Overview of Drought and Hydrologic Conditions in the United States and Southern Canada, Water Years 1986–90

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Looking northeast and upstream at the starboard stern section of the steamboat, with keelson, hull framing, and sternpost assembly on June 24, 1988. The wreckage (ca. 1910–30) was revealed by the record-low water level in the Mississippi River. Note the gudgeon strap and hole (extreme right on stern) for mounting one of several rudders. The paddlewheels would have been turning immediately behind and above these rudders. The bridge in the background carries I-55 across the Mississippi River to Memphis, Tenn., on the upper right. (Photograph by Leslie C. Stewart-Abernathy and published with permission.)

Overview of Drought and Hydrologic Conditions in the United States and Southern Canada, Water Years 1986–90

By SANDRA L. HOLMES

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WATER-RESOURCES CONDITIONS IN THE UNITED STATES AND SOUTHERN CANADA

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PREFACE

This report is the second in a series by the U.S. Geological Survey to provide the public with summary information about water-resources conditions in the United States and southern Canada and is for water years 1986–90. The first report, entitled "Monthly Streamflow and Ground-Water Conditions in the United States and Southern Canada, Water Years 1945–85," was published as Water-Supply Paper 2314, but will be redesignated Water-Supply Paper 2314–A when it is reprinted.

Successive reports in the series, each for periods of 5 water years, are designated as chapters under the volume title "Water-Resources Conditions in the United States and Southern Canada." Each chapter has a title that reflects the content of the report and presents the maps depicting monthly streamflow conditions for the 5 years covered by the chapter.

SLH

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FIGURES

FIGURES—Continued

CONVERSION FACTORS AND VERTICAL DATUM

For readers who wish to convert measurements from the inch-pound system of units of the metric system of units, the conversion factors are listed below:

Multiply	By	To obtain
acre	0.004047	square kilometer
	4,047	square meter
acre-foot	1,233	cubic meter
cubic foot per second	0.02832	cubic meter per second
foot	0.3048	meter
gallon per minute	0.00006309	cubic meter per second
inch	0.0254	meter
mile	1.609	kilometer
	1,609	meter
million gallons per day	0.04381	cubic meter per second
square mile	2.590	square kilometer
	2,590	square meter
	Temperature	
degree Fahrenheit (°F)	°C = 5/9 X (°F −32)	degree Celsius (°C)

Sea level: In this report, "sea level" refers to the 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 Sea Level Datum of 1929.

Overview of Drought and Hydrologic Conditions in the United States and Southern Canada, Water Years 1986–90

By Sandra L. Holmes

Abstract

This report describes the drought and hydrologic conditions in the United States and southern Canada during the 1986–90 water years. This drought, which spread from the Eastern United States, where it was referred to as "the drought of the century," through the Midwest to the West Coast, brought to mind the Dust Bowl era of the 1930's. However, generally localized floods were numerous, but only one hurricane (Hugo) was of any consequence to the United States, Puerto Rico, and the Virgin Islands during a coincident period of anomalously low hurricane activity.

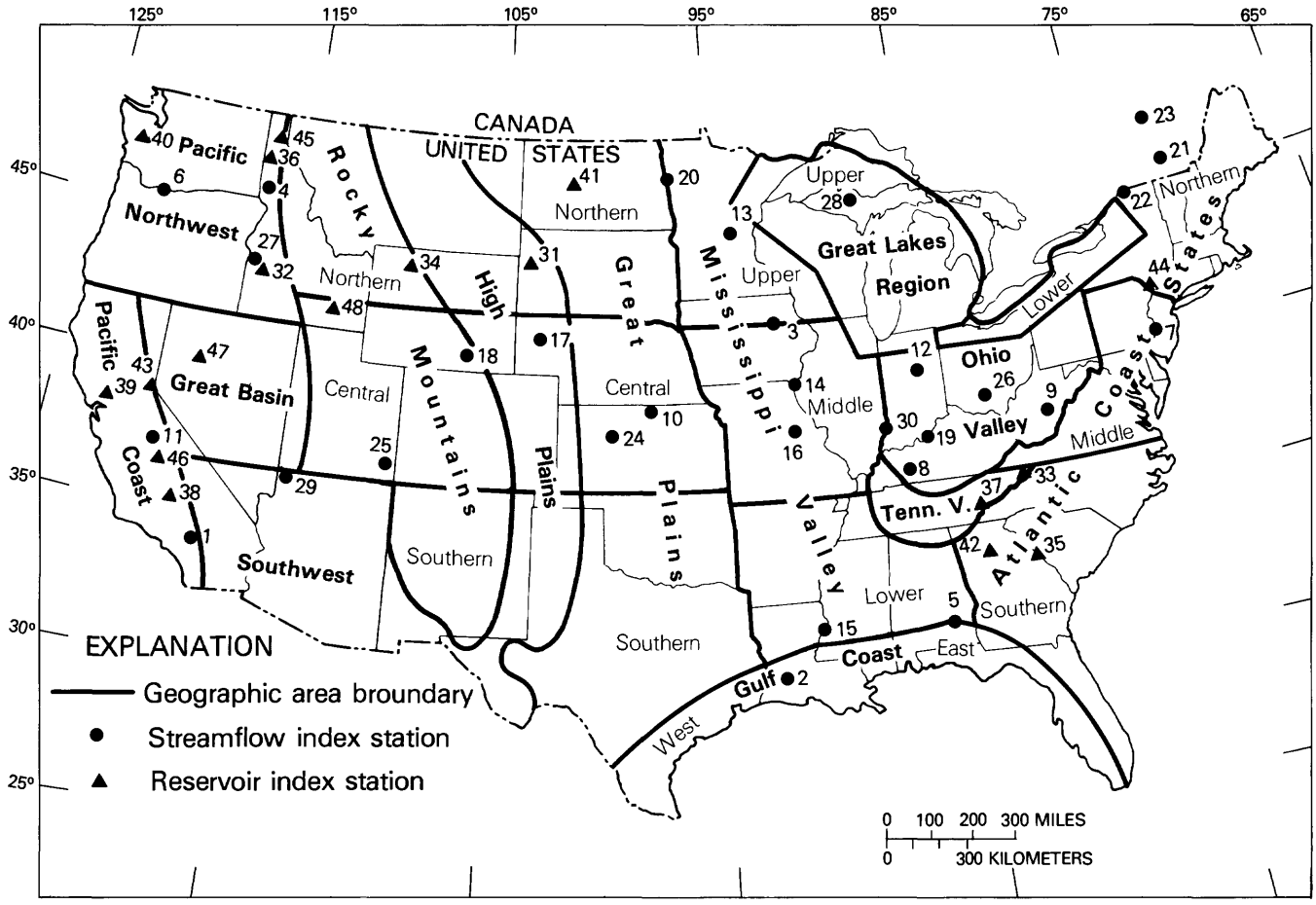
The drought began in early 1984 as an "agricultural drought," which is a precipitation deficiency that results in a lack of soil moisture that is detrimental to agricultural production. This condition did not affect streamflow until about March or April 1986. A "hydrological drought," which is far more serious and widespread than an agricultural drought, was apparent from the low streamflow conditions that occurred after April 1986. To illustrate the changing nature of the drought, maps and synopses of monthly hydrologic conditions for the water years 1986–90 are presented.

INTRODUCTION

This report describes hydrologic conditions in the United States and southern Canada during the 1986–90 water years. The report focuses on drought conditions that spread from the Eastern United States, where it was referred to in the news media as "the drought of the century," through the Midwest to the West Coast. The plight of farmers, their dessicated crops and starving cattle, brought to mind the Dust Bowl era of the 1930's. During the 1986–90 drought, however, localized floods caused by intense rainfall from thunderstorms or stalled low-pressure centers were numerous. Few hurricanes approached the United States during this 5-year period, but one that moved inland—Hugo—brought little precipitation. The destruction caused by Hurricane Hugo in September 1989 is discussed in the section on the 1989 water year later in this report.

The drought began in the Eastern United States early in 1984 as a precipitation deficiency that resulted in a lack of soil moisture injurious to agricultural production ("agricultural drought"); streamflow was not affected until about March or April 1986. The effects of agricultural drought conditions on streamflow might not be apparent because of rapid increases in runoff caused by localized storms or snowmelt or releases from impoundments, none of which alleviate drought conditions. Agricultural drought conditions can occur frequently and for short durations (for example, one spring and summer or 1 year) and can affect only a small area of the country at any given time. However, a "hydrological drought," which is apparent as a result of extreme low-flow conditions, indicates a far more serious and widespread condition than an agricultural drought. For purposes of this report, the term "drought" is used for both situations. The geographic boundaries of areas affected by the drought as well as streamflow and reservoir index stations specific to this report are shown in figure 1.

The measurement of streamflow and collection of ground-water data have been integral functions of the U.S. Geological Survey (USGS) since the late 1800's. The monthly publication, "National Water Conditions," provides information quickly to the public on the status of surface- and ground-water resources of the United States and southern Canada (water resources are not influenced by political boundaries). The map on the cover of each issue, which is compiled on the basis of data from about 180 stations in southern Canada and the conterminous United States, graphically displays streamflow data relative to normal (long-term median) for that month; ground-water and reservoir-storage data are discussed only in the text. These monthly streamflow maps, each of which is accompanied by a synopsis, cover water years 1986–90 and are reproduced herein. (A water year begins October 1 and ends September 30 of the following year and is designated by the year in which it ends.) These maps (figs. 2–61) show the magnitude and shift in location of the drought from east to west during the 5 water years. The maps and synopses for water years 1945–85 are contained in



Streamflow index stations

1. Arroyo Seco near Pasadena, Calif.
2. Calcasieu River near Oberlin, La.
3. Cedar River at Cedar Rapids, Iowa
4. Clearwater River at Spalding, Idaho
5. Conecuh River at Brantley, Ala.
6. Columbia River at The Dalles, Oreg.
7. Delaware River at Trenton, N.J.
8. Green River at Munfordville, Ky.
9. Greenbrier River at Alderson, W. Va.
10. Little Blue River near Barnes, Kans.
11. Merced River at Happy Isles Bridge near Yosemite, Calif.
12. Mississinewa River at Marion, Ind.
13. Mississippi River near Anoka, Minn.
14. Mississippi River at Keokuk, Iowa
15. Mississippi River at Vicksburg, Miss.
16. Missouri River at Hermann, Mo.
17. Niobrara River above Box Butte Reservoir, Nebr.
18. North Platte River near Sinclair, Wyo.
19. Ohio River at Louisville, Ky.
20. Red River of the North at Grand Forks, N. Dak.
21. St. Francois River at Hemmings Falls, Quebec, Canada
22. St. Lawrence River at Cornwall near Massena, N.Y.
23. St. Maurice River at Grand Mere, Quebec, Canada
24. Saline River near Russell, Kans.
25. San Juan River near Bluff, Utah
26. Scioto River at Higby, Ohio
27. Snake River at Weiser, Idaho
28. Sturgeon River near Sidnaw, Mich.
29. Virgin River at Littlefield, Ariz.
30. Wabash River at Mount Carmel, Ill.

Reservoir index stations

31. Belle Fourche, S. Dak.
32. Boise River System (four reservoirs), Idaho
33. Boone (Holston Projects), Tenn.
34. Buffalo Bill, Wyo.
35. Clark Hill (Strom Thurmond Lake), S.C.-Ga.
36. Coeur d'Alene Lake, Idaho
37. Douglas Lake, Tenn.
38. Isabella, Calif.
39. Lake Berryessa, Calif.
40. Lake Cushman, Wash.
41. Lake Sakakawea (Garrison), N. Dak.
42. Lake Sidney Lanier, Ga.
43. Lake Tahoe, Calif.-Nev.
44. New York City Reservoir System, N.Y.
45. Pend Oreille Lake, Idaho
46. Pine Flat, Calif.
47. Rye Patch, Nev.
48. Upper Snake River System (eight reservoirs), Idaho-Wyo.

Figure 1. Geographic areas and selected streamflow and reservoir index stations in the United States and southern Canada.

U.S. Geological Survey Water-Supply Paper 2314 (Holmes, 1987).

Unless otherwise indicated, data used in preparing this report were taken from the National Oceanic and Atmospheric Administration's (NOAA) reports entitled "Great Lakes Water Levels," "Daily Weather Maps, Weekly Series," and "Weekly Weather and Crop Bulletin," which is prepared and published jointly with the U.S. Department of Agriculture (USDA); from the USDA's "Snow-Precipitation Update"; and from the USGS's "National Water Conditions." Geographic designations generally conform to usage in the "Weekly Weather and Crop Bulletin" (fig. 1).

Explanation of Data

The maps (figs. 2–61) show the generalized streamflow patterns (above-normal range, normal range, below-normal range) nationwide from October 1985 through September 1990. Streamflow for each month is compared with normal for the same month in the 30-year base period. For the period covered by this report, the base period is water years 1951–80. Streamflow is considered to be in the below-normal range if it is less than the lower quartile of flows that occurred during the base period; streamflow is considered to be in the above-normal range if it is greater than the upper quartile of the flows that occurred during the base period. Flows greater than the lower quartile but less than the upper quartile are considered to be within the normal range. The upper and lower quartiles are values that set off the highest and lowest 25 percent of flow, respectively, for the base period. The flow depicted on the maps is obtained by ranking the daily flows for each month of the base period in order of magnitude: The highest daily flow is number 1, the lowest flow is number 30, and the average of the 15th and 16th flows is normal.

About 100 index reservoirs and reservoir systems are in the conterminous United States and southern Canada. These large reservoirs, many of which are multiple-use, store water for public supply, irrigation, power generation, recreational use, and maintenance of streamflow for fish habitat and migration. Reservoir contents, which are useful indicators of hydrologic conditions, are reported at the end of each month as "usable" storage levels.

Ground-water levels, which are not shown on the maps but are discussed in the text, refer to water-level conditions near the end of each month. The water level in each index well (selected well sites in different parts of the country) is compared with its daily average level for the end of the same month. The average level is determined either from a 30-year base period or, if only limited records are available, from the entire historical record for that well.

Seasonal Patterns of Precipitation and Streamflow

Highest and lowest streamflows generally occur seasonally. Because spring is the season of high levels of soil moisture, conditions are favorable for high flows caused by runoff from rain falling on saturated soils. For example, increasing rainfall in the Midwest and the East generally causes high flows from January through March in the Gulf Coast States, in March and April in the Midwest, and usually in April and May in the eastern Provinces of Canada. Florida is an exception because its rainy season generally extends from June to October; therefore, streams have their highest flows in October.

Topography also influences streamflow. Highest flows in streams in the North and in mountainous areas typically are caused by melting of the accumulated snowpack during spring. Snowmelt reaches its maximum with the arrival of warm weather. In the Southwestern United States, snowmelt occurs in April and May. In Canada, snowmelt peaks in July. In the Pacific Coast States, however, peaks of flow are common during midwinter because warm heavy rains fall on moderate-to-low snowpack and melt the snow; this combination of rain and snowmelt can produce large floods.

