >100	Storms affected most of eastern Kansas and were preceded by greater than normal rainfall. Lives lost, 15; damage, $800 million.
Drought	1952–57	Statewide	10 to >25	Regional.
Drought	1962–72	Statewide	10 to >25	Regional. Most severe in central and southeastern Kansas.
Flood	June 1965	Arkansas, Little Arkansas, Solomon, Marais des Cygnes, and Big Blue River basins.	25 to >50	Storm on plains east of Rocky Mountains. Damage, $16 million, mostly to cropland.
Flood	Sept.–Oct. 1973	Solomon, Smoky Hill, and Big Blue River basins.	>25 to >50	Caused by rainfall in north-central Kansas.
Drought	1974–82	Statewide	10 to >25	Most severe in north-central and southeastern Kansas. Severity undefined in western part.
Flood	July 2–4, 1976	Verdigris River basin	25 to >100	Intense storms near headwaters.
Flood	Sept. 12–13, 1977	Kansas City area	>100	Two severe storms on successive days. Lives lost, 25; damage, $50 million.
Flood	June 15, 1981	Arkansas River tributaries at Great Bend.	>100	Intense thunderstorms produced 5 to 20 inches of rainfall over 300 square miles. Damage, $42 million.
Flood	June 9, 1984	Kansas City suburbs	>100	Most severe flooding in southwestern part of metropolitan area.
Drought	1988–present	Statewide	Unknown	Most severe in southwestern, central, and northeastern Kansas.

Areal Extent of Floods

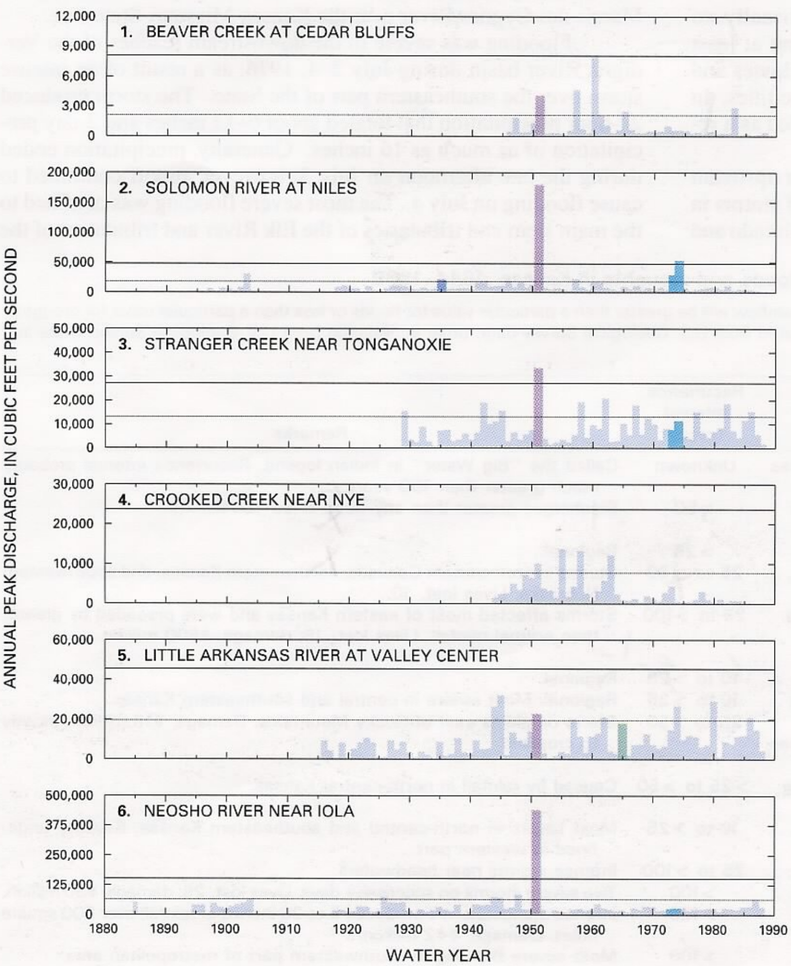






U.S. Geological Survey streamflow-gaging stations and corresponding drainage basins — Numbers refer to graphs

