MINNESOTA
Floods and Drought

The most damaging floods in Minnesota in terms of area affected, lives lost, and property damage have resulted from later than normal spring snowmelt of unusually thick snowpack combined with precipitation during the melting period. Other floods that were locally catastrophic resulted from intense summer thunderstorms. Developments that encroached on exposed lakebeds when lake levels were low were flooded when lake levels recovered. Wave action caused shore damage on several large lakes when lake levels were high.

Flood-plain and shoreland management in Minnesota is administered by local units of government, with technical and financial assistance from State and Federal agencies. Ninety percent of the communities having flood problems have adopted flood-plain zoning ordinances. Flood-warning systems are in place in a few communities along streams that are susceptible to flash floods. Flood-control works have been constructed in some communities to protect development on flood plains.

Droughts result also in substantial economic losses in Minnesota. Agricultural losses were large during the long drought of 1921–42. Short droughts have been severe, have been destructive riculture, and have stressed municipal water supplies.

To allocate water to users, the Minnesota Department of Natural Resources uses a permit system based on water-use priorities established by the legislature. The Commissioner of Natural Resources may establish protected flows on streams to ensure water availability for instream requirements and for users having priority. Permits may be suspended during periods of limited supply.

GENERAL CLIMATOLOGY

Minnesota is affected by a variety of airmasses. In winter, the weather is dominated by cold, dry, polar continental airmasses from northwestern Canada. In summer, the weather is dominated by dry, tropical continental airmasses from the desert Southwest or by warm, moist, tropical maritime airmasses from the Gulf of Mexico. In spring and fall, the weather is transitional and is affected by alternating intrusions of these three airmasses.

The principal source of moisture (75 percent or more) for precipitation is tropical maritime airmasses from the Gulf of Mexico that move into the State from the south (fig. 1). The quantity of precipitation received by Minnesota is determined by the distance these moist airmasses travel before the moisture is condensed. Therefore, southeastern Minnesota (which averages about 32 inches annually) receives more precipitation than northwestern Minnesota (20 inches). The Pacific Ocean is a minor moisture source. Airmasses that bear moisture from the Pacific are greatly modified as they pass over the continent. Lake Superior is a local moisture source that affects locations several miles inland from the lake (fig. 1).

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.

Almost 45 percent (about 12 inches) of Minnesota's annual precipitation is received from June through August, when moisture from the Gulf of Mexico is most available. Only 8 percent of the annual precipitation is received from December through February.

Cyclonic and convective storms are the two major types of storms that bring moisture into Minnesota. Cyclonic storms are large-scale, low-pressure systems