Streamflow is lowest in late summer and fall in the East and along the West Coast and in winter in the Northeast. In the Great Plains region, low winter streamflow is caused by a lack of rainfall in the area, whereas in mountainous regions and in Canada, winter streamflow is low until snowmelt occurs in the spring.

PRELUDE TO DROUGHT

Notwithstanding precipitation and consequent streamflow in the Northeast, the seasonal patterns described above had, early in water year 1985, already been so deficient as to result in the declaration of a drought emergency by the Delaware River Basin Commission (DRBC) on May 13, 1985 (Holmes, 1987, p. 1). The Delaware River basin supplies water for New York City and a large area of Pennsylvania. Because of concerns about the severity and duration of the drought, the declaration was not lifted until December 18, 1985. At that time, the contents of New York City's reservoir system were still slightly below average, but streamflow had recovered to a normal range for the season because above-average rainfall during November 1985 created wetter-than-average conditions in most of the East.

By the end of the 1985 water year, other indicators of the drought included streamflow that was below the lower quartile of historical flow record in Maine; persistent low streamflow in the Mid-Atlantic region, the Southeast, the northern Rocky Mountains, and parts of California; and record-low flow in the Columbia River at The Dalles, Oreg. Water use was restricted in New York City and vicinity,

and in areas in Massachusetts, Pennsylvania, New Jersey, Maryland, Virginia, and Florida.

Precipitation deficits for calendar year 1985 fluctuated widely from more than 2 inches in Lewiston, Idaho; 5 inches in Salisbury, Md., and Sacramento, Calif.; 6 inches in the Washington, D.C., metropolitan area; 7 inches in Omaha, Nebr., and Portland, Maine; 9 inches in the Seattle-Tacoma area, Washington; 10 inches in Savannah, Ga., and Portland, Oreg.; 11 inches in West Palm Beach, Fla.; to 14 inches in Nashville, Tenn. The deficits indicated that the East was in a serious drought, and the deficits in the Midwest and Western States would turn out to be a harbinger of drought for those areas.

STREAMFLOW CONDITIONS DURING THE DROUGHT YEARS

1986 Water Year

[Figs. 2–13]

During water year 1986 in the Southeast, the mild winter, which was followed by a balmy spring, was the result of a seasonally anomalous jet-stream pattern. The jet stream, which normally would have been flowing across Mexico and bringing moisture from the Gulf of Mexico, had already retreated toward the Canadian border (most precipitation occurs near the track of this massive air flow). Consequently, the Midwest, New England, and Canada received the precipitation.

While the worst drought in more than a century was affecting large parts of the Southeast, other parts of the Nation also were dry. Central Wyoming was extremely dry, but it was only a small part of a much larger area of agricultural dryness that included most of Montana, Kansas, Colorado, and Nebraska. Other dry areas included the junction of California, Nevada, and Arizona and the border of Wisconsin and the Upper Peninsula of Michigan.

By April, most of the United States east of the Mississippi River was dry. Fires in Tennessee had consumed 56,000 of the State's 12 million acres of forest. In the normally humid, moist East, where agricultural crops and pasturelands are rarely irrigated because rainfall is usually sufficient for growth, farmers planted fewer crops than usual and hoped for more rain. For the normally rainy season in the Southeast (January 1–April 30), rainfall deficits ranged from 9 inches in Macon, Ga.; 9.5 inches in Huntsville, Ala.; 10 inches in Blue Ridge, N.C.; 10.5 inches in Columbia, S.C.; 12 inches in Atlanta, Ga., and Nashville, Tenn.; 13 inches in Jackson, Miss.; 15.5 inches in Birmingham, Ala.; to 16.5 inches in Columbus, Miss.

During April, streamflows decreased sharply in much of the United States east of the Mississippi River. The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—was 789 billion gallons per day, which is 14 percent below the long-term April average; this is an indication of the dry conditions in parts of the Nation. These "Big Three" rivers drain more than half of the conterminous United States, and their flows provide a quick check on the overall condition of the Nation's surface-water resources. The below-normal combined flow was caused, in part, by decreased flow in the Mississippi River (30 percent below the long-term normal for April and 14 percent below the March 1986 flow) and record-low April flow in the Ohio River at Louisville, Ky. (at 48 billion gallons per day, the lowest April flow in 58 years of record), which is a major contributor of streamflow to the Mississippi.

Heavy rains in the Midwest in April increased streamflow in north-central Kansas but did little to alleviate low flows elsewhere in the State. In western Kansas, contents of reservoirs that are used primarily for irrigation remained substantially below irrigation-pool levels. In California, most streamflows were in the normal range.

As summer 1986 progressed, the drought intensified in the Southeast, as indicated by persistent below-normal streamflow conditions. More than 16,000 acres of brush and forest burned in North Carolina from May 5 to 9. Groundwater levels in most index wells in the Southeast continued to decline, crops continued to be distressed, and contents of reservoirs continued to decline, which caused reduced power generation in many hydropower systems; for example, Tennessee Valley Authority (TVA) officials reported a 50-percent reduction in power production by midyear. Dissolved-oxygen concentrations were extremely low in several Tennessee reservoirs, and bacterial contamination in the upper part of Boone Reservoir and in the Sinking Creek Embayment of Fort Loudon Reservoir forced Tennessee State authorities to post a warning against recreational use of those waters (J.L. Cook, U.S. Geological Survey, written commun., July 1986).

By July, the Southeast was also in the midst of a sustained heat wave. Many areas placed restrictions on outdoor water use, most restaurants served water only on request, and the news media reported that some North Carolina communities restricted indoor water use, such as curtailing the length of time of showers. During July and August, thousands of tons of hay, which had been donated by farmers from New England to the Great Plains, were sent to farmers in the Southeast to alleviate severe shortages of hay needed to feed their cattle.

By mid-August, Tropical Storm Charley, which had hovered for 3 days off the East Coast centered about 90 miles south-southeast of Wilmington, N.C., began to drift toward the northeast. Tropical Storm Charley was upgraded to hurricane status on August 17. Because it had sustained winds of only 75 miles per hour, it was barely classified as a category 1 storm on NOAA's Saffir-Simpson Hurricane Scale. The thunderstorms that were spawned by

Hurricane Charley brought some much-needed rain to the coastal areas of the Southeast, primarily in the area from the Outer Banks, N.C., to Ocean City, Md. By the time the storm veered to the northeast off Ocean City on August 18, Hurricane Charley was downgraded to tropical storm status. Wind damage from the hurricane was scant because it did not come ashore, and coastal areas were closest to the western side of the storm where winds were weakest.

By September, streamflows across most of the Nation were generally normal to above normal, except for below-normal streamflow conditions that persisted over most of the Southeast. For the first time since February 1986, however, no new record-low flows were set in the Southeast. In the Mid-Atlantic region, streamflows throughout Maryland and Delaware were extremely low for September.

Localized floods occurred at the end of September and continued into October in Montana and in a broad area that extended from Oklahoma eastward into western Pennsylvania. Flows in two of the Big Three rivers in the United States were above normal for the month (Mississippi River at Vicksburg, Miss., and St. Lawrence River at Cornwall, Ontario, Canada); flow in the third (Columbia River at The Dalles, Oreg.), however, averaged 50 billion gallons per day, which is 20 percent below the long-term normal flow for September.

Of the 100 index reservoirs in the conterminous United States and southern Canada, the only reservoirs that recorded significant declines in contents or below-average contents at the end of September were Clark Hill (renamed "Strom Thurmond Lake" in December 1988) along the South Carolina-Georgia border, Douglas Lake in the Tennessee Valley, Lake Cushman in Washington, Pend Oreille Lake in Idaho, and Buffalo Bill in Wyoming. The reservoirs in western Kansas that are used primarily for irrigation remained well below irrigation-pool levels.

1987 Water Year

[Figs. 14–25]

Early in water year 1987, nationwide precipitation temporarily alleviated drought conditions, especially in surface soil moisture. November 1986 was unusually wet, but most of the high streamflows were in the northern Great Plains and the West. For example, flow of the San Juan River near Bluff, Utah, was the highest in 71 years of record. In contrast, flow in the Columbia River at The Dalles, Oreg., which continued to be low, was 15 percent below the long-term normal flow for December. Two reservoirs, Lake Cushman in Washington and Coeur d'Alene Lake in Idaho, continued to record significantly below-average contents, which reflected inadequate inflow and continuing dry conditions in that area. By the end of December in the drought-affected Southeast, streamflow had increased to normal or above-normal flows. In southwestern Florida, however, water restrictions were implemented December 12 in parts of Lee and Collier Counties because of low groundwater levels.

For the first time in a decade, California State water-resources officials began in January 1987 to talk about a major drought. More than midway through that State's rainy season, measurements of snowpack, precipitation, and reservoir storage indicated that the western slope of the Sierra Nevada in California, which is the source of most of that State's surface-water supply, would likely be dry—the snowpack was only 30 percent of average. In Idaho, the snowpack was estimated to be 50 percent of average.

As had happened the year before in the Eastern United States, the pattern of precipitation in the Western United States was not consistent during 1987. A mild winter, premature melting of the less-than-average snowpack, and below-average spring rainfall contributed to low streamflows throughout Idaho, Montana, Washington, Oregon, Nevada, and California. In Idaho, no rain fell at all during April, which established a historic precedent. The water-supply situation in Idaho was further exacerbated by abnormally low reservoir storage; irrigation depends on releases from storage.

In Oregon, USGS hydrologists were able to reach the stage and temperature station at Crater Lake on May 22, which is the earliest that the gage has ever been accessible. The station is usually snowed-in until the last of June or the first part of July. The lake elevation reading showed that the lake had declined 0.10 foot during winter 1986–87; this was another indication of the dry conditions in the region (T.J. Conomos, U.S. Geological Survey, written commun., July 1987).

Throughout the West, streamflows were well below normal during water year 1987. Some of the most extreme low flows occurred in southern Idaho (Hubbard, 1987, p. 8). In Oregon, flow in the Columbia River at The Dalles set a new record low of 42 billion gallons per day for September. Reservoir storages were depleted, especially those used for irrigation. By the end of the water year, forest fires in the West had consumed more than 500,000 acres in northern California and 100,000 acres in Oregon (Hubbard, 1987, p. 16).

In the East and parts of the Southeast, snow accumulations from major storms that occurred on January 22 and 25 ranged from about 1 foot through the New England area to 29 inches in the Washington, D.C., metropolitan area. On February 22, another storm deposited from 1 to 1.5 feet of snow in the Mid-Atlantic area. Patrick J. Michaels, Virginia State Climatologist, reported that some low-lying areas in southwestern Virginia might have received snow in excess of 100 inches during January and February (Virginia Water Resources Research Center, May 1987, p. 3). Because moderating air temperatures followed each storm, most of the snow evaporated, soaked into the dry soil, or drained off so slowly that streamflows did not appreciably increase.

Because the snowmelt increased topsoil moisture, spring-planted crops were harvested successfully.

In addition, the summer heat wave killed more than 1 million chickens in the Southeast and Mid-Atlantic States. Then, beginning with the Labor Day holiday weekend, this parched region was deluged by a series of thunderstorms, the last of which occurred on September 12. Rainfall totals ranged from less than 3 inches to a high of almost 12 inches. The heaviest rainfall and worst flash flooding were in the western Piedmont of Virginia.

Because the fall rains increased topsoil moisture, soybeans and other fall crops were successfully harvested. Forestlands were still dry, however, and, late in water year 1987 and continuing into water year 1988, smoke from forest fires as far away as West Virginia and Kentucky reduced visibility in Washington, D.C.

1988 Water Year

[Figs. 26–37]

During fall and winter of water year 1988, precipitation was below-average nationwide. In the West and in British Columbia, Canada, snowpacks were below average. A massive high-pressure system that formed in the Pacific Ocean off the Pacific Northwest prevented Pacific storms from entering the region. The jet stream split: One part flowed across Mexico and the other part across Canada, which deprived the Central and Southeastern States of precipitation.

In the Pacific Northwest, the snowpack was only 50 to 80 percent of average. In the Midwest, the 0.74 inch of precipitation recorded at the Lincoln, Nebr., airport for the first 3 months of calendar year 1988 was the second driest first quarter since recordkeeping began in 1878.

By the end of March, drought conditions had persisted for 12 consecutive months in the Northwest and for 6 consecutive months in the Southeast. Record-low March flows occurred at all 11 streamflow index stations in the Southeast (excluding the Gulf Coast and Florida), at one station in Idaho, and at one station in far northern California.

Of the Big Three rivers in the United States, flow during March in the Mississippi was 15 percent below normal and flow in the Columbia was 36 percent below normal. Only the St. Lawrence River had flow above normal—4 percent. In southern Canada, streamflow data from the 18 index stations, most of which are in the east, indicated flows below normal for 10 of 11 months, May 1987 through March 1988; above-normal flow occurred during December 1987.

The cumulative effects of many months of below-average precipitation and below-normal streamflow affected contents of reservoirs, particularly in the West. Of the 25 index reservoirs in California, Idaho, Montana, Nevada, Washington, and Wyoming, 18 recorded below-average contents in storage at the end of March.

As spring progressed into summer, below-average precipitation persisted over most of the Nation. Precipitation from January to June in Iowa was only 47 percent of average; this was the driest 6-month period in 116 years of record. The high-pressure system that had been off the Pacific Northwest settled in over the Midwest, where it stayed until late July/early August. Drought, coupled with record-high temperatures during mid-June, so stressed the corn and soybean crops that Iowa Department of Agriculture agronomists rated 21 percent of these crops poor and 57 percent fair.

In the Southeast, streamflows ranged from 22 to 50 percent of normal during May and June in Alabama, Arkansas, Georgia, Louisiana, and Tennessee. Drought warnings were issued and water use was restricted by State and local officials in Alabama, Georgia, Mississippi, and Tennessee.

In the Midwest, streamflows ranged from 10 to 30 percent of normal at the end of June in many river basins in the southeastern part of Nebraska, whereas in Kansas, drought conditions prevailed where streamflows were less than 35 percent of normal. At St. Louis, Mo., flow of the Mississippi River on June 24, 1988, was only 63,400 cubic feet per second; this was the second lowest June daily flow in 55 years.

In the West, streamflows were affected by less-than-average snowmelt and precipitation. In Montana, runoff from melting snow occurred 2 to 3 weeks earlier than usual because late spring/early summer temperatures were above average. In Wyoming, runoff was estimated to be about 50 percent of normal.

The Western States most affected by the drought, however, were California, Oregon, Washington, and Idaho. Most of this area was under stringent measures to conserve water; some cities cut back to about half of the water supplied in previous years. In California, Nevada, Arizona, and drier parts of Oregon and Washington, irrigated agriculture predominates, but crop harvests were less than average as a result of less-than-optimum amounts of irrigation water.