Peak Discharge



EXPLANATION

Areal extent of major flood

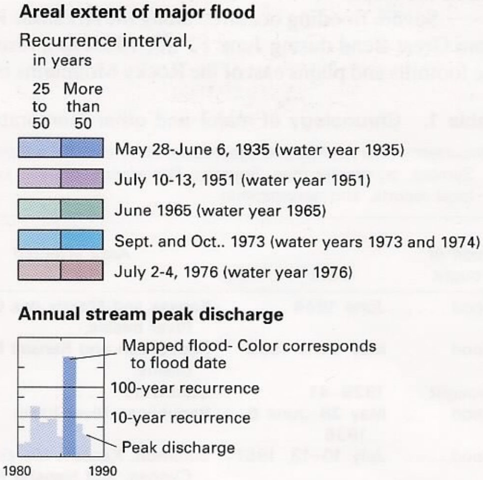


Figure 3. Areal extent of major floods with a recurrence interval of 25 years or more in Kansas, and annual peak discharge for selected sites, water years 1885–1988. (Source: Data from U.S. Geological Survey files.)

Fall and lower Verdigris Rivers. Flooding was moderate on the main stems of the Verdigris and Fall Rivers; some flooding extended across the State line into Oklahoma.

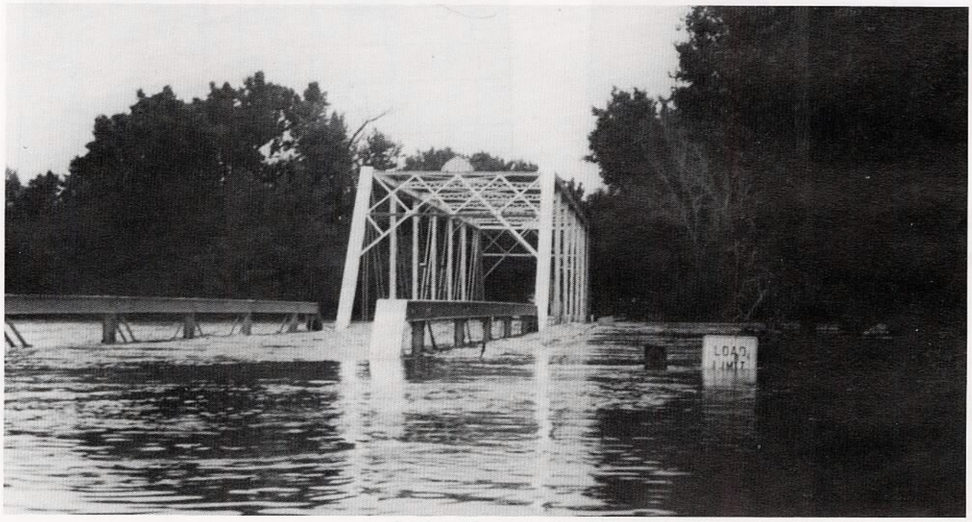
Occasionally, intense local storms of short duration produce extremely large quantities of runoff. On the afternoon of June 14, 1981, a series of intense thunderstorms along the forward edge of a stalled cold front produced from 5 to 20 inches of precipitation in about 12 hours near Great Bend (Clement and Johnson, 1982). The storm affected about 300 square miles of tributaries to the Arkansas River upstream from Great Bend. The resulting runoff produced peak discharges on June 15 that were 1.5–3 times the discharge having a 100-year recurrence interval and caused about $42 million in damage. The storm was so localized that gaging stations around its perimeter recorded only nominal discharge, generally having a recurrence interval less than 2 years. A similar storm occurred in the Kansas City, Kansas-Missouri, metropolitan area on September 12–13, 1977 (Hauth and Carswell, 1978). As much as 11 inches of precipitation in 24 hours resulted in peak discharges having recurrence intervals greater than 100 years on most streams that flow through the metropolitan area.