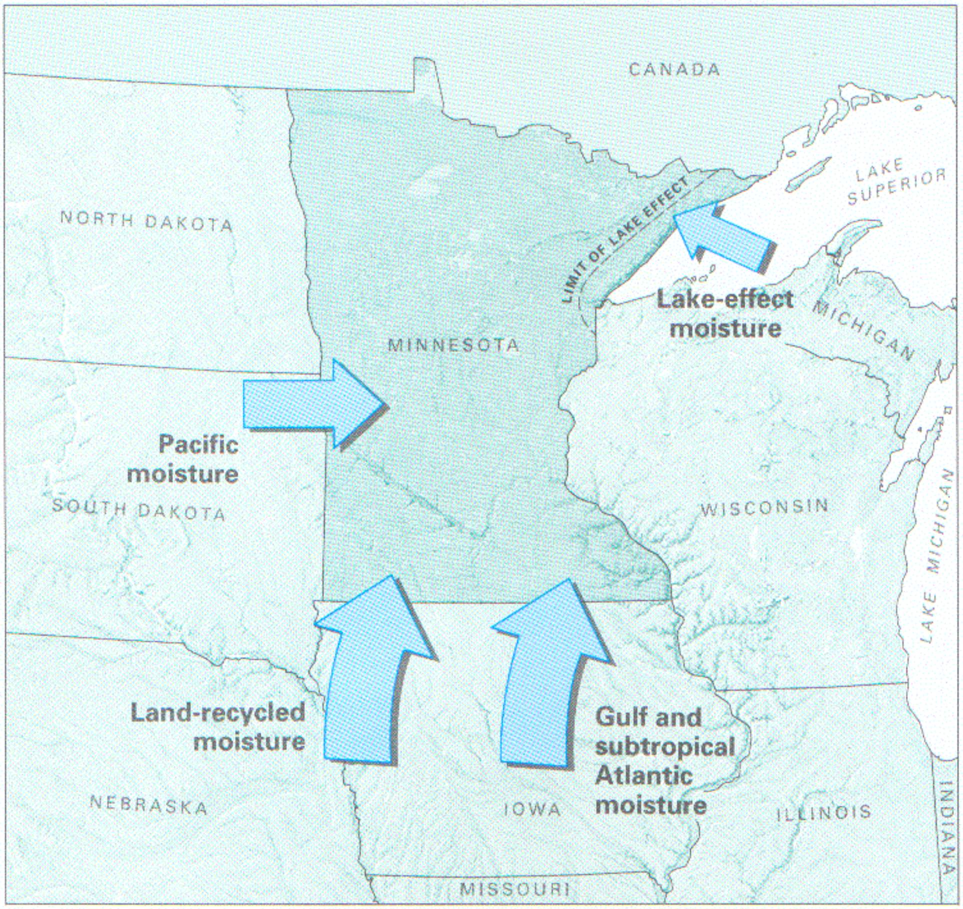


Figure 1. Principal sources and patterns of delivery of moisture into Minnesota. Size of arrow implies relative contribution of moisture from source shown. (Source: Data from Douglas R. Clark and Andrea Lage, Wisconsin Geological and Natural History Survey.)

associated with frontal systems that approach the State from the northwest or southwest. Cyclonic storms that approach from the northwest are common in winter and produce small quantities of precipitation. Cyclonic storms that approach from the southwest occur in the fall, winter, and spring and can bring substantial quantities of rain or snow by drawing moisture northward from the Gulf of Mexico. Cyclonic storms in combination with unstable conditions can produce severe weather and excessive precipitation.

In late spring and summer, thunderstorms are common. These small-scale convective storms typically form because of the presence of unstable, warm, tropical air near the surface and colder air above.

Floods in Minnesota are of two forms—large-scale floods in late winter and early spring and small-scale flash floods in late spring and summer. Large-scale floods generally result from a combination of deep, late-winter snowpack, frozen soil that prevents infiltration, rapid snowmelt due to an intrusion of tropical air, and widespread precipitation caused by cyclonic storms that approach the State from the southwest. Flash floods result from powerful, slow-moving thunderstorms.

Minnesota occasionally has been affected by long-term droughts. Because of the State's location near the northern limit of movement of airmasses from the Gulf of Mexico that bring much of Minnesota's moisture, an interruption of this moisture supply can cause droughts. Dry periods commonly result when a persistent high-pressure system (the Bermuda High) over the southeastern United States blocks the northward transport of moisture from the Gulf of Mexico and facilitates the movement of hot, dry air from the Southwest into the Upper Midwest.

MAJOR FLOODS AND DROUGHTS

Major floods and droughts described herein are those that had large areal extent and significant recurrence intervals—greater than 25 years for floods and greater than 10 years for droughts. These major events, along with those of a more local nature, are listed in table 1; rivers and cities are shown in figure 2. Although historic records indicate extreme floods on major rivers in the 1800's, the floods and droughts discussed herein are limited to those since 1900 for which streamflow records are available.

FLOODS

Data from more than 100 gaging stations were used to determine the areal extent and severity of the five major floods shown in figure 3. Also shown are annual peak discharges for six representative gaging stations, the location of each gaging station, and the associated drainage area. These gaging stations have long periods of continuous record, are currently in operation, and have records that are representative of hydrologic conditions in the major geographic and physiographic areas of the State. Streamflow data for these gaging stations 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).

The graphs in figure 3 include lines drawn at discharges expected to recur at 10-year and 100-year intervals. The probable 1-percent annual flood (100-year recurrence interval) is specified in the National Flood Insurance Act of 1968 and in State flood-plain zoning regulations as a criterion for determining the flood-hazard area along a watercourse. A Hydrology Review Committee confers to determine the discharge having a recurrence interval of 100 years that is appropriate for a flood plain subject to State or Federal regulation. This Committee is composed of representatives of the primary State and Federal agencies involved with water management. Agency-coordinated values for the discharge having a 100-year recurrence interval have been established for many locations, including gaging stations 1, 2, and 4–6 in figure 3. The coordinated values are used for regulatory purposes until the agencies involved reach a consensus that the value should be changed and until a new value is agreed upon.

The five major floods described in this report are among the most severe in Minnesota's history in terms of streamflow magnitude, areal extent, loss of life, and property damage. Four floods (1950, 1965, 1969, 1979) resulted from spring snowmelt in combination with precipitation, and one (1978) resulted from intense summer thunderstorms.

From the fall of 1949 through March 1950, weather conditions conducive to spring snowmelt flooding prevailed. Snowmelt began in late March, but unusual weather conditions prolonged the melt period and brought additional snow and rain. A peak flood discharge of record was observed on the Red Lake River on April 23, 1950, but that was exceeded 13 days later on May 6–7 (fig. 3, site 2) (U.S. Geological Survey, 1952a). The flood discharge peaked on the Little Fork River at Littlefork (fig. 3, site 3) on May 11. The recurrence interval for this flood was 59 years on the Red Lake River at Crookston and 50 years on the Little Fork River at Littlefork.

Figure 2. Selected geographic features, Minnesota.