By the end of June, the combined flow in the Nation's Big Three rivers in the United States had set a new record low for the month in 59 years of record—45 percent below normal. Flow in the St. Lawrence River at Massena, N.Y., was 11 percent below the normal flow for June for the 59-year period of record. Flow in the Columbia River at The Dalles, Oreg., was 42 percent below normal, which was the fourth lowest flow in 60 years. In the Mississippi River at Vicksburg, Miss., flow was 61 percent below normal, which was the lowest flow of record; the old record was set in 1934 during the Dust Bowl era. Flows in two other major rivers that provide inflow to the Mississippi River also reflect the drought conditions: the Ohio River at Louisville, Ky., was 59 percent below normal and the sixth lowest flow for 60 years of record, and the Missouri River at Hermann, Mo.,

was 46 percent below normal and the third lowest flow since recordkeeping began in 1898.

Michael Weisskopf reported in the *Washington Post* newspaper (June 28, 1988) that dredging kept barge traffic moving intermittently on the Mississippi River, which was closed to traffic at Memphis, Tenn., for 3 days during the week of June 19, 1988, and from June 25 to 26 at St. Louis, Mo. When a narrow channel was opened June 27, St. Louis area officials alternated upriver and downriver traffic until a 35-tow backlog at St. Louis was cleared. Weisskopf also reported that Atlanta, Ga., water department employees patrolled the city streets looking for violators of the 9-hour-per-day ban on outdoor water use and that the TVA's 29 hydroelectric plants were operating at only 55 percent of capacity because the plant reservoirs, which are filled by flow from the Tennessee River, were 40 feet below average levels.

Because the outflow from the Mississippi River was so slow, a saltwater wedge migrating upstream from the Gulf of Mexico at about 2 miles per day was detected June 28 at river mile 78. The municipal water supply intake for the city of New Orleans is at river mile 104. The Corps of Engineers built a saltwater barrier (sill) at the bottom of the river channel just south of New Orleans to prevent saltwater contamination of the water supply (J.L. Cook, U.S. Geological Survey, written commun., July 1988).

Other record-low June flows in representative streams nationwide included the Green River at Munfordville, Ky., 10 percent of normal; the Sturgeon River near Sidnaw, Mich., 12 percent; the Conecuh River at Brantly, Ala., 14 percent; the Mississinewa River at Marion, Ind., 15 percent; the Calcasieu River near Oberlin, La., 18 percent; the Scioto River at Higby, Ohio, 22 percent; the Greenbrier River at Alderson, W. Va., 24 percent; the Wabash River at Mount Carmel, Ill., 25 percent; and the Little Blue River near Barnes, Kans., 26 percent. Many rivers had flows of 30 percent of normal at some gaging stations, but the Red River of the North in North Dakota had only 30 percent everywhere along its reach. In Canada, two rivers had record-low June flows, both in Quebec Province: the St. Francois River at Hemmings Falls, 31 percent of normal, and the St. Maurice River at Grand Mere, 34 percent of normal.

A heat wave settled in during July and August over an area that encompassed the Midwest to the East Coast. Only a small part of the Northeast that bordered Canada had usual summer temperatures. Record temperatures were set, and little or no rain fell. The West continued to be parched, although that area was spared prolonged record heat.

In California, about a third of the population and more than 40 percent of irrigated agriculture were affected by water shortages; rainfall was insufficient even for dry-farmed crops. Drought emergencies were declared in 14 counties, ranchers from 42 counties were accepted for Federal emergency feed programs, and many urban areas implemented mandatory or voluntary measures to conserve water (Hunrichs, 1991, p. 58).

Many reservoirs nationwide had below to much-below average contents. In Idaho, Magic Reservoir, which is an impoundment that serves 300 farmers, ran dry early in July. Lake Tahoe in Nevada and California was at about 50 percent of its average level. In Georgia, Lake Sidney Lanier, which is a popular tourist reservoir for boating and waterskiing, was 10 feet below average, and Fontana Reservoir in North Carolina was 35 feet below average.

From Chicago to Atlanta, restrictions were placed on all outdoor water use, and Indiana officials implemented a locator service for emergency water supplies for endangered livestock in the State. On Maryland's Eastern Shore, the Associated Press reported that the number of counties that were declared agricultural emergencies grew from nine in July to include 50 percent of Maryland's farmland by mid-August.

At the end of July, the combined flow in the Big Three rivers in the United States set a second consecutive monthly record low with a flow of 341 billion gallons per day; this was 45 percent below normal for July. Individually, the Mississippi River was 60 percent below normal (a new record low for July); the St. Lawrence River, 11 percent below normal; and the Columbia River, 58 percent below normal. By the end of the water year, flow in the Mississippi was 44 percent below normal, which was the second lowest flow for September in 59 years of record, 40 percent below normal and a new record low for the month in the Columbia, and 6 percent below normal in the St. Lawrence.

Nationwide, the drought damaged crops and endangered livestock in 1,880 counties in 37 States. Sections of the Mississippi River were closed, opened, reclosed, and reopened to barge traffic all summer, and, at Natchez and Greenville, Miss., the depth of water in the river fell to 7 feet. Forest and brush fires in many areas of the Nation were difficult to control, and thousands of tinder-dry acres were charred. Open fires at campsites and picnic grounds in national parks were banned for the season; only fires in propane or gas grills or stoves or in fixed on-site grills were permitted.

During summer 1988, great fires swept through more than 45 percent of the 2.2 million acres that constitute Yellowstone National Park in Wyoming. The extraordinary dry, hot weather conditions that persisted in the West during the water year (and even earlier) occurred at a time when the floor of mature Yellowstone forests was littered with decaying timber among the dry underbrush. Of the nine major fires in Yellowstone in 1988, the five most damaging started outside of the boundary and spread into the park despite massive fire-fighting efforts. Although the Yellowstone fires were the largest and the most covered by the news media, huge acreage burned in Oregon,

The unusually low water level in the Mississippi River during 1988 provided a rare opportunity for USGS hydrologists to study the materials in the bed of the river. A backhoe is being used to trench a large exposed sandbar in the river opposite Helena, Ark., on October 7, 1988. (Photograph by Robert H. Meade, U.S. Geological Survey.)

Montana, and Alaska. In total, over 3.7 million acres burned in the West during water year 1988.

Hydroelectric power production nationwide was greatly affected by the drought in 1988. For example, hydropower production in the TVA system was down 47 percent during water year 1988, the Alabama Power Company was forced to close 14 of its plants, the Idaho Power Company had to use more costly coal-fired generators because of low flows in the Snake River, and, at another coal-fired plant on the Mississippi River near Memphis, Tenn., a dam was built around intake pipes that draw cooling water for the generators so that plant could run at 60 percent of capacity.

In addition to hydropower-production problems, Michael Kernan reported in the *Washington Post* (July 16, 1988) that costs for shipping freight on the Mississippi River had about tripled (from about $5 or $6 to $17 a ton) when barge traffic slowed radically (barges carry about 80 percent of the Nation's diesel oil and 60 percent of its grain). Reports from the U.S. Department of Labor, as reported by J.M. Berry and Stuart Auerbach in the *Washington Post* on July 16, attributed the rise in producer prices for consumer goods to the drought. For example, prices of unprocessed foods and feed increased 4.2 percent, and partially processed foods and feed, 6.8 percent. Prices for many grains and for poultry increased more than 20 percent. The 5.2 percent fall in price for cattle and 4 percent fall for hogs were attributed to the sale of these animals because of rising feed prices and shortage of pasture.

Nationally, according to crop reports (''Weekly Weather and Crop Bulletins''), corn production fell 31 percent from 1987; soybeans, 21 percent; sunflowers, 46 percent; and durum wheat, 50 percent. Yield for corn dropped from an average of 119 bushels per acre to 82 bushels. In Illinois, Minnesota, South Dakota, and Wisconsin, however, the harvest of corn ranged from 45 to 60 percent less than in 1987. In Stevens County in west-central Minnesota, the drought destroyed 75 percent of the corn crop and 60 percent of the soybean crop; the soybean crop in the rest of the State was harvested, albeit with below-average yield, after some showers in mid-July helped the shallow soil-moisture

content; no summer rains fell in west-central Minnesota until August, which was too late to save the corn and soybeans. As the water year ended, North Dakota and Montana still had had no summer/early fall rains, officials of some counties reported crop losses of 80 percent, and concern was growing over subsoil-moisture content for 1989 (B. Peterson, *Washington Post*, December 20, 1988).

Titus Lucretius Carus (99–55 B.C.) wrote ("On the Nature of Things," book IV, l. 637), "What is food to one, is to others bitter poison." The declining water level in the Mississippi River wreaked havoc on commerce along its entire reach, but hulks of long-lost ships from much earlier river traffic were gradually revealed on the river bottom. This was a rare opportunity for hands-on examination of shipbuilding techniques and materials used by early shipbuilders.

On June 23, 1988, archeologists from the Arkansas Archeological Survey (AAS) were called in to one wreck site on the Arkansas side of the Mississippi River just below the I–55 bridge near West Memphis. On a nearly 2-mile-long reach of exposed river bottom, among about 4 acres

Archeologists at work on the steamboat wreckage (ca. 1910–30) on August 13, 1988, under cover of sunshades in the 98-degree-Fahrenheit heat, surrounded by debris from other wooden rivercraft. The river was at −10.1 feet below river-gage zero and 34 feet below the top of the bank from which the photograph was taken. In the background (view is to the southeast) is a steel barge that sank circa 1960 along what was then the river bank. (Photograph by Leslie C. Stewart-Abernathy and published with permission.)

Archeologist John Mintz records section of smokestack from the steamboat wreck (ca. 1910–30), exposed with other debris on the bottom of the Mississippi River at site 3CT243, West Memphis, Ark., on August 11, 1988. (Photograph by Leslie C. Stewart-Abernathy and published with permission.)

of wrecked wooden, flat-bottom workboats used on the river 70 to 100 years ago, lay huge chunks of what turned out to be a 19th-century sternwheeler. At that time, AAS archeologist Dr. Leslie Stewart-Abernathy said (M. Kernan, *Washington Post*, July 16, 1988) the steamboat was "at least 150 feet long and could be as long as 180 feet."

The most exciting find, however, may have been the huge, 3-foot-diameter, 40-foot-long sections of very thin iron pipe (no thicker than the sides of a paint can) (Stewart-Abernathy, in press). In February 1991, Stewart-Abernathy (AAS, oral commun.) stated ". . . the iron pipe is indeed a smokestack." These sections of the smokestack survived only because they quickly filled with river-bottom clay, which kept their shape intact. Among other artifacts, the huge metal collar of the steamboat's smokestack was saved, but the sections of the thin-walled stack, which were too fragile to move, along with the rest of the wreckage exposed in summer 1988, have been reclaimed by the rising waters of the Mississippi River.

At the end of September, contents of 34 of the 100 index reservoirs were below average, including most reservoirs in New Jersey, North Dakota, Montana, Wyoming, Idaho, Nevada, and California. The most extreme statewide shortages occurred in Idaho, Nevada, and California. For example, in Idaho, the Boise River reservoir system had 20 percent of average usable contents, and the Upper Snake River system 10 percent of average usable contents. In Nevada, Rye Patch Reservoir had 6 percent of average usable content. Lake Tahoe, which is in Nevada and California, fell to 2 percent of average usable content. In California, Pine Flat Reservoir with 6 percent and Lake Isabella with 13 percent of average usable contents were the two low extremes in that State. One reservoir in South Dakota, Belle Fourche, recorded 16 percent of average usable content, but usable contents of the other reservoirs in that State were in the average range for September. Belle Fourche, however, is principally used for irrigation, and its low content was of concern to State officials and the farming community.

Ground-water levels continued to decline in most areas affected by the drought, including a persistent pattern of decline on Long Island in New York. New low levels for August occurred in index wells in Fairfax County, Va., Montgomery, Ala., Las Vegas Valley, Nev., and the Logan area in Utah. Two new alltime lows occurred in index wells at the Kansas Agricultural Experiment Station (41 years of record) in Colby and on Cockspur Island (32 years of record) near Savannah, Ga. By the end of the water year, new low levels for September were recorded in index wells near Memphis, Tenn., and El Paso, Tex., and in Idaho, North Dakota, and Kansas. New alltime low levels for the period of record occurred in index wells in Ruston, La. (13 years of record), Wyndmere, N. Dak. (25 years of record), the Holladay area in Utah (40 years of record), and Halstead, Kans. (48 years of record).

1989 Water Year

[Figs. 38–49]

During fall 1989, dry conditions persisted in the Great Plains region, most of central and southern Texas, California, and southern Florida, which had its driest autumn in 50 years. Only the eastern half of the Nation received substantial precipitation. Unseasonally mild weather generally prevailed in the western third of the United States, whereas cold Canadian air kept temperatures below average in much of the East.

Streamflow, however, increased in November. Of the 189 reporting stream-gaging stations in the United States, southern Canada, and Puerto Rico, 80 percent had flows in the normal to above-normal ranges. Nevertheless, the total November streamflow for these stations was the second lowest flow for that month in the previous 7 years. November was also the first time in 6 months that each of the Big Three rivers in the United States had flows in the normal range; their combined flow was 429 billion gallons per day for the month. These were encouraging signs for the drought-weary country, but sustained much-above-average precipitation is required to break a drought, and there were no indications of favorable weather patterns as winter set in.

Winter 1988–89 was unusually mild, primarily in the same areas that were unusually dry. December temperatures set no records, but, on a nationwide basis, January was the second warmest in the previous 35 years. In February, however, bitter arctic air covered the Central Plains States; the below-zero temperatures damaged winter crops because snow cover was insufficient to protect them. Nationally, February 1989 was the eighth coldest since 1895.

Winter 1988–89 also was unusually dry in large areas of the country. Nationally, it was the ninth driest winter since recordkeeping began in 1895. In the Northeast, it was the third driest winter of record; for example, Burlington, Vt., received less than 2 inches of precipitation. The Northeast and southern Atlantic regions received as a whole less than 50 percent of average precipitation, and southern Florida registered its driest fall and winter ever. Precipitation totaled less than a quarter of an inch in western portions of Nebraska, Kansas, and Oklahoma, and, in California, the third consecutive year of below-average precipitation raised the potential for shortages in water supplies used for irrigation. In contrast, unusually wet weather prevailed throughout the winter in a broad band that extended from central Texas northeastward through the Tennessee and Ohio Valleys.

As had happened in the Southeast in 1986, in the Southeast and Mid-Atlantic region in 1987, and from the Midwest to the East Coast in 1988, the West in 1989 bore the brunt of abnormally warm, dry weather. A short period of wet weather in early March in California did permit the delivery of agricultural water supplies, but the rains did not benefit the central coastal area of the State. The central

coastal area is not part of the large State water projects, and water-use restrictions remained in effect in that area (Hunrichs, 1991, p. 58). In April, southern California baked in one of the worst heat waves of the century.