Droughts

Monthly flows recorded at 63 gaging stations were used to analyze droughts in Kansas by evaluating the cumulative departures of monthly streamflows from long-term average monthly discharges for each of the station records. As a result of the analysis, five droughts were identified: 1929–41, 1952–57, 1962–72, 1974–82, and 1988.

The 1929–41 drought was regional in scale and affected many of the Midwestern and Western States. The recurrence interval was greater than 25 years throughout Kansas. Although the number of streamflow records long enough to include the entire drought was insufficient, data from adjoining States confirmed the severity. Agricultural losses during the 1929–41 drought were extreme, and many farms were abandoned.

The drought of 1952–57 also was regional. The drought recurrence interval was greater than 25 years statewide except in the Big Blue River basin, where the recurrence interval was 10–25 years. Because of its severity and areal extent, the drought of 1952–57 is used as the base period for studies of reservoir yields in Kansas.



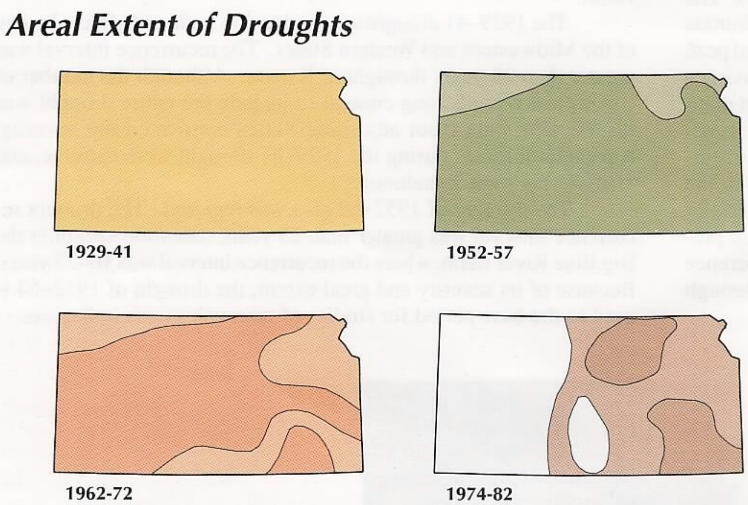
Solomon River near Beloit, Kans., on July 13, 1951.

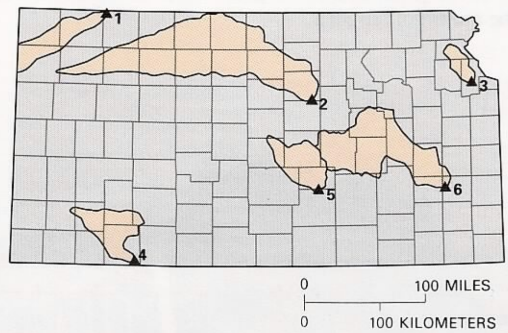
Flood of the Solomon River, July 1951. Major flooding occurred throughout eastern Kansas, causing about $800 million in damage. (Photographs from U.S. Geological Survey files.)

July 15, 1951. Flooding in the flood plain along the Solomon River near Bennington, Kans.