During the March–May 1950 flood, peak discharges approximated a 100-year recurrence interval on the St. Louis River at Scanlon and on the Mississippi River at Aitkin. Damage was extensive in the communities of Moorhead, Crookston, East Grand Forks, Floodwood, and Aitkin. This flood is described in detail in two reports (U.S. Geological Survey, 1952a,b) that include damage estimates reported by various agencies. Total damage reported in Minnesota was about $16 million.

Weather conditions that produce spring snowmelt floods again developed in the fall of 1964 and persisted through March 1965. Much of the snowpack south of the Twin Cities melted in late February during a warming trend. In southeastern Minnesota, the melting produced some of the largest flows of record the first few days of March 1965 on some Mississippi River tributaries, such as the South Fork Zumbro River at Rochester (fig. 3, site 6). March brought much snowfall to the southeastern one-third of the State. By the end of March, the water equivalent of the snowpack ranged from about 4 inches near Albert Lea to 11 inches near St. Cloud. Spring storms and warmer weather produced 1–3 inches of rainfall during April 3–7, and the combination of rain and melting snow resulted in 4–12 inches of runoff within a few days.

On the Minnesota River, flooding in April 1965 became severe downstream from New Ulm. Large flood flows from the Cottonwood, Blue Earth, and Le Sueur River basins contributed to the peak on the Minnesota River at Mankato (fig. 3, site 4). Damage was greatest in communities near the Minnesota River at Mankato, where several emergency levees failed and in the downstream communities of St. Peter, Henderson, Carver, Chaska, and Savage.

On the Mississippi River, the April 1965 flooding became severe downstream from Aitkin. From Fort Ripley downstream to the southern Minnesota border, the maximum flood stage exceeded any previously recorded. At Elk River, the Mississippi River cut across a horseshoe bend, washed out a highway, and flooded 26 homes. Downstream from the confluence with the Minnesota River, the combined flows produced a peak discharge on the Mississippi River at St. Paul (fig. 3, site 5) that had a recurrence interval greater than 100 years. The associated peak stage of 26.01 feet was the highest at St. Paul since 1851.

During April 1965, peak discharges had greater than a 100-year recurrence interval on the Blue Earth, Le Sueur, Cannon, Crow, and South Fork Crow Rivers, as well as all along the Mississippi River from its confluence with the Minnesota River downstream to beyond the southern Minnesota border. Thirteen lives were lost in Minnesota because of the flood. Damage in Minnesota was estimated at $91.3 million in the Minnesota, Mississippi, and Red River of the North basins (U.S. Army Corps of Engineers, 1966). The Mississippi River basin flood is described in detail by Anderson and Burmeister (1970).

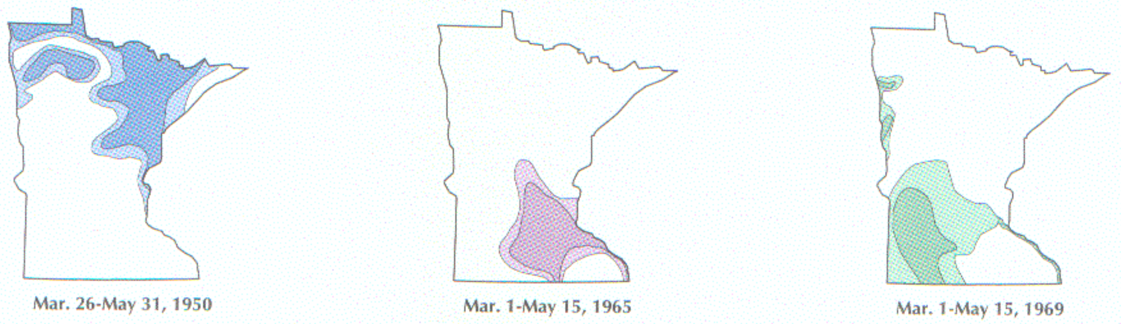
During fall and winter of 1968–69, conditions conducive to snowmelt floods developed in southwestern Minnesota. At the end of March 1969, water content in the snowpack ranged from 3 inches near Mankato to 8 inches at the Minnesota-South Dakota border.

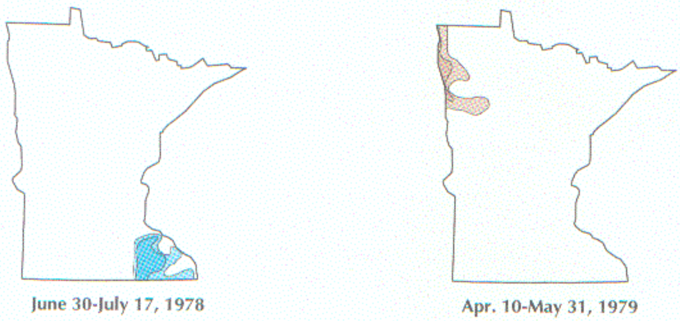
Table 1. Chronology of major and other memorable floods and droughts in Minnesota, 1911–88