In the Northeast and adjoining southern Canada, the lack of precipitation throughout winter 1988–89 left the region without sufficient snowpack to fill the reservoirs with snowmelt in the spring. For example, Sam H. Verhovek reported in the *New York Times* (February 1, 1989) that by late January, Skaneateles Lake, which is the main source of water supply for Syracuse, N.Y., was 3 feet below average levels and that the city was pumping nearly 10 million gallons per day from Lake Ontario (average pumpage is 750,000 gallons per day). In New York City, usable contents of the reservoir system were 40 percent below average. With precipitation in the upper Delaware River basin at 60 percent below average in January, the Delaware River Basin Commission (DRBC), under a 1954 Supreme Court Decree, reduced diversions of water from the basin from 800 million to 680 million gallons per day for New York City and from 100 million to 85 million gallons per day for communities in New Jersey. By February 5, the DRBC further reduced New York City's allotment to 560 million gallons per day and New Jersey's to 70 million gallons per day.

By mid-February, officials of the State of Massachusetts issued a drought warning. In Stamford, Conn., where reservoirs were at only 60 percent of capacity in mid-March, restrictions on watering lawns and washing cars remained in effect from October 1988. On March 22, Mayor Edward I. Koch declared a drought emergency for New York City, banning outdoor use of water even for ornamental uses, such as fountains that recirculated the water. At the end of March, flow in the Delaware River was 2.4 billion gallons per day, which was 61 percent below normal and the second lowest March flow since recordkeeping began in 1940.

Drought also persisted in southwestern Florida where ground-water levels had been below average since September 1988. In Lee County, for example, the water level in a well in the lower Hawthorn aquifer, which had declined 20 feet since September 1, had stopped flowing as an artesian well by the end of March for the first time since water-level records began in 1977. In central Collier County, ground-water levels were several feet below sea level, and saltwater from deeper saline aquifers was contaminating shallow aquifers. The lowered ground-water levels also contributed to minor limestone collapses in the 1- to 4-foot range in southwest Florida, but no new major sinkholes were reported.

Spring 1989 brought an unusual amount of severe weather nationwide. In early March, a late-season winter storm in the Pacific Northwest brought above-average precipitation into the Northwestern States, triggered severe thunderstorms across the Southeast, brought freezing rain from the Midwest to the Mid-Atlantic Coast, and heavy snow from Texas to the middle Mississippi Valley and to the central Appalachian Mountains. Later in the month, slow-moving frontal systems that brought warm, moist air from the Gulf of Mexico caused heavy rains from the southern and central Great Plains to the southern and Mid-Atlantic Coast. The northern Great Plains, Southwestern States, and southern Florida remained dry. By the end of March, the abnormally warm weather in the West spread over much of the United States and immediately melted the snow that had fallen earlier in the month. There would be no further snowmelt to fill reservoir systems.

In late April, the northern Great Plains and the Midwest received much-needed rain; the Southeast northward along the Atlantic seaboard into New England received showers and thunderstorms throughout the month. The remainder of the Nation remained dry, and the West remained abnormally warm as well.

As May arrived, conditions changed drastically for the drought-stricken area from the mid-Atlantic to the Northeast. Record cold reached well into the Southeast, and unusually heavy rains wiped out the threat of drought in the Northeast. For example, 7.77 inches of rain in May were recorded at Washington, D.C., most of which fell during the first 2 weeks of the month (average precipitation for May is 3.48 inches); a new May record high of 10.22 inches of precipitation (average precipitation for May is 3.76 inches) was set at New York City, most of which fell during the first 2 weeks of the month. The DRBC officially lifted the drought declaration on May 12, 1989. The wet weather continued throughout this area through the end of the water year. For the first time in 5 years, the Mid-Atlantic and Northeast regions would end the year with precipitation figures in the excess column: +10.46 inches for Washington, D.C., and +20.56 inches for New York City.

What happened to bring about this seemingly sudden turn around in the prevailing weather pattern that had caused the 5-year drought in the eastern half of the United States? The spring 1989 jet stream shifted from the pattern that had predominated for those 5 years: From April to early May 1989, the jet stream again split, but this time the southern fork moved around a low-pressure system off the Pacific Northwest Coast bringing ocean moisture that then fell on the Pacific Northwest. At the same time, the northern fork moved north of a high-pressure system centered off Alaska and into cold polar air. This split jet stream then joined approximately over the Dakotas (another low-pressure system was positioned over Canada and the Great Lakes States and a strong high-pressure system was positioned over the western and central Atlantic Ocean). The now-single jet stream passed west and south of this Canadian/Great Lakes low-pressure system, and the winds brought the cold polar air that caused unusually chilly temperatures in the region. Moisture was also drawn from the Gulf of Mexico, and, as the jet stream headed north again in the trough between the low-pressure system over Canada and the Great Lakes and

The topography of Puerto Rico significantly affects the occurrency of wind damage: This east-west-trending ridge was stripped of vegetation by Hurricane Hugo winds on its north (right) face but sustained little damage on its south face. (Photograph by Matthew C. Larsen, U.S. Geological Survey.)

the strong high-pressure system in the Atlantic Ocean, the exchange of energy between the moisture-laden jet stream and the high- and low-pressure systems caused the heavy early-May rains from the mid-Atlantic through the Northeast. This particular jet-stream pattern, with slight fluctuations, was, in effect, the prevailing pattern throughout the rest of water year 1989 that brought the well-above-average precipitation that was required to break the drought in the East (Wagner, 1990, p. 19–20).

May precipitation also eased drought conditions from the central Great Plains to the central Gulf and from the Great Lakes through the middle Mississippi Valley. Dry, hot weather prevailed, however, in the northern Great Plains (Omaha, Nebr., had the driest May of record), the Southwest, California, and southern Florida. Record-low streamflow for May occurred in the Clearwater River, Idaho, the North Platte River, Wyo., the Saline River, Kans., the Niobrara River, Nebr., and the Virgin River, Ariz. In Texas, where the winter wheat harvest was underway, more than 50 percent of the crop was poor because of months of little to no precipitation. The following percentages of poor winter wheat crops were also reported: Kansas, 90 percent; Nebraska, 50 percent; Montana, 40 percent; Colorado, 30 percent; Oklahoma, 25 percent; and South Dakota, 15 percent.

During the summer, precipitation generally increased over the central Midwest during June and July, but the West and the Northern Plains States remained dry; the West remained anomalously warm. Record-low streamflow occurred in only one river during July—Cedar River at Cedar Rapids, Iowa, which had a monthly flow of 344 million gallons per day; the previous record low had been 348 million gallons per day in July 1911.

In August, the reverse occurred; heavy rains fell in the previously dry areas of the Midwest, and weather was dry in the previously wet areas of the South. In parts of North Dakota, Minnesota, Illinois, Iowa, Missouri, and Nebraska, rainfall was sufficient to relieve the long-term agricultural drought, but parts of Ohio, Pennsylvania, Maryland, and Virginia had one of the driest Augusts—less than 1 inch of rain accumulated. The combined flow of the Big Three rivers in the United States, which was a normal-range 456 billion gallons per day, was only 4 percent below normal for August, although the flow in the Mississippi River was 9 percent below normal for August for the period of record.

Throughout the years of the drought, there had been a coincident period of anomalously low hurricane activity. During the late evening and early morning hours of September 17–18, 1989, however, Hurricane Hugo, which was a category 4 storm (sustained winds of 131–155 miles per hour on NOAA's Saffir-Simpson Hurricane Scale), hit St. Croix in the U.S. Virgin Islands with sustained winds of 140 miles per hour and gusts of 200 miles per hour. The island, which was battered by Hugo for 8 hours, had damage to 90 percent of all homes and other buildings. The main power station was destroyed and all sources of freshwater supplies to the island were cut off (Holmes, 1991, p. 8). Rainfall in the islands generally was less than 10 inches, a relatively minor amount when compared with rainfall totals commonly associated with hurricanes. Rainfall could have caused localized flooding, but most of the flood damage in the islands was caused by tidal flooding: from about 3 to 11.5 feet on St. Croix and from 4.5 to 6.5 feet on St. Thomas and St. John (Schuck-Kolben and Kaufman, 1991, p. 6).

Hugo also struck eastern Puerto Rico on September 18. Storm-tide elevations generally ranged between 4 and 10 feet along the eastern and northern coasts but exceeded 12 feet near San Juan. Vegetation in the Caribbean National Forest in northeastern Puerto Rico was severely damaged. More than 200 shallow landslides, half of which were associated with highway construction and roadcuts, occurred on the steep slopes of this mountainous area (Schuck-Kolben and Kaufman, 1991, p. 7).

Hurricane Hugo weakened in passage over the islands, but when it was again over open water, it veered slightly to the north, then turned northwest, and headed straight for South Carolina, intensifying again to category 4 as it neared the coast. Hugo came ashore about 1:00 a.m. on September 22 in the vicinity of Charleston, S.C.

In South Carolina, as in the islands, rainfall associated with Hugo was less than expected: A maximum of 10 inches fell south of Charleston, more than 4 inches in the southern coastal area, and about 2 inches in the upland part of the State. Once again the severe flooding that occurred in the coastal areas was caused by storm-surge elevations of 10 feet above sea level at the Charleston tide gage, from 12 to 16 feet above sea level in the area from Myrtle Beach south to Sullivans Island, to the maximum of 20 feet above sea level in Bull Bay (Schuck-Kolben and Kaufman, 1991, p. 8).

Storm damage from Hurricane Hugo (inclusive of the islands and conterminous United States) was estimated to be about $10.4 billion, and at least 50 persons lost their lives (Schuck-Kolben and Kaufman, 1991, p. 6). The damage and loss of life were generally caused by the high winds and the flooding that had been caused by accompanying storm surges. Interestingly, the rainfall totals that were much less than would be expected from a storm of this magnitude are probably attributable to the fact that Hugo was an exceptionally fast-moving storm and that it weakened rapidly once it moved inland where it stayed rather than skirting northward along the East Coast.

As the water year ended, dry conditions persisted across central Florida from Daytona Beach southwest through Tampa and southeast to West Palm Beach. Precipitation deficits ranged from about 9 inches at Daytona Beach to about 11 inches at West Palm Beach. In the north-central and western parts of Illinois, precipitation deficits ranged from about 8 inches at Peoria to about 14 inches at Quincy. In

Iowa, which had its 11th driest year in 116 years of record, State Climatologist Harry Hillaker reported that statewide average precipitation was 81 percent of average; the deficits ranged from 5.28 inches at Sioux City to 11.61 inches at Waterloo (W.B. Kastner, U.S. Geological Survey, written commun., December 1989). In Nebraska, deficits ranged from about 6 inches at Lincoln to 8 inches at Omaha in the eastern part of the State to about 4 inches in the central and western parts of the State.

For the 1989 water year as a whole, however, the combined flow of the Big Three rivers in the United States averaged a normal-range 1.08 trillion gallons per day, which is nearly 8 percent above normal. Individually, flow was about 669 billion gallons per day and in the above-normal range in the Mississippi River, about 243 billion gallons per day and in the normal range in the St. Lawrence River, and about 170 billion gallons per day and in the below-normal range in the Columbia River.

1990 Water Year

[Figs. 50–61]

In water year 1990, the focus of attention on drought conditions centered primarily on the Western United States, although pockets of drought persisted in parts of the Midwest and Southeast. In Wisconsin, for example, ground-water levels continued to decline in October and November in response to the 1988 statewide drought and persistent below-average precipitation in 1989 and 1990. Record-low water levels for the 43-year period of record were recorded in shallow wells near Rhinelander in north-central Wisconsin. Mandatory water restrictions were implemented throughout southern Florida on December 18 (parts of that area had had water restrictions in place earlier). Southern Florida, which was in its third year of drought, had precipitation deficits of as much as 13 inches in many areas.

In the central and southern Midwest, no precipitation fell during November, and the driest November ever was recorded at Kansas City, Mo. (only a trace of rain). After Pacific storms brought early season rains to California in late October, dryness again returned: December precipitation was less than 10 percent of average statewide (the driest December of record), and central coast community reservoirs contained only 22 percent of average contents.

As the New Year progressed toward spring, dry conditions did not lessen in the West, the north-central Midwest, or Florida, although January storms did bring relief to the Pacific Northwest. By the end of March, when California's rainy season was just about over, snowpack was less than 63 percent of average and streamflow was less than 35 percent of normal—the fourth straight year of drought had arrived. Nevada and Arizona were also affected.

Winter 1989/spring 1990 was a different story in the central and southern Midwest: Ample precipitation fell in a band from central Texas through Oklahoma, western Arkansas, southern Missouri, southwestern Kansas, and southeastern Colorado; western and southern Louisiana also received above-average precipitation. As it turned out, the saturated soils were not able to absorb the above-average spring rainfall, and the rivers and reservoirs, already full from winter runoff, were not able to carry additional runoff from the spring rains. The first storms to affect this area (principally southeastern Oklahoma, western Arkansas, and northern Texas) were in a slow-moving series; rain fell from April 16 to 26. The second storm over the same area was caused by a stationary front; torrential rains fell from April 30 to May 3 and sporadically through mid-May. [For a complete account of these storms and extreme flooding, see Wahl (1991).] Wahl (1991, p. 53) reported that in Oklahoma, Arkansas, Texas, and Louisiana, millions of dollars in damage and 17 deaths were attributed to the storms and floods and that 104 counties were declared eligible for Federal disaster assistance.

During May, rains from a tropical depression in the Atlantic Ocean helped ease the drought in southeastern Florida, but mandatory restrictions on water use remained in effect. In Michigan, wildfires charred more than 16 square miles in the Lower Peninsula before being brought under control. Record-high streamflows caused by heavy rains occurred in more than a dozen streams in Illinois, Oklahoma, Arkansas, and Texas and a small area of Iowa, but pockets of long-term drought continued to persist. In North Dakota, where drought began in 1988, contents of most major reservoirs were of concern to State water officials and farmers. For example, Lake Sakakawea reservoir was nearly 71 percent below average, flows in Missouri River tributaries were about 25 percent of normal, and the Red River of the North had flow of about 26 percent of normal. With California in its fourth year of drought, reservoir storage statewide ranged from 13 to 67 percent below average, and most urban areas had placed restrictions on water use. Precipitation for the rainy season (and the year) was only 65 percent of average, which made 1990 the driest of the four consecutive drought years. [For a complete account of the drought in California, see Hunrichs (1991).]

During summer 1990, extreme weather conditions continued unabated in the West. A record-high temperature for June of 112 degrees Fahrenheit was set in Los Angeles, Calif., and Phoenix, Ariz., followed suit with a record-high 122 degrees Fahrenheit. The hot, dry conditions facilitated numerous wildfires in the Southwest. In June, fires caused loss of life and extensive damage; for example, in Arizona, six firefighters were killed in the Tonto National Forest, and, near Santa Barbara, Calif., arsonists set fires that caused over $500 million in damage.

Fires caused by lightning also broke out in the interior of Alaska in June. Aided by unusually high Alaskan temperatures of near 90 degrees Fahrenheit, low humidity, gusting winds, and tinder-dry conditions, the fires charred

Red River, looking downstream, at Arthur City, Tex., on May 7, 1990, shortly after the flood crested at 34 feet. (Photograph by Dale L. Boyle, U.S. Geological Survey.)

more than 2 million acres of spruce and brush by the end of July. Wet, cool weather, which arrived in late August/early September, helped to quell the fires; however, more than 3 million acres had been burned.