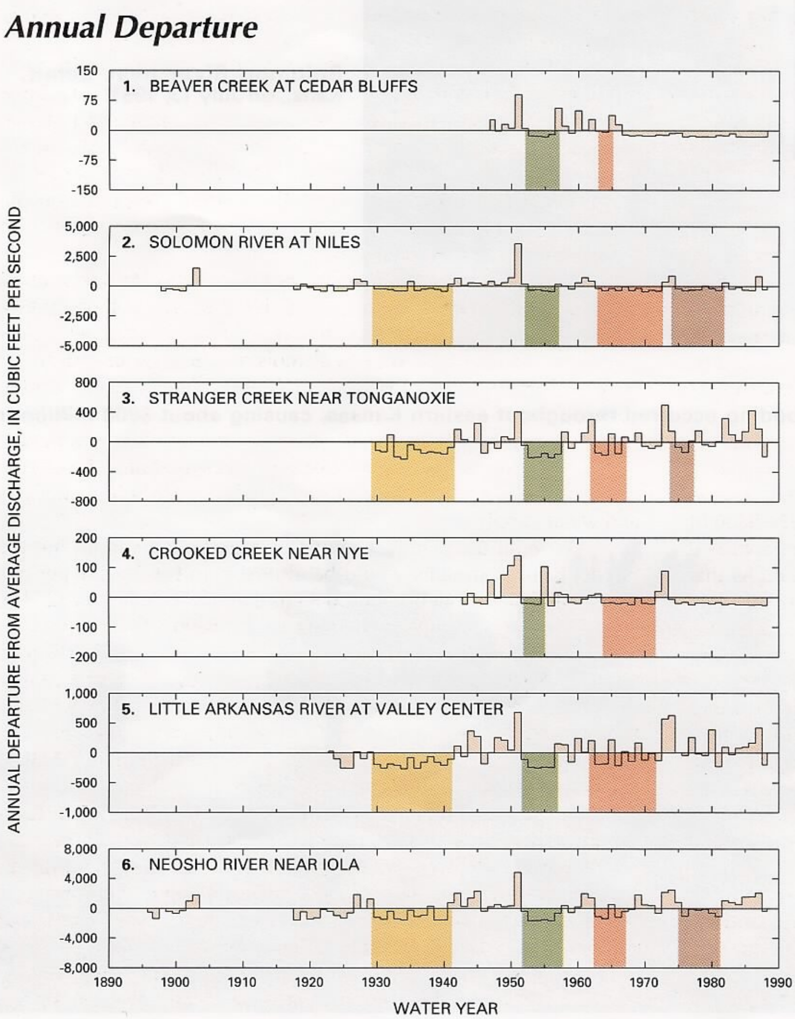
The duration of the 1962–72 regional drought varied considerably across the State. Many of the streamflow records indicated alternating less than average and greater than average flows whereas others indicated a steady deficit throughout the entire period. Similarly, the drought of 1974–82 appeared to be a series of relatively short-duration droughts at several gaging stations but sustained or long-term droughts at others.

During the 1962–72 drought, the recurrence interval generally was greater than 25 years. However, in parts of the northwestern, northeastern, southern, and southeastern areas of the State, recurrence intervals were 10–25 years. The recurrence interval of the 1974–82 drought was greater than 25 years in the north-central and southeastern parts but was between 10 and 25 years across the remaining eastern two-thirds of the State. Because of inadequate





U.S. Geological Survey streamflow-gaging stations and corresponding drainage basins — Numbers refer to graphs



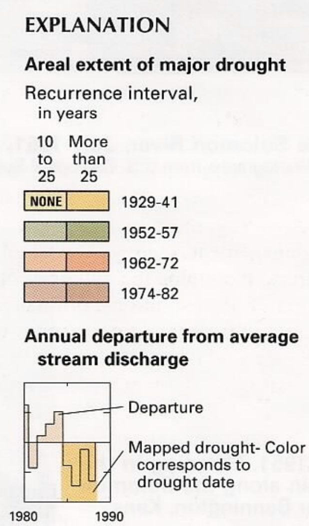


Figure 4. Areal extent of major droughts with a recurrence interval of 10 years or more in Kansas, and annual departure from average stream discharge for selected sites, water years 1896–1988. (Source: Data from U.S. Geological Survey files.)

streamflow information for comparison, the severity of the 1974–82 drought could not be determined in the western one-third of the State.