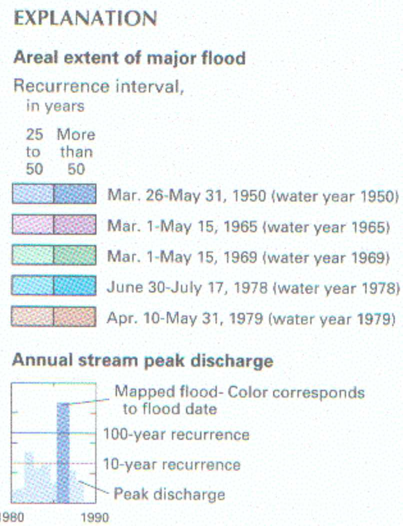
[Recurrence interval: The average interval of time within which streamflow will be greater than a particular value for floods or less than a particular value for droughts. Symbols: <, less than; >, greater than. Sources: Recurrence intervals calculated from U.S. Geological Survey data; other information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

Flood or drought	Date	Area affected (fig. 2)	Recurrence interval (years)	Remarks
Drought	1911–14	Statewide	10 to 30	Most severe in Red River of the North and Mississippi headwaters.
Drought	1921–42	Statewide	60 to 70	Most severe in 1934–37 except in northeast.
Flood	Mar. 26–May 31, 1950	Northern one-half of State	<25 to >100	Snowmelt and rainfall. Damage, $16 million.
Drought	1954–61	Statewide	15 to >50	Most severe in northeastern corner of State.
Flood	Mar. 1–May 15, 1965	Minnesota and Mississippi Rivers.	<25 to >100	Snowmelt and rainfall. Multistate; record stages on Mississippi River. Lives lost, 13; property damage, $91.3 million.
Flood	Mar. 1–May 15, 1969	Red River of the North, Minnesota and Des Moines Rivers.	<25 to >100	Snowmelt and rainfall. Several States designated disaster areas. Lives lost, 9; property damage, $69 million.
Flood	May 27–28, 1970	Downstream tributaries to Cannon and Zumbro Rivers.	<25 to >100	Caused by intense rainfall. Lives lost, 3 by drowning.
Flood	July 21–22, 1972	Central Minnesota from west of Little Falls east to border.	<25 to >100	Largest 24-hour rainfall recorded in Minnesota. Hundreds of road washouts. Lives lost, 3.
Flood	Sept. 20, 1972	Tributaries to Lake Superior along North Shore and in city of Duluth.	<25 to 100	Third and largest "flash flood" to affect Duluth in 1972. Lives lost, 2; property damage, $1 million.
Flood	June 28–July 2, 1975	Red River of the North tributaries near Detroit Lakes and Thief River Falls.	<25 to >100	Agricultural area had much crop damage.
Drought	1976–77	Statewide	10 to 30	Most severely affected areas were Ottertail and Lac Qui Parle River basins.
Flood	Aug. 30–31, 1977	Twin Cities metropolitan area and suburbs.	<25 to 100	Third largest 24-hour rainfall of record in Twin Cities area.
Flood	Sept. 24–25, 1977	Lake Superior tributaries along North Shore.	<25 to 100	Widespread storm from Duluth to Canadian border.
Flood	June 30 to July 17, 1978	Mississippi River tributaries in southeastern Minnesota.	<25 to >100	Flash floods at Rochester and Austin. Lives lost, 5 by drowning; property damage in Rochester, $60 million.
Flood	Apr. 10 to May 31, 1979	Red River of the North and tributaries.	<25 to 70	Second largest since 1882 at Grand Forks, N. Dak., and East Grand Forks, Minn. Property damage, $43.7 million.
Flood	June 16, 1979	Local area between Paynesville and St. Cloud.	<25 to >100	Intense rainfall for 2 hours caused flooding of many roads and basements.
Flood	Aug. 20–21, 1979	Blue Earth and Des Moines River basins.	<25 to >100	Intense thunderstorms south and west of Fairmont.
Flood	June 21, 1983	South-central Minnesota between Willmar, St. Cloud and Buffalo.	<25 to >100	As much as 12 inches of rainfall in 12 hours.
Flood	July 20–21, 23–24, 1987	Twin Cities metropolitan area and suburbs.	<25 to >100	Most rainfall ever recorded in the area. Damage estimates, $25 million; 7,000 homes damaged.
Drought	1987–88	Statewide	Unknown	Generally dry conditions in 1987 became extreme during April–July 1988.