On August 11, Timothy Egan reported in the *New York Times* that wildfires in Yosemite National Forest in California had caused the park to be closed August 9 for the first time in more than 20 years. One of the fires came within 2 miles of the famed giant sequoias, some of which are 2,000 years old, near Merced Grove. Firefighters sprayed the trees with a fire retardant to help save them (Hunrichs, 1991, p. 60). By the time the fires were out, an estimated 17,000 acres in Yosemite had been charred. In all, 14 major fires and several smaller ones burned over 200,000 acres across California, including 24,000 acres in Sequoia National Forest, 114,000 acres in Tehama County 200 miles east of Yosemite, and 17,500 acres east of Red Bluff (Associated Press, *Washington Post*, August 13–14, 1990).

During August, fires also burned in Washington, Oregon, Idaho, and Utah. The worst of these charred 110,000 acres in southeastern Oregon, another 73,000 acres near Burns, Oreg., and about 40,000 acres near Twin Falls, Idaho. Over 3.7 million acres burned in the West in 1990 (T. Egan, *New York Times*, August 11, 1990).

Summer streamflow reflected the continuing California drought. For example, flow in Arroyo Seco, which is east of Pasadena, was only about 70,000 gallons per day during July. At 87 percent below long-term normal, the flow was one of the lowest of record (since 1910). Normal July flow in the Merced River at Happy Isles Bridge in Yosemite National Park was only 122 million gallons per day, which was 44 percent below the long-term normal. Both streams continued to decline throughout the rest of the water year, Arroyo Seco to the extreme that flow was barely enough to measure.

Of the 10 reservoirs in California for which the USGS maintains water-level records, all had contents less than during summer 1989. Seven had contents that ranged from a high of 11 percent below the storage level of a year earlier (Lake Berryessa) to a low of 95 percent below the storage level (Lake Isabella). Three other reservoirs had contents only 1.5 to 2 percent below the storage level of a year earlier; one of these, Lake Tahoe, had storage levels below its natural outlet to the Truckee River at the end of the water year.

Water year 1990 was the 10th driest year in the California/Nevada region. For the Nation as a whole, however, 1990 was the 12th wettest year, especially in the region that encompasses Illinois, Indiana, Ohio, Missouri, Kentucky,

Remains of an 85-year-old steel bridge swept away during flooding in the Ouachita River at State Highway 84 near Malvern, Ark. The nearly 13 inches of rain that fell within an 8-hour period May 19–20, 1990, at Hot Springs, Ark., upstream of Malvern, produced a peak discharge greater than a 100-year recurrence interval at the Malvern site. (Photograph by Rodney E. Southard, U.S. Geological Survey.)

Tennessee, and West Virginia, where 52.9 inches of precipitation were recorded for the area.

The Big Three rivers in the United States further indicated a return to normalcy for most of the United States. Their combined flow of about 758 billion gallons per day for the year was about 17 percent above normal. The trend began in 1989 when combined flows averaged 700 billion gallons per day, which was 8 percent above normal. Individually, flow averaged 470 billion gallons per day (29 percent above normal) in the Mississippi River, 172 billion gallons per day (3 percent above normal) in the St. Lawrence River, and 116 billion gallons per day (6 percent below normal) in the Columbia River.

DROUGHT AND THE GREAT LAKES

Historically, the water levels in the Great Lakes (Superior, Michigan, Huron, Erie, and Ontario) have continually fluctuated over time, and only during extreme low or extreme high levels does anyone seem to notice. The lakes, which occupy a total surface area of about 95,000 square miles (Crane and Stanish, 1986, p. 1), are so vast that changes in water levels are gradual and generally go unnoticed by those living and working along the shoreline. The lakes contain 6 quadrillion gallons of freshwater, which is 20 percent of the world's fresh surface-water supply and 95 percent of the United States' supply (Michigan Sea Grant College, 1990).

During the mid-1980's, however, the high water levels in the Great Lakes were given prominent coverage in the news media. Homes, port facilities and buildings, and beaches and revetments were being systematically damaged and destroyed by flooding and wave action. Such measures as building new structural barriers to protect cities and harbors along the lakeshore and even the tripling of outflow from Lake Michigan into the Chicago River and on down the Illinois River to the Mississippi were discussed. Some scientists thought also that the lakes might be returning to their natural (historical) levels and that the high water levels might be permanent (Begley and others, 1987, p. 76–77).

As stated earlier, water levels in the Great Lakes have always fluctuated, so why would the rise during the mid-1980's become such a concern? The answer probably lies first in the hydrologic cycle and second in shoreline development.

The hydrologic cycle is the constant circulation of water from the atmosphere to the Earth back to the atmosphere. Precipitation that falls onto the Great Lakes and their basin is the major natural factor that controls water levels in the lakes: Water levels decline during periods of below-average precipitation and rise during periods of above-average precipitation. Other factors include runoff and ground-water inflow to the lakes, as well as evapotranspiration, ground-water outflow, and consumptive use (Crane and Stanish, 1986, p. 2).

From about 1900 to 1940, precipitation on the Great Lakes Basin was below average, and, therefore, lake levels declined during the period. The low water levels soon were perceived to be "the normal levels," and development of the shoreline burgeoned during the 1940's. From the early 1940's to about 1985, precipitation was above average basin-wide. Since the decline in temperature began about 1960, temperatures in the Great Lakes Basin have been about 2 degrees Fahrenheit cooler than those earlier in the century (Crane and Stanish, 1986, p. 3). Above-average precipitation (a record-high 40 inches fell on the Great Lakes Basin during 1985), together with cooler temperatures that retarded evapotranspiration, caused lake levels to rise in four of the

five lakes (Ontario was the exception) to about 3 feet above average levels for the century by 1986. Average elevations are 600 feet for Lake Superior, 581 feet for Lakes Michigan and Huron (these two lakes are considered to be one lake hydrologically), 571 feet for Lake Erie, and 246 feet for Lake Ontario (Michigan Sea Grant College, 1990). Because of shoreline development during a low-water period, an estimated $100 million in damage was done to homes, businesses, and other structures along the shores of the Great Lakes during 1987, and millions of cubic yards of sand along the beaches was washed away during storms.

By spring of water year 1986, precipitation patterns in the Great Lakes basin began to change. Precipitation deficits for May, for example, ranged from only about 2 to 3 inches throughout the Great Lakes Basin. The change in precipitation patterns was welcomed in the area. Lake levels remained high for the rest of the water year because of the size of the Great Lakes; consequently, there is a lag time of many months in lake-level changes in response to precipitation-pattern changes.

During water year 1987, as the drought progressed from the East Coast westward to the Midwest, lake levels in the Great Lakes began to decline. Precipitation from November 1986 through June 1987 on the Great Lakes Basin, which was 25 percent below the long-term average, was the lowest total on record for that 8-month period. By the end of July 1987, average water levels in the Great Lakes were lower than levels measured for July 1986. At the end of September 1987, for example, the water level in Lake Erie was 0.74 foot lower than in September 1986 and in Lake Ontario, the water level was 1.63 feet lower. The Great Lakes Commission (1990, p. 12) reported that by December 1987, water levels had fallen 2.7 feet in Lakes Michigan and Huron and 1.9 feet in Lake Erie.

Because snowfall in the Great Lakes Basin was light during winter 1987–88, little snowmelt was available for spring runoff or recharge to the basin. By June 1988, precipitation on the entire basin was 25 percent below the long-term average; precipitation, however, was 35 percent below average on Lake Michigan's basin and 40 percent below average on Lake Erie's basin (Great Lakes Commission, 1990, p. 6). Precipitation from March through July 1988 was the lowest on record for that 5-month period. As a result, the water levels declined below the levels recorded in December 1987—0.8 foot in Lakes Michigan and Huron and 1.2 feet in Lake Erie (Great Lakes Commission, 1990, p. 12).

The drought in the Great Lakes Basin was short term compared with the drought in the East and Southeast, the Northwest, and California where drought conditions continue to date (1992). Precipitation accumulation that began in August 1988 was 33 percent above average by December 1988 (average annual precipitation is about 32 inches). As a result of the precipitation surplus, the Great Lakes drought ended during winter 1988–89 (water levels in the lakes rose to normal levels by May 1989). The Great Lakes were never in danger of "going dry," but the rapid decline in water levels was unprecedented (according to recorded history). Navigation channels on the Great Lakes/St. Lawrence River system and its commercial harbors and connection channels were significantly affected during the drought of 1988. Shipping tonnage on the Great Lakes was reduced, which, in turn, increased shipping costs, but traffic was not halted on the Great Lakes as happened on the Mississippi River during summer 1988.

The full effects of the drought that occurred in the Great Lakes basin in water year 1988 caught citizens and officials by surprise because attention had been so focused on the record-high precipitation on the basin in 1985, which led to the historically high water levels in the lakes by 1986. The reversal of this precipitation trend and the rapid return to long-term average lake levels during 1987–88 "was unprecedented in this century and certainly not expected" (Great Lakes Commission, 1990, p. 2).

REFERENCES

Associated Press, 1990, Drought aggravates California fire outlook: Washington, D.C., The Washington Post, August 13, 1990, p. A12.

_____1990, 1,600 homes threatened in north California fire—Yosemite blazes remain out of control: Washington, D.C., The Washington Post, August 14, 1990, p. A3.

Begley, S., Murr, A., and Turque, B., 1987, The greater lakes: New York, N.Y., Newsweek, March 16, 1987, p. 76–77.

Berry, J.M., and Auerbach, Stuart, 1988, Drought blamed for increase in June wholesale food prices: Washington, D.C., The Washington Post, July 16, 1988, p. D11.

Crane, Thomas, and Stanish, Sylvie, 1986, Water level changes—Factors influencing the Great Lakes: Great Lakes Commission, Ann Arbor, Mich., 13 p.

Egan, Timothy, 1990, Wildfires force closing of Yosemite Park; 10,000 evacuated: New York, N.Y., The New York Times, August 11, 1990.

Great Lakes Commission, 1990, A guidebook to drought planning, management and water level changes in the Great Lakes: Ann Arbor, Mich., 61 p.

Holmes, S.L., 1987, Monthly streamflow and ground-water conditions in the United States and southern Canada, water years 1945–85: U.S. Geological Survey Water-Supply Paper 2314, 260 p.

_____1991, USGS employee restores water supply to St. Croix disaster relief center: U.S. Geological Survey Yearbook, fiscal year 1990, p. 8.

Hubbard, L.L., 1987, Low streamflow conditions in the Western States during 1987: U.S. Geological Survey Water-Resources Investigations Report 87–4267, 29 p.

Hunrichs, R.A., 1991, Drought in California, 1987–90: U.S. Geological Survey Yearbook, fiscal year 1990, p. 57–60.

Kernan, Michael, 1988, As drought shrinks the Mississippi, long-lost ships emerge: Washington, D.C., The Washington Post, July 16, 1988, p. B11.

Michigan Sea Grant College, 1990, Great Lakes basin and Lakes Superior, Michigan, Huron, Erie, and Ontario: East Lansing, Mich., Michigan State University, Extension Bulletins E-1865 through E-1870 (leaflets).

National Ocean Service, U.S. Department of Commerce, October 1985–September 1990, Great Lakes water levels: Rockville, Md., published monthly, each separately paged.

National Weather Service (U.S. Department of Commerce) and National Agricultural Statistics Service and World Agricultural Outlook Board (U.S. Department of Agriculture), October 1985–September 1990, Weekly weather and crop bulletin: Washington, D.C., published weekly, each separately paged.

_____Climate Analysis Center, October 1985–September 1990, Daily weather maps, weekly series: Washington, D.C., published weekly, each separately paged.

Peterson, Bill, 1988, Few Midwest farmers failed to weather drought: Washington, D.C., The Washington Post, December 20, 1988, p. A14.

Schuck-Kolben, R.E., and Kaufman, Lionel, 1991, Hurricane Hugo, September 1989: U.S. Geological Survey Yearbook, fiscal year 1990, p. 6–8.

Soil Conservation Service, U.S. Department of Agriculture, October 1985–September 1990, Snow-precipitation update: Portland, Oreg., published weekly, each separately paged.

Stewart-Abernathy, L.C., in press, Ghost boats: Archaeology on the parched bottom of the Big Muddy, *in* Symposium on Ghost Boats on the Mississippi: Opportunity, Obligation, and Watercraft at West Memphis, Arkansas, in the Drought Summer of 1988—the Society for Historical Archaeology, 23d annual meeting, Tucson, 1990, Preliminary report: Arkansas Archeological Survey, Fayetteville, Ark.

U.S. Geological Survey, October 1985–September 1990, National Water Conditions: Reston, Va., published monthly, each separately paged.

Verhovek, S.H., 1989, Dry winter melts pride and profits: New York, N.Y., The New York Times, February 1, 1989, p. B5.

Virginia Water Resources Research Center, 1987, Winter snow storm has some merits: Blacksburg, Va., Water News, v. 18, no. 5, p. 3.

Wagner, Jim, 1990, Northern hemisphere circulation: Washington, D.C., Weatherwise, v. 43, no. 1, p. 19–22.

Wahl, K.L., 1991, Flooding in the Arkansas, Red, and Trinity River basins in 1990: U.S. Geological Survey Yearbook, fiscal year 1990, p. 51–53.

Weisskopf, Michael, 1988, Nation's big rivers reach lowest levels in decades: Washington, D.C., The Washington Post, June 28, 1988.