The severity of the 1988 drought varied across the State. The drought was most severe in the southwestern, central, and northeastern parts of the State but minimal in the northwestern and southeastern parts. At the beginning of the drought, reservoir storage was near or above average; hence, surface-water supplies were sufficient to meet demands through the end of water year 1988. Rainfall during the period generally was less than 50 percent of the long-term average, and quantities were insufficient to maintain soil moisture or contribute to ground-water supplies. The decreased soil moisture resulted in considerable damage to maturing grain crops, decreased the growth of forage grasses, and threatened the germination of the winter wheat crop. Estimated losses to 1988 crops resulting from the effects of the drought were $1 billion (Wichita Eagle and Beacon, June 7, 1989). Water levels in the shallow aquifers declined rapidly, which resulted in the abandonment of many domestic water wells. At the end of 1988, the effects of the drought were continuing to worsen. As a result, State and local officials were considering measures to decrease water use and were requesting financial relief for the agricultural industry.

WATER MANAGEMENT

The responsibility for planning water-management functions before and during floods and droughts requires coordination between various Federal, State, county, city, and other local governmental agencies. The water-management functions involve three areas of responsibility: (1) flood-plain management to decrease loss during floods, (2) flood-forecast and warning systems, and (3) planning efficient use of water resources during droughts. As population densities in Kansas change, the priorities of the water-management functions also change to meet the increasing need for protection of life and property and to meet new demands on water resources during periods of deficient supply.

Flood-Plain Management.—Flood-plain-management programs in Kansas are regulated by the Division of Water Resources, Kansas State Board of Agriculture.Cities and Counties (unincorporated areas) have the authority to establish flood-plain regulations to ensure the protection of people and structures within the designated flood-plain zones [Kansas Statutes Annotated (KSA 12–705)]. The statutes define a flood plain as the area adjacent to a watercourse that would be inundated by a flood having a 100-year recurrence interval (KSA 12–734). Generally, the delineation of a flood-plain zone for a community coincides with zones identified through the National Flood Insurance Program, which is implemented by the Federal Emergency Management Agency. The Chief Engineer, Division of Water Resources, maintains the authority of review and approval before adoption of all resolutions, ordinances, or regulations that pertain to the establishment of or changes in existing flood-plain zones (KSA 12–734). The Chief Engineer is responsible for ensuring that proposals are consistent with the following minimum standards: (1) no human habitation of the flood plain unless protected against floods having a 100-year recurrence interval; (2) flood-proofing of all new or reconstructed existing structures to the altitude of a flood crest having a 100-year recurrence interval; and (3) no structure, encroachment, or other use, not otherwise prohibited in the flood plain, that would raise the altitude of a flood crest more than 1 foot so as to cause an undue restriction of floodflows within the flood plain (KSA 12–735).

Mitigation of flood damage is the responsibility of the Division of Emergency Preparedness of the Adjutant General's office. A postflood requirement is the formulation of a set of recommendations that would lessen the effect of future floods. These recommendations are contained in a Mitigation Plan prepared by the Division of Emergency Preparedness with assistance from other State and Federal agencies (J.W. Funk, Division of Water Resources, Kansas State Board of Agriculture, oral commun., 1988).

Of the 390 cities in the State that have been identified as flood prone by the Federal Emergency Management Agency, 271 participate in the National Flood Insurance Program. Forty-two of the 55 counties in the State that have identified flood-prone areas also participate in the program (J.W. Funk, written commun., 1988).

Flood-Warning Systems.—The reliability and timeliness of flood forecasts are important to the safety of lives and property. Reliable forecasts can facilitate a rapid return to normal operations after flood threats have passed.

The primary flood-warning systems in Kansas are operated by the National Weather Service River Forecast Centers in Kansas City, Mo., and in Tulsa, Okla. The Kansas City office is responsible for the upper Missouri River basin, which includes the Kansas and Osage River basins in Kansas. The Tulsa office is responsible in part for the Arkansas River and its major tributaries in Kansas. River forecasts are prepared primarily from meteorological data from the various National Weather Service Forecast Offices and meteorological and hydrologic data from other agencies including the U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation, the U.S. Geological Survey, and local agencies. The River Forecast Centers review and process the data to determine the anticipated runoff and then combine the estimated runoff with existing river flows to forecast future flows at selected locations within the network. The timeliness of the data is important to the speed with which a forecast can be made. Advanced technology in automated recording and rapid communication permit information to be obtained promptly through use of radar and satellite imagery and telemetry.