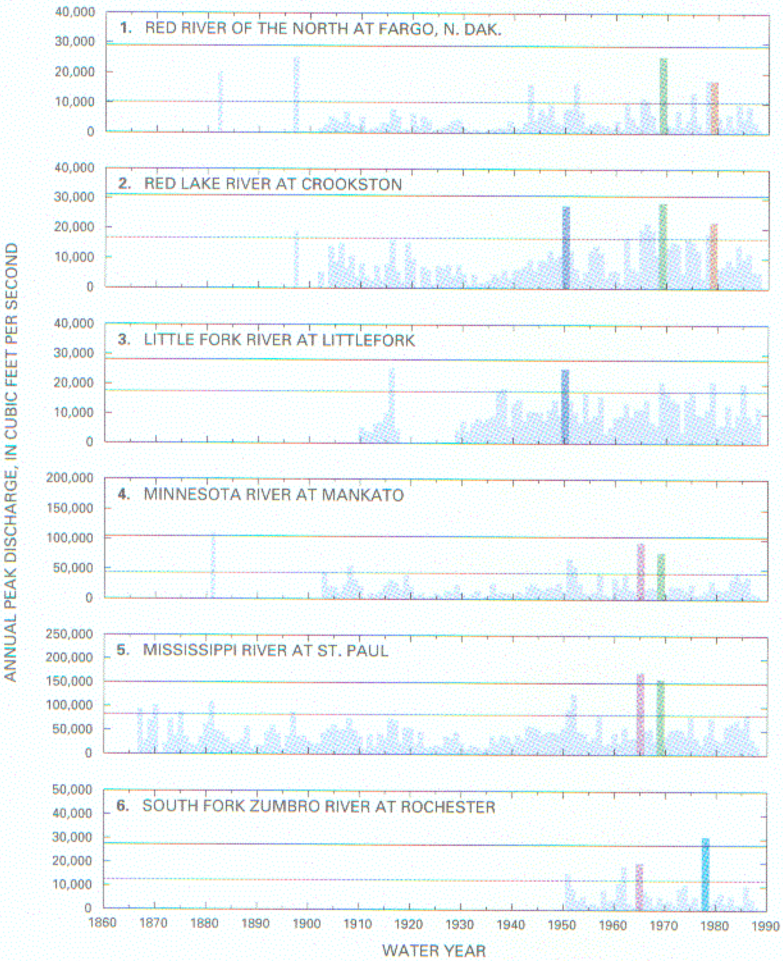
Areal Extent of Floods

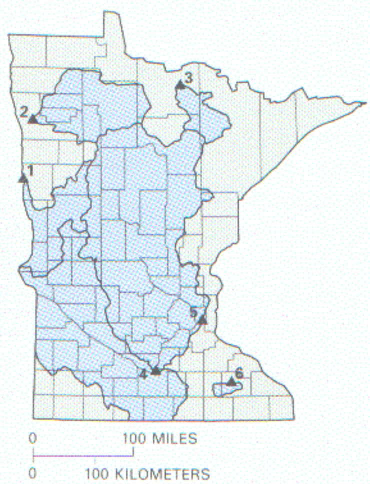






Peak Discharge





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

Figure 3. Areal extent of major floods with a recurrence interval of 25 years or more in Minnesota, and annual peak discharge for selected sites, water years 1867–1988. (Source: Data from U.S. Geological Survey files.)

Homes in Carver, Minn. flooded by overflow from the Minnesota River, April 10, 1965. (Photograph by David B. Anderson, U.S. Geological Survey.)

Sudden warming and rainfall, locally as much as 3 inches during April 7–10, resulted in rapid melting of the snowpack.

In April 1969, severe flooding developed on the Minnesota River downstream from Ortonville. The Minnesota River and tributaries near Montevideo and south, including the Des Moines River basin, were most severely affected (fig. 3). The peak discharge on the Yellow Medicine River near Granite Falls was about 1.2 times the discharge having a 100-year recurrence interval. On the Chippewa River near Milan and on the Minnesota River at Montevideo, the recurrence intervals of peak discharges were about 100 years. Moderate runoff in downstream tributaries to the Minnesota River decreased the relative severity of the flood on the Minnesota River at Mankato (fig. 3, site 4) and farther downstream to a recurrence interval of about 40 years. However, when the Minnesota River floodflow combined with that of the Mississippi River at St. Paul (fig. 3, site 5), the 100-year recurrence interval at St. Paul again was exceeded. Flooding elsewhere was most severe in the Red River of the North basin (fig. 3, sites 1, 2). The recurrence interval of the 1969 flood on the Red River of the North was about 70 years at Moorhead but less than 25 years at East Grand Forks.

Nine lives were lost in Minnesota as a result of flooding in April 1969. Damage was extensive throughout the southwest. Total damage in Minnesota was estimated at $69 million (U.S. Army Corps of Engineers, 1969). This flood is documented in detail by Anderson and Schwob (1970).