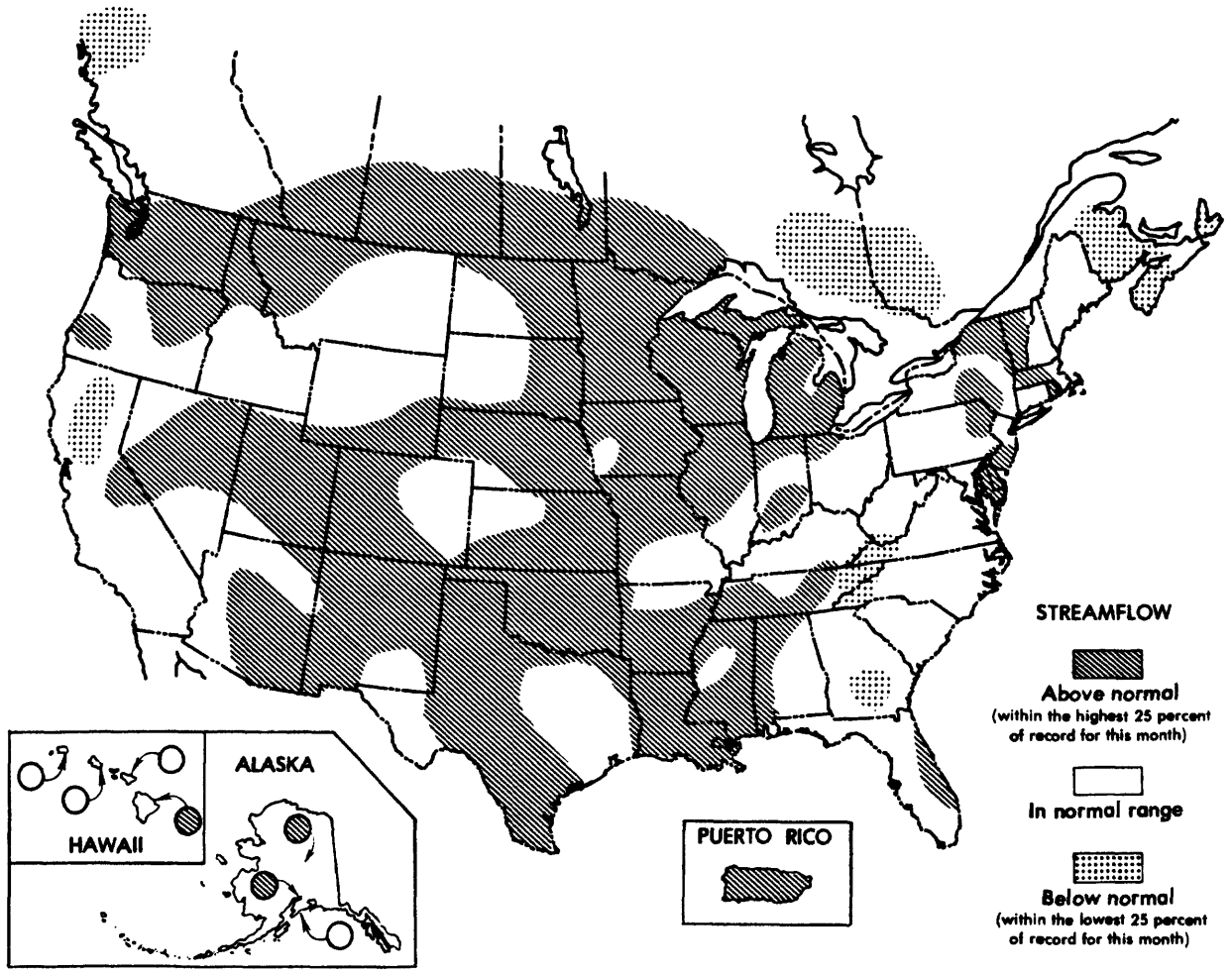


Figure 2. Streamflow during October 1985.

October 1985

Heavy precipitation fell over much of the central to eastern United States and south-central Puerto Rico. A tropical depression, which was upgraded to Tropical Storm Isabel on October 8, moved across Puerto Rico between October 4 and 7, causing what the Governor called the greatest natural disaster ever to befall the island. A massive landslide and severe flooding killed about 190 people and caused estimated damages of $50 million to $500 million. From October 9 to 11, heavy rains from remnants of Hurricane Waldo caused localized flooding in an area from western Texas to Michigan. From October 27 to 31, Hurricane Juan caused severe flooding in Louisiana's Bayou area and coastal erosion in Louisiana and Mississippi; damages to public and private property were estimated to be about $1 billion.

Streamflow was in the normal or above-normal range at 93 percent of the index stations in the United States and southern Canada; this is up from 91 percent for September. Decreases in streamflow occurred only in Florida, South Carolina, South Dakota, Idaho, and Alaska and in Saskatchewan and Alberta in Canada. Monthly discharge and the maximum daily flow were highest of record for October at six index stations. The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 805,513 cubic feet per second, which was 11 percent above September and 26 percent above normal.

Contents of 64 percent of the reporting (index) reservoirs were at or above average at the end of October. Contents of the New York City reservoir system remained below average but increased slightly during the month, as did the contents of Belle Fourche in South Dakota, Lake Altus in Oklahoma, and Twin Buttes in Texas. Storage declined significantly in the Clinch Projects, Douglas Lake, and the Little Tennessee Projects reservoirs; all were below average at the end of October.

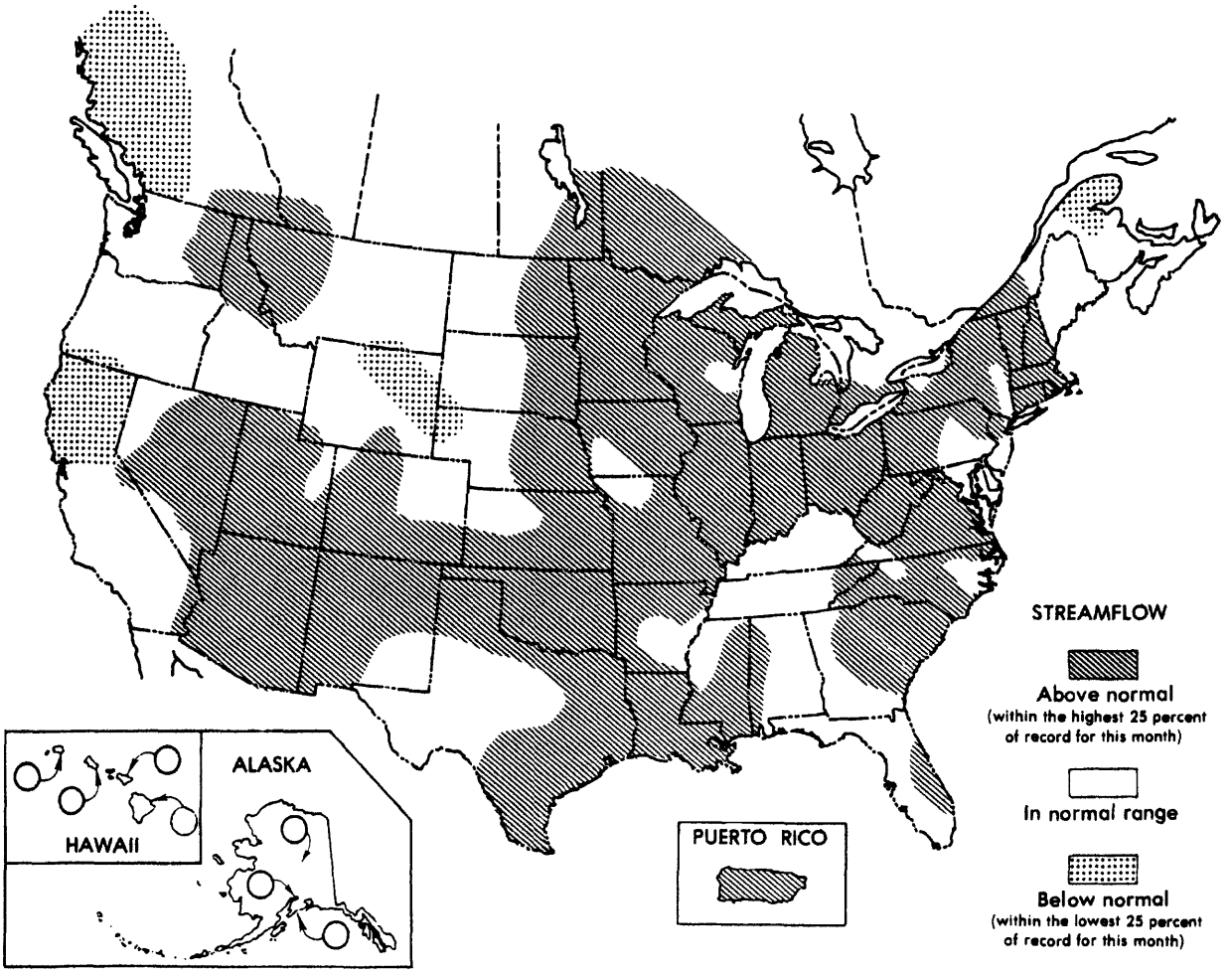


Figure 3. Streamflow during November 1985.

November 1985

Above-average precipitation fell over much of the United States, particularly in the East. A blocking high-pressure system off the East Coast caused unusual amounts of moisture to move northward, which caused heavy rains between November 3 and 5 from North Carolina to New York. The most severe flooding occurred from November 3 to 7 in an 11,000-square-mile area that encompasses eastern West Virginia, western Virginia, the Maryland panhandle, and along the Monongahela River south of Pittsburgh, Pa. Flood records were broken at about 40 gaging stations, and flood magnitudes equaled or exceeded the 100-year recurrence interval at 45 gaging stations. The most severe flooding occurred along the flanks of the Appalachian Mountains in West Virginia and Virginia. The flood at gaging station Cheat River near Parsons, W. Va., for example, peaked at 200,000 cubic feet per second, which is about 3.5 times the 100-year flood. About 40 people were killed, 50 were missing, damages were estimated to be over $600 million, and eight West Virginia counties were declared Federal disaster areas.

Severe local flooding from November 19 to 20 in Missouri's White River basin killed one person at Potosi. One gaging station was destroyed as recurrence intervals exceeded 100 years at three of the five gaging stations in the area.

Streamflow generally decreased in southwestern Canada, Alaska, Hawaii, Puerto Rico, Florida, and Wisconsin and in most States between the Mississippi River and the Great Basin; was generally variable in southeastern Canada, Arizona, and Idaho; and increased elsewhere. About 94 percent of the index stations had flows in the normal to above-normal range; this was up slightly from the 93 percent for October. Only one index station recorded a November record low (Skeena River at Usk, British Columbia, Canada), and only 11 index stations recorded flows in the below-normal range. In sharp contrast, monthly discharge for November was the highest of record at 25 index stations; 15 of those sites also had record-high daily flows for November. The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 1,151,000 cubic feet per second, which was 43 percent above October and 75 percent above normal.

Contents of 77 percent of the index reservoirs, including the New York City reservoir system, were at or above average at the end of November. As a result, all mandatory restrictions on water use were lifted for New York City on November 27. Significant declines in storage occurred at only 9 percent of the reporting sites, over half of which were in Washington and Idaho.

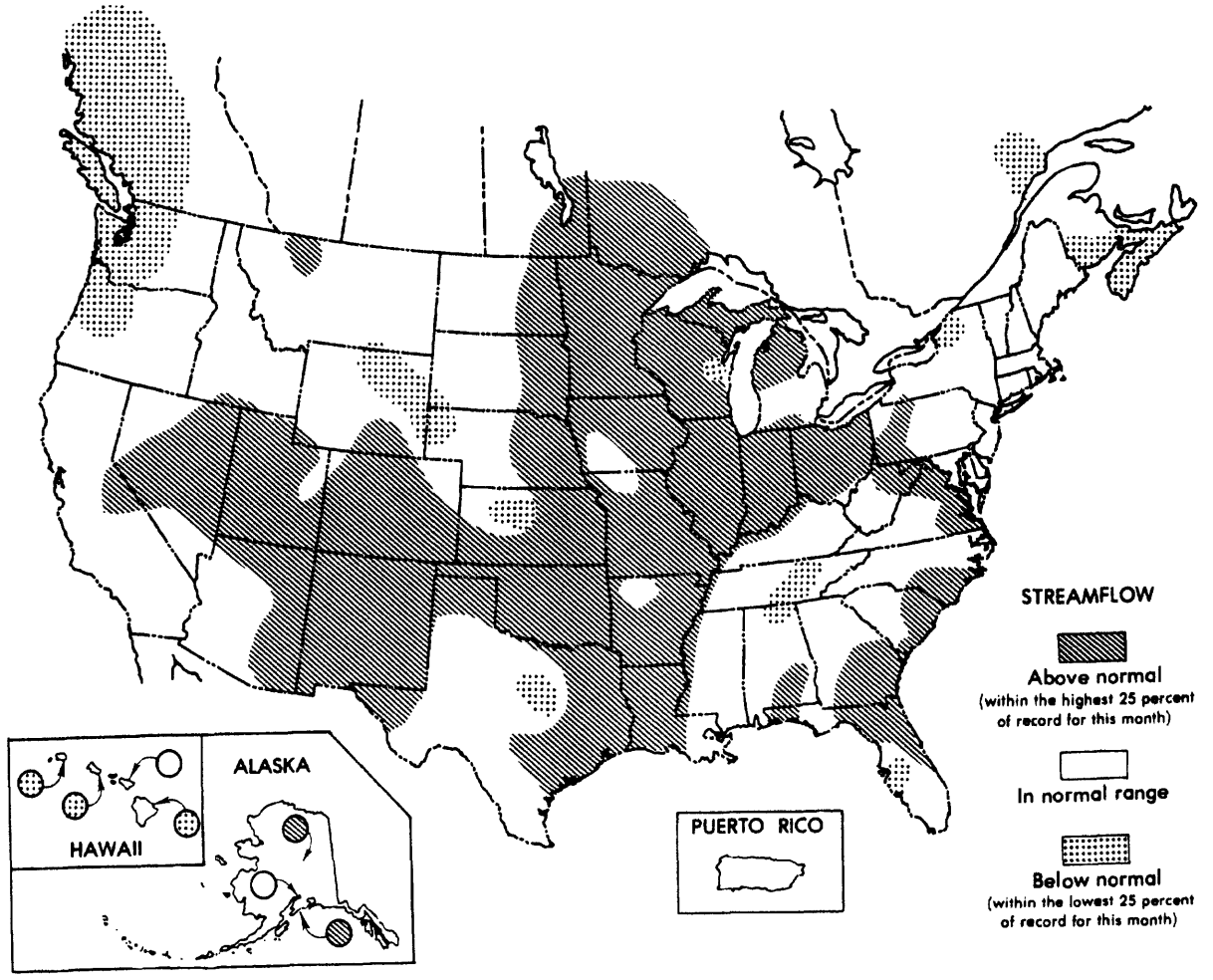


Figure 4. Streamflow during December 1985.

December 1985

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 1,527,500 cubic feet per second during December; this was a record high for the month. The Mississippi River at Vicksburg, Miss., also set a record high for the month—1,184,200 cubic feet per second, or about 78 percent of the combined flow of the three rivers.

Streamflow generally increased in Alaska, Oregon, California, Nevada, Arizona, Indiana, Kentucky, Tennessee, Alabama, and Georgia and in Saskatchewan in Canada; was variable in Idaho, Wyoming, New Mexico, Texas, Arkansas, Mississippi, and the Carolinas; and generally decreased in the rest of the United States and southern Canada. About 86 percent of the index stations had flows in the normal to above-normal range; this was down from the 94 percent for November.

The Snow River glacier-dammed lake on Alaska's Kenai Peninsula broke out and peaked at 12,000 cubic feet per second on December 3. A breakout occurs every 3 to 4 years, usually in September or October.

Contents of 72 percent of the index reservoirs were at or above average at the end of December and only 26 percent reported a significant decline in contents during December. On December 18, the Delaware River Basin Commission ended its drought emergency, which had been in effect since May 13, 1985. At the end of the month, New York City's reservoir system was below average in spite of an increase in contents during the month; on December 17, however, the contents of the system were about 74 percent of maximum, which equaled that at the end of the month.