Although several local flood-control projects in the State use forecast data in specific operations, two Kansas cities—Great Bend and Overland Park—have developed ongoing data-collection and reporting systems that contribute information to local and municipal forecast systems. Because of the small areal distribution of urban drainage networks, rapid data collection and dissemination and forecast computations are critical because of the extremely short response times of these small urban basins.

Water-Use Management During Droughts.—Droughts can be defined by the nature of the water deficit (Dracup and others, 1980). In Kansas, droughts are classified as either from meteorological (rainfall) deficits, agricultural (soil-moisture) deficits, or hydrologic (streamflow) deficits (T.C. Stiles, Kansas Water Office, written commun., 1988). Water management in Kansas mitigates the latter two types of droughts or deficits. Agricultural deficits are mitigated by conservation techniques or supplemental irrigation, whereas the legal institutions of the State primarily address hydrologic deficits and water supply.

Without the benefit of impoundments, flows in all but the largest Kansas streams would be almost zero for 30-day periods during moderate drought conditions (Jordan, 1983, table 1, p. 32–44). As such, natural streamflow is an unreliable supply to meet present-day demands. Most water used in Kansas is ground water (Kenny, 1986, p. 12; Kansas Water Office, 1987). As much as 85 percent of the water appropriated for use in the State is ground water, which is used mostly for irrigation (U.S. Geological Survey, 1985, p. 217). Eighty percent of this ground water is from the western one-half of the State (Kansas Water Office, 1987, p. 35).

Institutional management of water during droughts in Kansas takes two forms—appropriation of surface and ground water and use of stored water. Water-appropriation rights are issued for the diversion and beneficial use of water under the Water Appropriation Act by the Division of Water Resources of the Kansas State Board of Agriculture. Under State law, allocation of water during drought is based on the priority date specified at the time the water right is filed. A water right does not guarantee water, only the user's place in priority relative to other users. Water management under this law is by reaction, whereby the holder of a water right must file a complaint if that water right is impaired. After receipt of the complaint, the Division of Water Resources investigates the impairment and takes subsequent regulatory action. Hence, during a drought, extensive field investigation and regulation are required.

Another legal method of obtaining water during droughts is the use of reservoir storage. Recognizing the dependence of the user on surface water in eastern Kansas, the State used the Federal Water Supply Act of 1958 to develop water-supply storage in some of the 24 Federal reservoirs (Kansas Water Office, 1982, p. 11). Numerous cities also have developed storage on small tributaries to meet local needs. The Kansas Water Office manages the Water Marketing Program, which sells water to cities and industries from nine U.S. Army Corps of Engineers' reservoirs in eastern Kansas. The program is intended to provide reliable water supplies during droughts.

During droughts, many downstream users, including irrigators, divert releases made from reservoir storage that is dedicated for maintenance of water quality. Because the State treats such releases as natural flow, the users are in compliance with their water rights (Kansas Water Office, 1985). However, as streamflows become dependent on releases from water-quality-related storage, users are vulnerable to any alteration in those releases (Hart and Stiles, 1984). Drought-simulation exercises conducted by the Kansas Water Office have confirmed the users' vulnerability when relying on water rights supplemented by water-quality-maintenance releases (T.C. Stiles, Kansas Water Board, written commun., 1986).

In 1985, the State developed the Water Assurance Program, which is a management approach that uses both water rights and reservoir storage. The basic concept is recognition that low-flow releases from storage enhance downstream flows and thus benefit water rights as well as instream uses along the river (Kansas Water Office, 1985). The program creates a water-assurance district, a consortium of downstream cities and industries that contract with the State for storage in appropriate reservoirs. Storage in each reservoir is operated as a system with other reservoirs and in conjunction with river flows. System operations effectively increase availability of water during droughts (Sheer, 1986, p. 111).

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