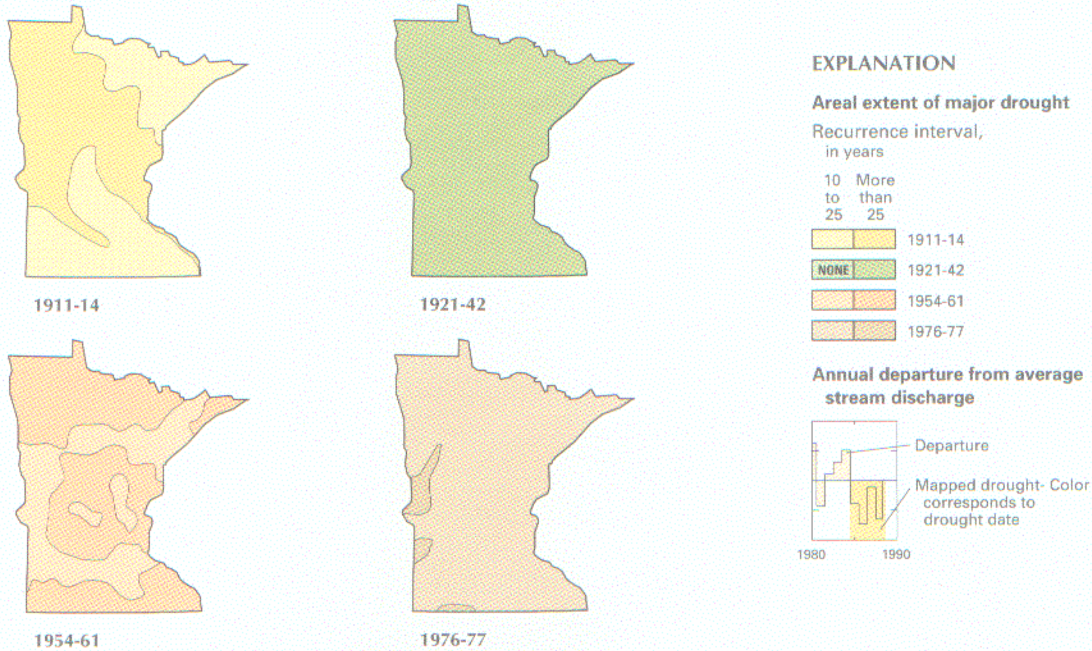
The summer floods of 1978 in southeastern Minnesota resulted from a series of intense thunderstorms. The thunderstorms of June 30–July 1 produced 6–8 inches of rain in 14 hours in seven to nine areas in eastern and southeastern Minnesota (Kuehnast and others, 1988). During July 5, 1978, another storm developed southwest of Rochester and moved generally east-northeastward. At the Rochester airport, the National Weather Service (NWS) gage recorded 5.0 inches of rain in 3 hours. The area of greatest rainfall (more than 6 inches) was centered over the headwaters of the South Fork Zumbro River and the Cedar River.

The resulting flood of July 1978 was catastrophic to the city of Rochester. About one-fourth of the city was inundated. Five people drowned. By noon on July 6, about 5,000 people were evacuated from their homes. Peak discharge on the South Fork Zumbro River at the upstream (southwest) side of the city was 20,500 ft^3/s (cubic feet per second), which is about twice the discharge having a 100-year recurrence interval. The peak discharge of the South Fork Zumbro River at Rochester (fig. 3, site 6) at the downstream side of the city was 30,500 ft^3/s, 1.1 times the discharge having a 100-year recurrence interval for that site. On the Cedar River near Austin, the peak discharge was 10,100 ft^3/s, a new record for 38 years of streamflow record. A third storm in the headwaters of the Cedar River on July 16–17 produced an even greater peak discharge on July 17—12,400 ft^3/s. That discharge had a recurrence interval of about 50 years.

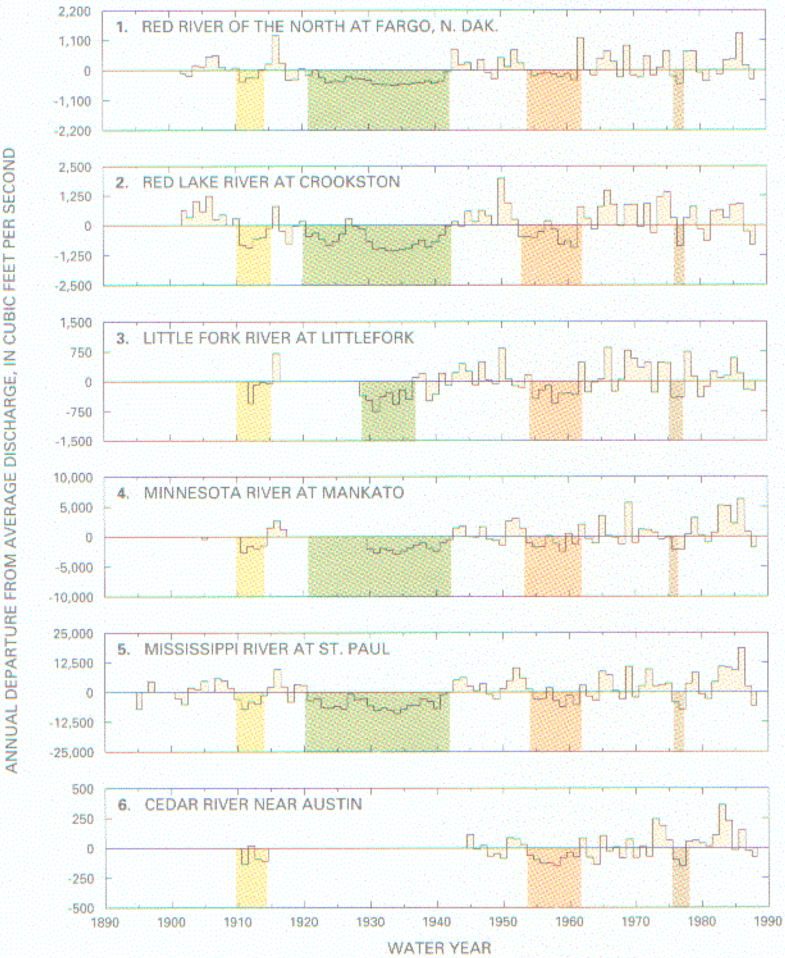
Flood damage for the 1978 floods in Rochester alone has been estimated at $60 million (James Cooper, Minnesota Department of Natural Resources, oral commun., 1988). The flooded area in Rochester and flood data at gaging stations in southeastern Minnesota are reported by Latkovich (1979a,b).