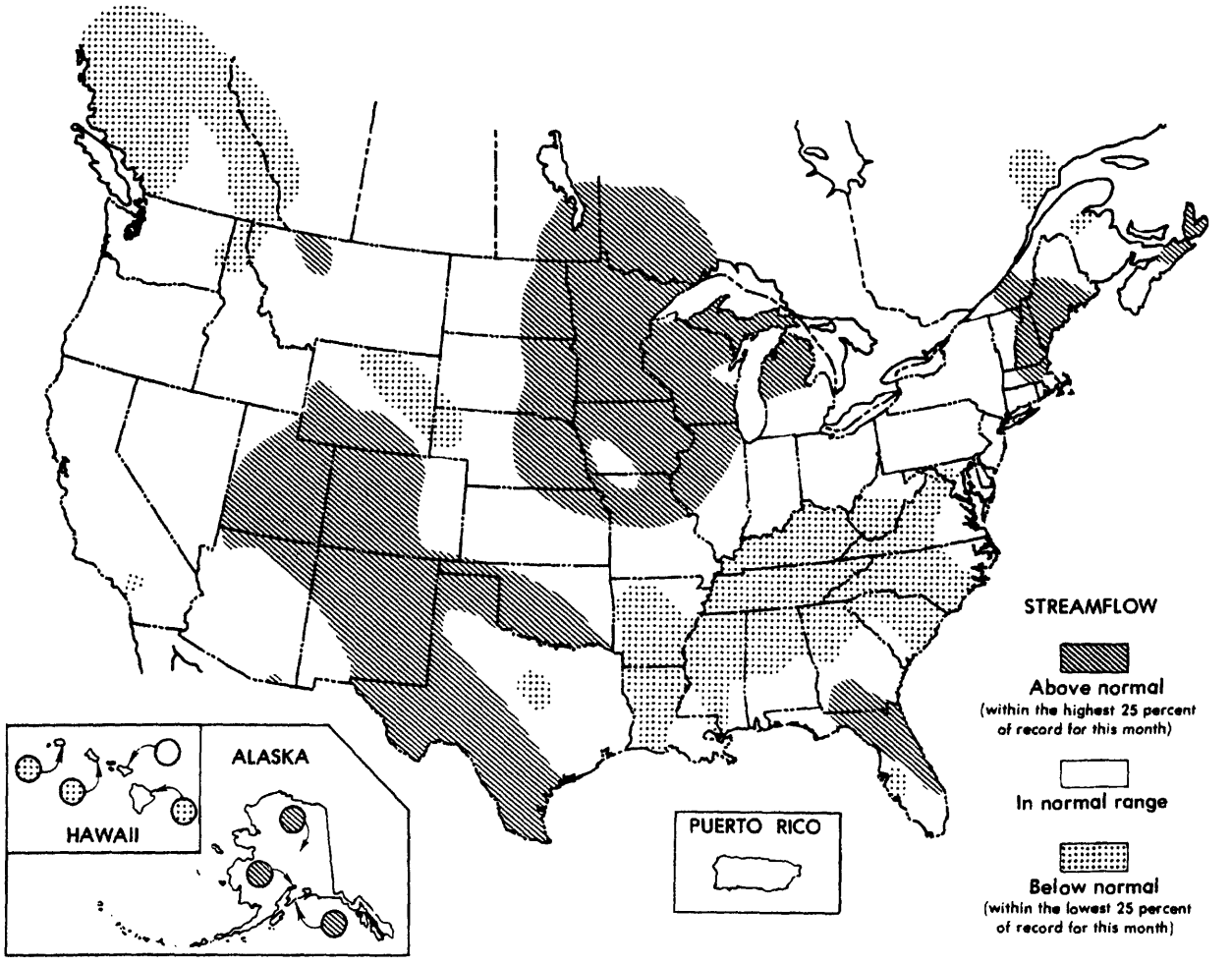


Figure 5. Streamflow during January 1986.

January 1986

Streamflow generally increased in British Columbia and Nova Scotia, Canada, the Pacific Coast States, Nevada, Nebraska, Florida, Connecticut, Massachusetts, New Hampshire, and Maine. Flows generally changed variably in Idaho, North Dakota, Texas, and New Brunswick, Canada; remained unchanged in South Dakota; and generally decreased in the rest of the United States and Canada. About 74 percent of the index stations had flows in the normal to above-normal range; this figure is down from the 86 percent for December.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 803,500 cubic feet per second, which was 47 percent below December and 16 percent below normal. The flow of the Mississippi River at Vicksburg, Miss. (drainage area 1,140,500 square miles), dropped sharply from 1,184,200 cubic feet per second (a December record high) to 476,200 cubic feet per second, which was only 74 percent of normal.

Contents of 74 percent of the index reservoirs were at or above average at the end of January, and only 22 percent recorded a significant decline in contents during January. Significant declines in contents occurred at only three reservoirs, which had below-average contents: International Amistad and International Falcon in Texas and High Rock Lake in North Carolina.

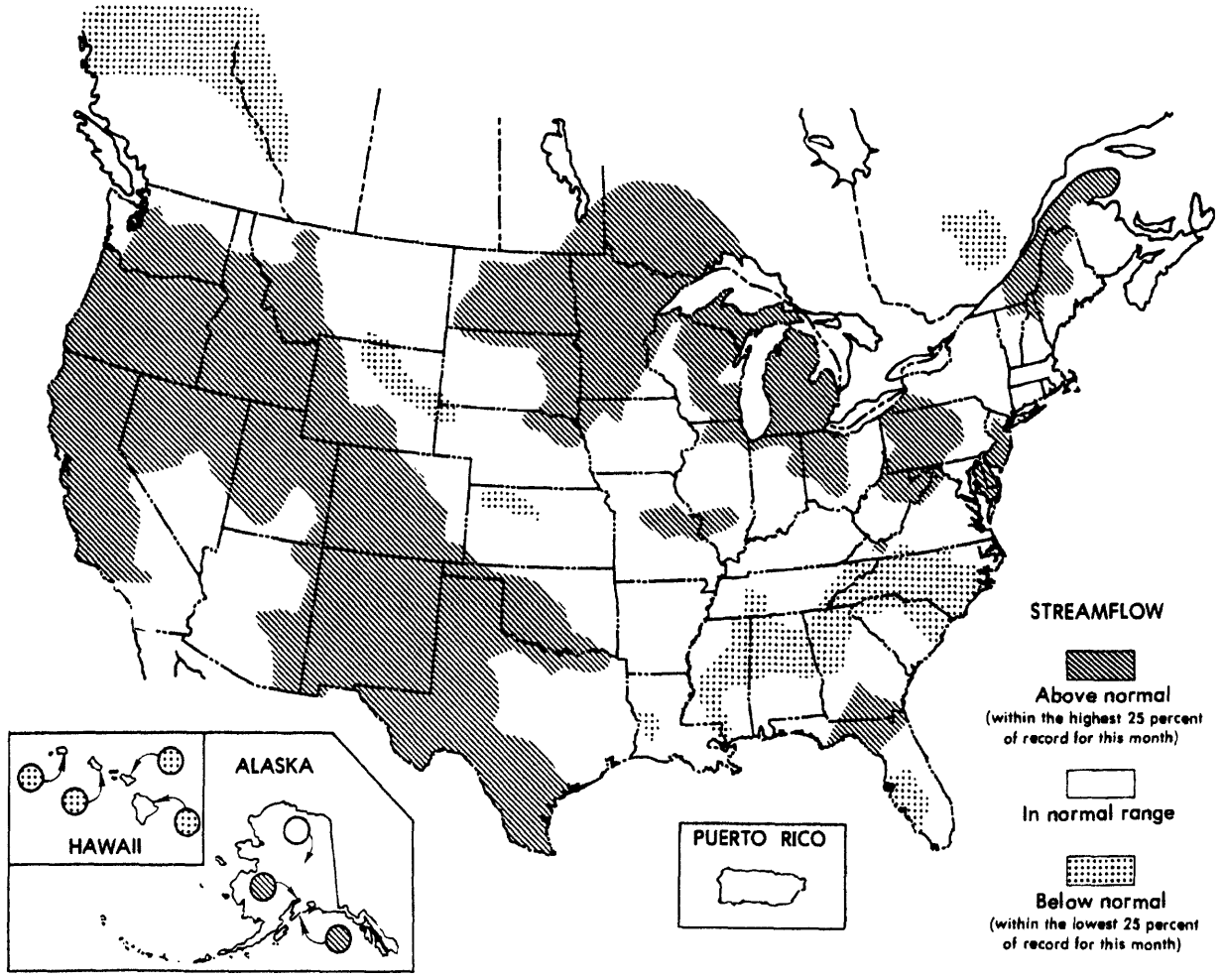


Figure 6. Streamflow during February 1986.

February 1986

Severe flooding occurred from February 17 to 20 in north-central California, where record peaks were equaled or exceeded at nine sites, and in western Nevada, where record flood peaks occurred on the Carson River near Fort Churchill and on the Truckee River near Sparks. Damages were estimated to exceed $300 million. About 27,000 people were evacuated from flood- and landslide-affected areas in the two States. Floods also occurred in Oregon, Georgia, Florida, and Utah, but damages were minimal in those States because of sparse population in the affected areas.

Streamflow generally decreased in Ontario, Quebec, and Nova Scotia in Canada, Alaska, Hawaii, Puerto Rico, Minnesota, Michigan, New Hampshire, Massachusetts, and Connecticut; changed variably in New Brunswick and British Columbia in Canada, Wisconsin, Mississippi, New York, Maine, and Florida; remained unchanged in South Dakota; and increased in the rest of the United States and southern Canada. About 85 percent of the index stations had flows in the normal to above-normal range, compared with the 75 percent for January.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 1,213,400 cubic feet per second during February, which was 20 percent above normal and 51 percent above last month; this reversal was as sharp as that from December 1985 to January 1986. Flow in the St. Lawrence River at Cornwall, Ontario, Canada, increased 16 percent to a February record high of 287,500 cubic feet per second.

Contents of 76 percent of the index reservoirs were at or above average at the end of February, and 15 percent recorded significant declines in contents. The only two sites that had below-average contents reported significant declines: Burton Reservoir in Georgia and Lake Merwin in Washington. Most reservoirs in California, Nevada, Utah, Colorado, Arizona, and New Mexico had above-average contents at the end of February.

The Great Salt Lake rose 0.75 foot during the month and reached an elevation of 4,209.90 feet above sea level on February 28. This level is 0.75 foot higher than at the end of February 1985 and only 0.05 foot lower than last year's maximum, which occurred on May 21.

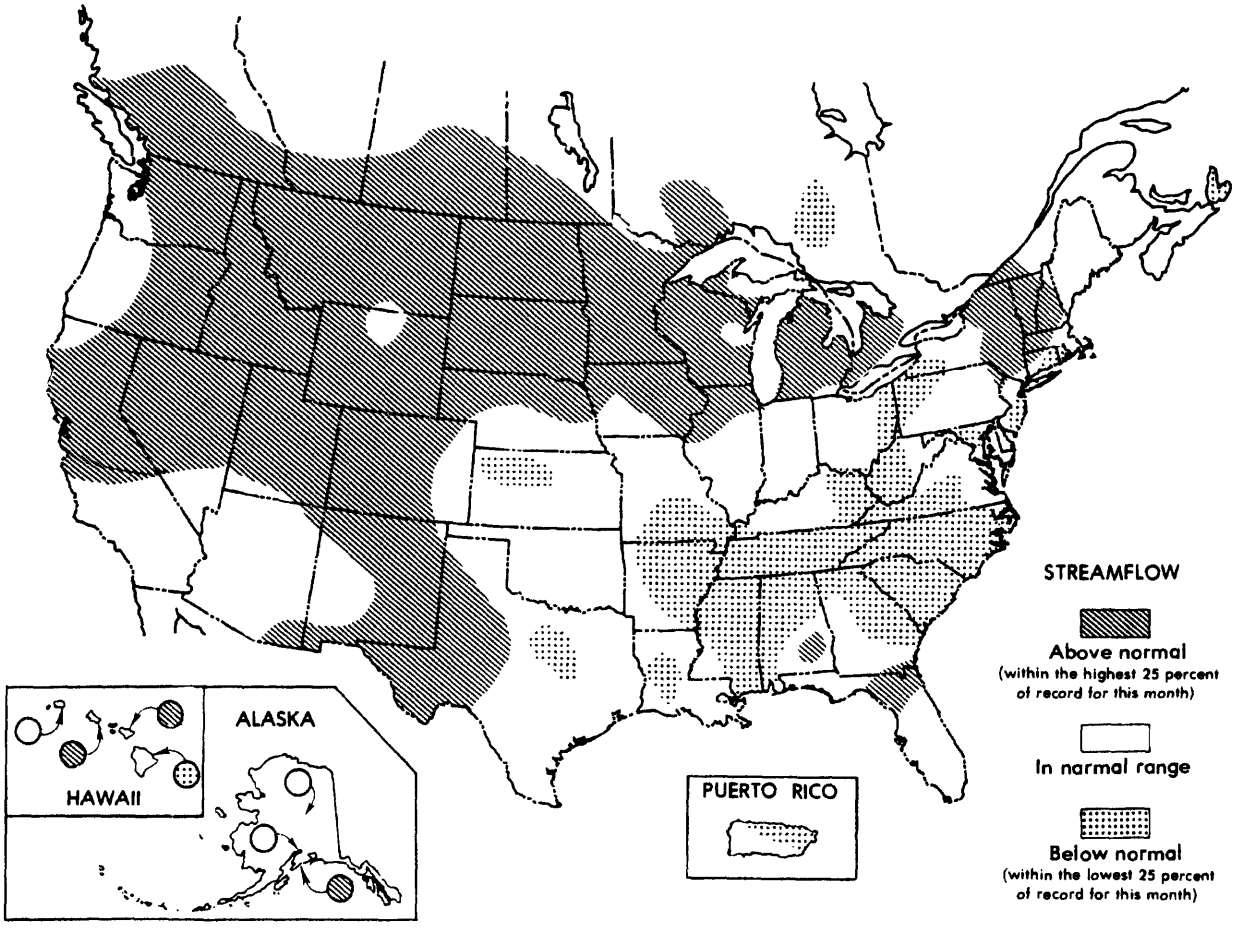


Figure 7. Streamflow during March 1986.

March 1986

The Great Salt Lake rose 0.60 foot during the month and reached an elevation of 4,210.50 feet above sea level on March 31; this was 0.55 foot higher than last year's maximum, which occurred on May 21. The National Weather Service predicted a 1986 maximum elevation of 4,211 feet above sea level (later changed to 4,211.6 feet) for the lake, given normal spring weather.

Streamflow decreased in Alaska, Puerto Rico, Washington, Nevada, Texas, Louisiana, Arkansas, Missouri, Indiana, Kentucky, West Virginia, Virginia, and Rhode Island and in New Brunswick and Ontario in Canada; changed variably in Oregon, California, New Mexico, Tennessee, Mississippi, Alabama, Georgia, and Ohio; and increased in the rest of the United States and southern Canada. About 77 percent of the index stations had flows in the normal to above-normal range compared with the 85 percent for the preceding month. Dry conditions in the Southeast led to many forest fires, and some parts of Hawaii were under water-use restrictions during March. During the month, the combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 1,321,500 cubic feet per second, which was 11 percent above normal and 9 percent above February.