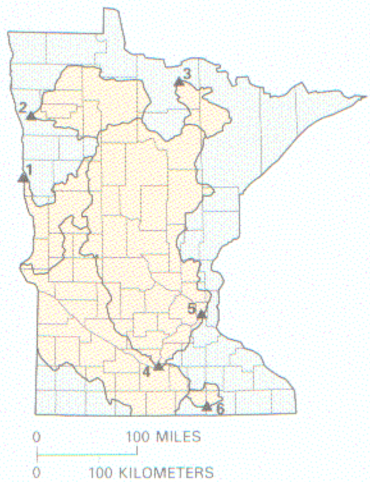
Flood peaks during the April–May 1979 flood on the Red River of the North were the largest of record, or the largest of the century, for most of the area from Halstad north to the international boundary near Noyes. A deep snowpack that had accumulated during winter melted rapidly in early April. In the southern part of the basin, the Red River of the North at Fargo, N. Dak. (fig. 3, site 1), crested on April 19. The flood increased in relative magnitude as it moved downstream. The 1979 peak is the fifth largest of record in the Fargo, N. Dak.-Moorhead, Minn., area (fig. 3, site 1) and at the Grand Forks, N. Dak.-East Grand Forks, Minn., area is exceeded only by the 1897 flood. On the Red Lake River at Crookston (fig. 3, site 2), the 1979 flood is exceeded only by the 1950 and 1969 floods. During the 1979 flood, the Red River of the North was more than 10 miles wide at some areas downstream from East Grand Forks. About 1 million acres of farmland were inundated in Minnesota and North Dakota. Damage due to flooding in Minnesota totaled $43.7 million (U.S.

Areal Extent of Droughts



Annual Departure





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 Minnesota, and annual departure from average stream discharge for selected sites, water years 1895–88. (Source: Data from U.S. Geological Survey files.)

Army Engineer District, 1979). The 1979 flood is documented in detail by Ericson and others (1980).

DROUGHTS

Although droughts are not as sudden as floods, the economic aspects of droughts can be just as significant. Major droughts, as determined from streamflow records collected since the early 1900's, occurred nearly statewide during four periods: 1911–14, 1921–42, 1954–61, and 1976–77. In 1987–88, another significant drought affected Minnesota. The extent and severity of the droughts, as determined from streamflow records collected from a statewide network of gaging stations, are shown in figure 4. Also shown are annual departures from long-term-average streamflow at six selected gaging stations. Records from 39 gaging stations were used in the analysis.

Streamflow records for most gaging stations in Minnesota are incomplete before 1930. However, records are sufficient to show that the 1911–14 drought was statewide but locally differed in duration and intensity (fig. 4). Recurrence intervals for that drought were about 30 years. Little additional information is available. Records show that the drought of 1921–42 also was statewide (fig. 4). However, in the northeast, the drought was broken by 2–3 years of excessive runoff in the late 1920's.

In the annual-departure graphs (fig. 4), droughts are indicated by departures below the line of zero departure. The distance the bar extends below zero and the number of consecutive years the bars are below zero are indications of the relative severity of the drought. As is apparent from figure 4, no other Minnesota drought approaches the magnitude of the 1921–42 drought. Statewide, the recurrence intervals for this drought were 60–70 years.

During the drought of 1954–61, the most severely affected area was the extreme northeastern corner of the State, where the recurrence interval was about 50 years. The drought affected the eastern part of the State throughout the period but was broken temporarily in the Red Lake, Minnesota, and Mississippi River basins by greater than normal runoff in 1957 (fig. 4, sites 2, 4, 5). This drought also was severe in southern Minnesota (fig. 4, site 6).

The 1976–77 drought was widespread and by some measures was exceeded only by the severity of conditions during the 1930's. In the annual departure graphs (fig. 4), the magnitude of departure below normal for 1977 is greater than for any other year outside of the drought period 1921–42 for sites 1, 5, and 6. At sites 1 and 3–6, large negative departures are shown for 1976 as well. The 1976–77 drought began as early as July 1974 in parts of south-central and western Minnesota, as is apparent from the deficient streamflow in the Minnesota River at Mankato (fig. 4, site 4). In spring of 1976, the general lack of precipitation was statewide. Shallow residential and farm wells began to go dry in June. Some municipalities also were affected. Precipitation continued to be much less than normal for the rest of 1976 and gradually returned to normal during the summer of 1977. Recurrence intervals for the 1976–77 drought ranged from 10 to 30 years statewide.

Severe drought again developed in Minnesota in 1987–88. Signs of developing drought are apparent in some of the annual-departure graphs in 1987 (fig. 4, sites 2, 3, 6). Precipitation was less than normal statewide in 1987 with the exception of the Twin Cities area, which received an excess in July, and local areas of excess in the southeast. In the spring of 1988, the general lack of precipitation continued statewide. Daily temperatures were above average, and by mid-July, severe drought conditions had developed throughout all but the northeastern corner of the State. Precipitation for April through July was the second smallest in at least 100 years (Minnesota Department of Natural Resources, 1989). Flow in the Mississippi River decreased to levels experienced only in 1934 and 1976 and prompted the first ban on outdoor water use in St. Paul and Minneapolis. During 1988, temperatures at the Minneapolis-St. Paul Airport exceeded 90 degrees Fahrenheit on 44 days, 8 days more than the old record set in 1936.

WATER MANAGEMENT

Flood-plain and shoreland management programs in Minnesota are administered and enforced by local units of government and the State. The flood-insurance aspect of the programs is administered and enforced by the Federal Emergency Management Agency. Water use is regulated through a permit process administered by the Minnesota Department of Natural Resources, Division of Waters.

Flood-Plain and Shoreland Management.—State laws set minimum provisions and standards for regulation of flood plains and shorelands. Local units of government are required to adopt provisions and standards in their official zoning controls and enforce them at the local level. To qualify for the National Flood Insurance Program, local units of government (communities and counties) are required to adopt the minimum provisions and standards mandated by the Federal laws that govern the program.

Since passage of the Flood Plain Management Act in 1969, 334 community governments (275 municipalities and 59 counties) of the estimated 370 flood-prone communities have adopted flood-plain zoning ordinances. The remaining communities are in the process of adopting such ordinances. Since the Shoreland Management Act was passed in 1969, 85 counties and more than 100 municipalities have adopted shoreland ordinances.

Within State government, the Division of Emergency Management of the Department of Public Safety coordinates disaster response and recovery operations. The Division of Waters of the Minnesota Department of Natural Resources coordinates the Federal Emergency Management Agency's disaster assistance, the flood-hazard mitigation programs, and the National Flood Insurance Program. In addition, this Division provides technical information on flood-plain studies, provides technical assistance for developing community flood-plain and shoreland ordinances, monitors flood-plain and shoreland development, and oversees ordinance enforcement. Finally, this Division provides as much as 50 percent of the funding for flood-hazard mitigation projects to local units of government.

Flood-Warning Systems.—In Minnesota, the flood-warning system involves State and Federal agencies as well as local units of government. The NWS provides flood information through the National Warning System to the State Patrol and to the Bureau of Criminal Apprehension, and those agencies notify the affected counties. The NWS also disseminates information through the Weather Wire and the Weather Radio. The State Division of Emergency Services receives flood information from the NWS and notifies State officials.

Water-Use Management During Droughts.—Minnesota statutes define water-use priorities for allocating water among users in times or areas of limited supply and conflicting uses. The greatest priority is assigned to domestic water supply and to consumptive uses of less than 10,000 gal/d (gallons per day). Lower priority is assigned to industrial and commercial uses of municipal water supply, to processing of agricultural products, and to consumptive uses in excess of 10,000 gal/d. The Commissioner of the Department of Natural Resources has the authority to establish protected flows and protection altitudes and to suspend appropriation permits when conditions are less than the established protected flow or protection altitude. During periods of critical water deficiency, public water-supply authorities are required to adopt and enforce water-use restrictions or risk having their appropriation permit modified. The Department of Natural Resources, Division of Waters also is responsible for investigation and solution of well-interference complaints.

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Prepared by G.H. Carlson, U.S. Geological Survey; "General Climatology" section by James A. Zandlo, Minnesota Department of Natural Resources, Division of Waters, State Climatology Office; "Water Management" section by David B. Milles and Ogbazghi Sium, Minnesota Department of Natural Resources, Division of Waters, Permits and Land Use Section

FOR ADDITIONAL INFORMATION: District Chief, U.S. Geological Survey, 702 Post Office Building, St. Paul, MN 55101