Contents of 75 percent of the index reservoirs were at or above average at the end of March. Only two sites with below-average contents reported significant declines: Allard in Quebec, Canada, and International Amistad in Texas.

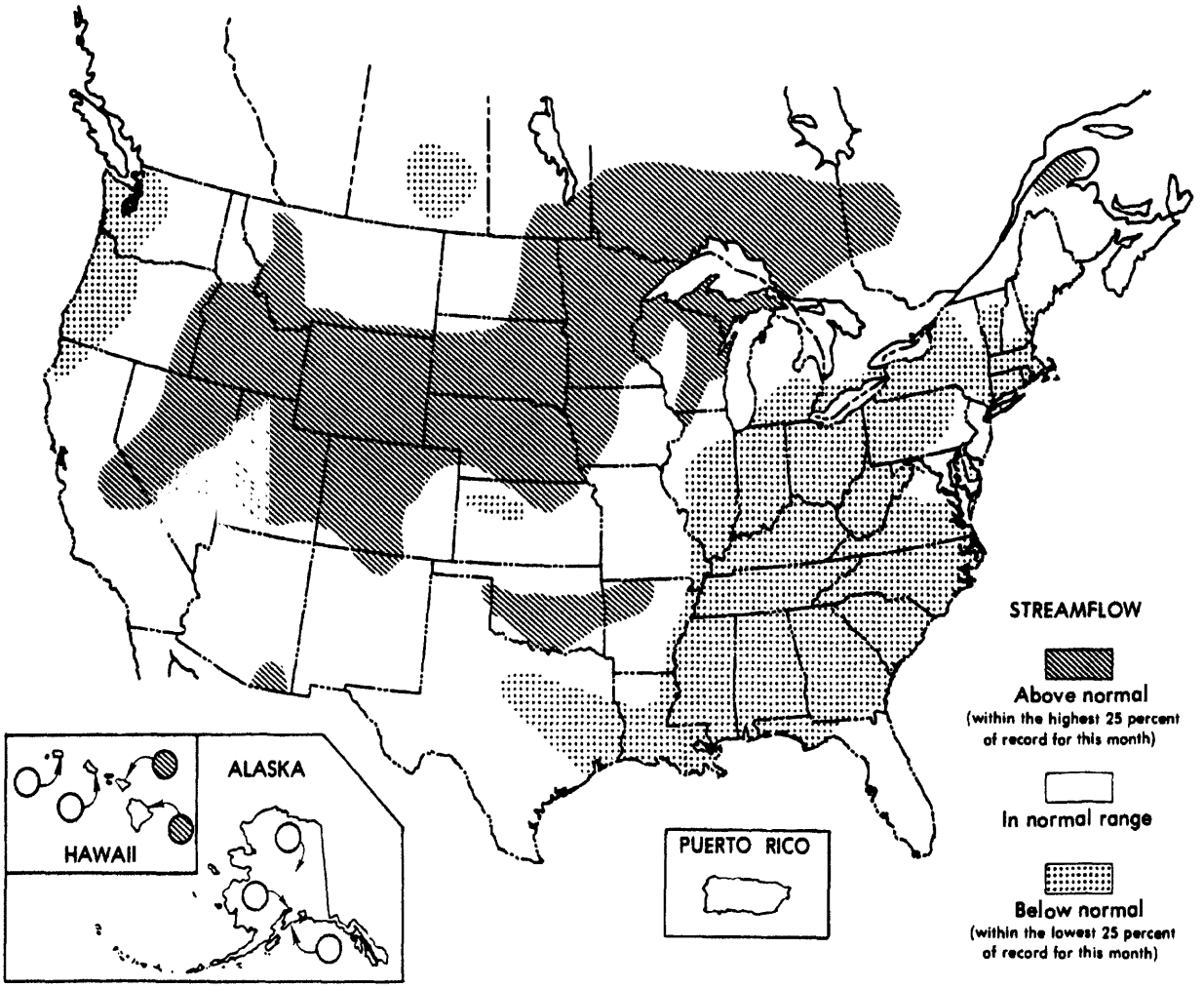


Figure 8. Streamflow during April 1986.

April 1986

Precipitation in the United States was well below average for April along the northern Pacific Coast and in Texas, Louisiana, and Missouri and was far below average in most States east of the Mississippi River. Streamflow decreased into the below-normal range in the Pacific Northwest and also in most of the area east of the Mississippi River, even where flows had been above normal during March; flows dramatically decreased in areas where flows had been in the below-normal range during March. About 71 percent of the index stations in the East had flows in the below-normal range, and one major forest fire burned in the Shenandoah National Park in Virginia. Record monthly lows for April occurred at 16 of the 38 index stations in the Southeast. In Alabama, for example, the monthly flow of 256 cubic feet per second and the daily flow of 194 cubic feet per second on April 27 at gaging station Cahaba River at Centreville were the lowest April flows in 59 years of record.

In sharp contrast, Utah's Great Salt Lake was at elevation 4,211.30 feet above sea level on April 30 after rising 0.80 foot during April. In what appears to be part of the same wet trend, the Great Lakes continue at or near record high levels.

For only the second time in 19 months, no new monthly high streamflows were recorded. Streamflow at the 12 index stations in Wyoming, Colorado, and Utah, which is the core of the area of above-normal flows, averaged 230 percent of normal for the month. The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 1,220,000 cubic feet per second, which was 8 percent below the preceding month and 14 percent below normal; flow of the Mississippi River at Vicksburg, Miss., decreased 109,000 cubic feet per second (14 percent) from March.

Contents of 72 percent of the index reservoirs were at or above average at the end of April. Most reservoirs with below-average contents were clustered in Nova Scotia in Canada, the Southeast (particularly the Tennessee Valley), Oklahoma, Texas, Wyoming, and Idaho.

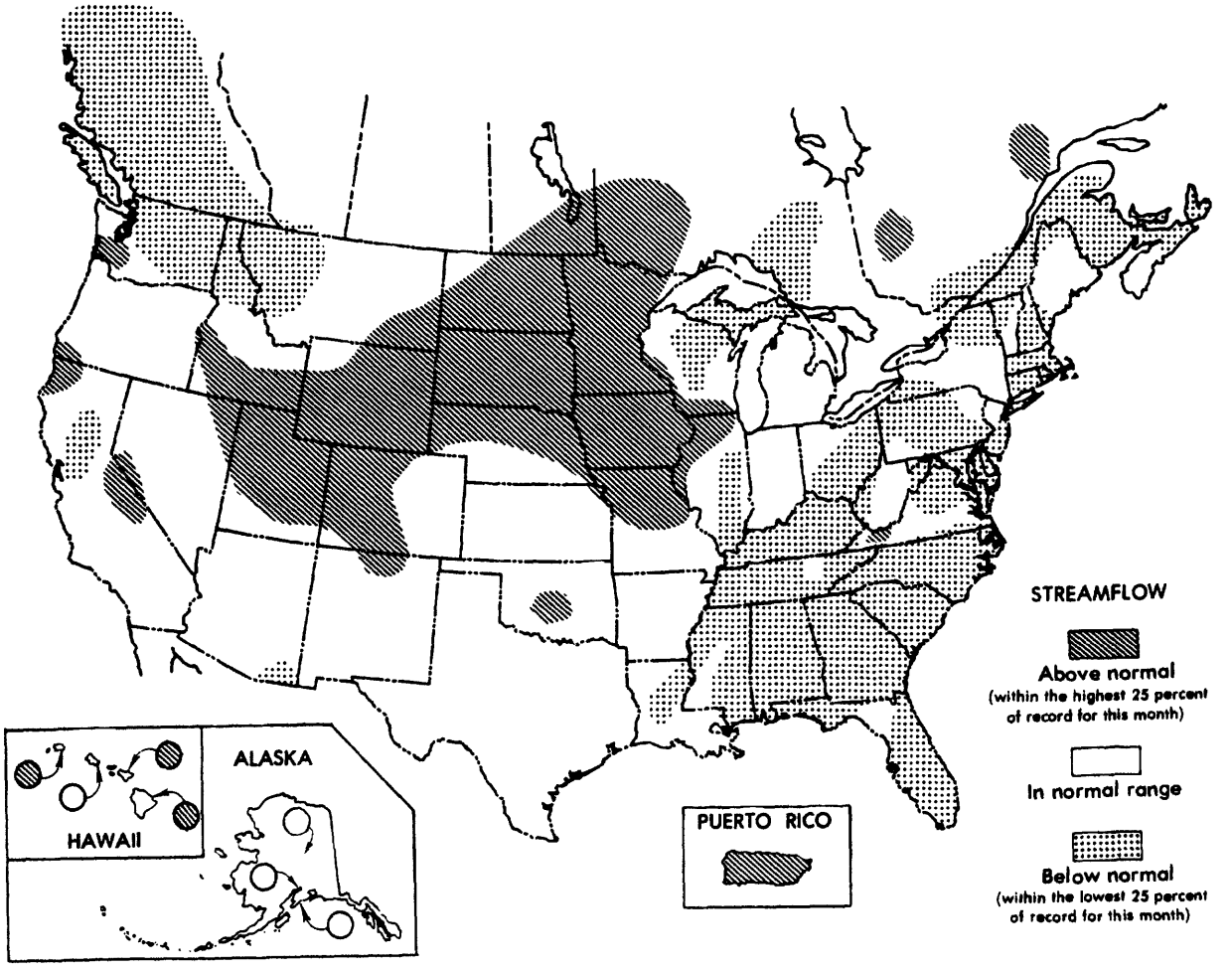


Figure 9. Streamflow during May 1986.

May 1986

Variability and persistence marked streamflow during May as precipitation across the United States fluctuated widely. For example, streamflow went from above normal to below normal in parts of Ontario, Canada, and in Michigan, Wisconsin, Montana, and Arizona and from below normal to above normal in parts of Washington, Oregon, California, and Virginia; record-high flows occurred in the upper midcontinent; record-low flows occurred in the East; and parts of the United States were in the fifth year of above-normal streamflow, the rise of Utah's Great Salt Lake being one symptom of the phenomenon.

About 57 percent of the index stations in the United States and southern Canada had flows in the normal to above-normal range compared with the 61 percent for last month. The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 1,237,200 cubic feet per second, which was 20 percent below normal but 1 percent above April.

On May 30, eight people were killed, one person was missing, and damages were about $20 million after flooding in the Etna, Pa., area. Little Pine Creek near Etna peaked at about 7,400 cubic feet per second as a result of more than 7 inches of rainfall in the headwaters area of the creek.

Contents of 71 percent of the index reservoirs were at or above average at the end of May. Only five reservoirs reported significant declines in contents during May and only two of those, International Amistad in Texas and Hungry Horse in Montana, had below-average contents at the end of May.

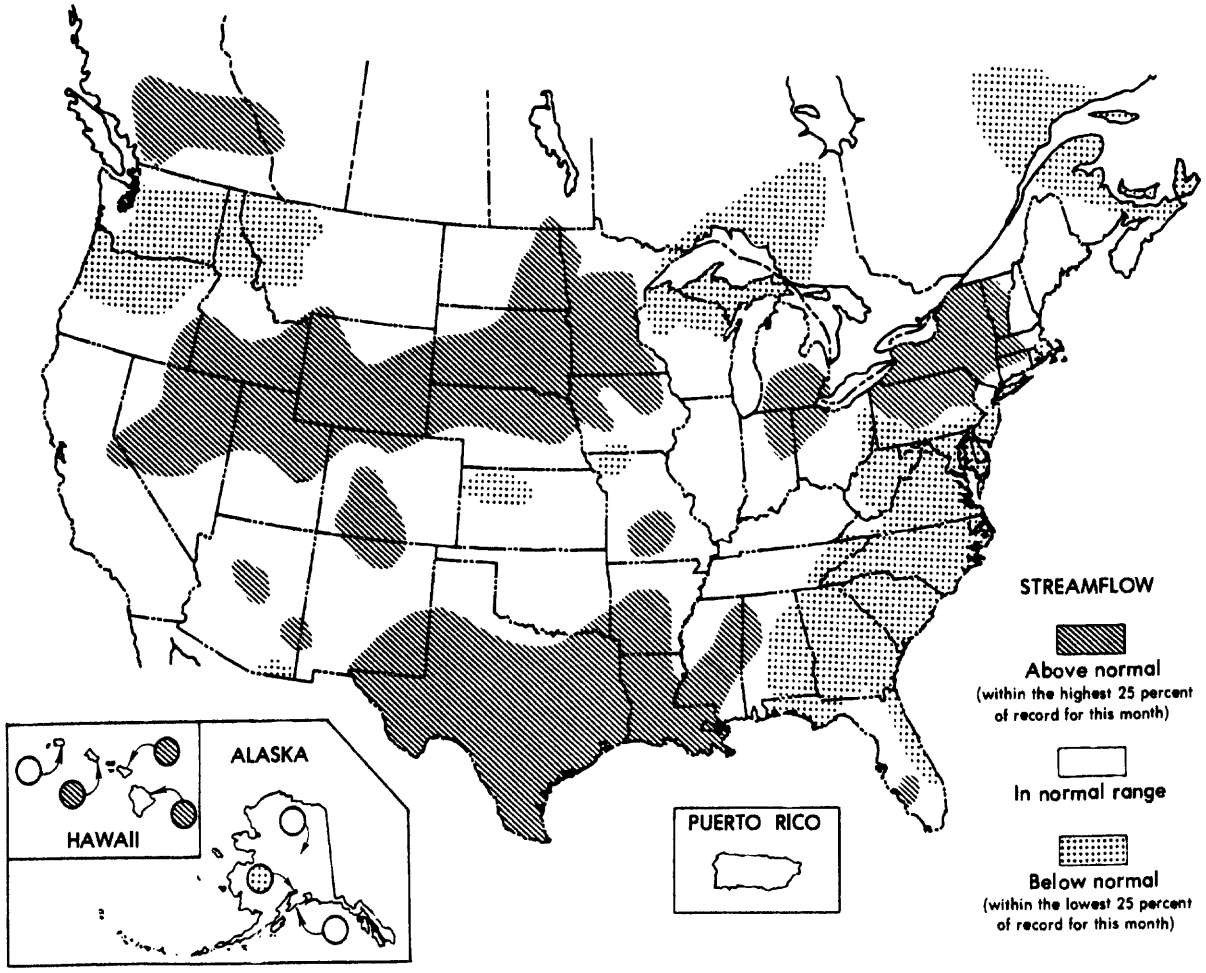


Figure 10. Streamflow during June 1986.

June 1986

Record low flows for June occurred in parts of Ontario, Canada, and in New York, Maryland, the Carolinas, and Georgia as drought conditions intensified in the Southeast. Streamflow was below normal at 10 index stations in the Southeast for the sixth consecutive month: five in North Carolina, two in South Carolina, and one each in Tennessee, Alabama, and Georgia. In sharp contrast, record floods occurred in parts of Iowa, Louisiana, Montana, and Utah. About 74 percent of the index stations in the United States and southern Canada had flows in the normal to above-normal range compared with the 57 percent for the preceding month. Precipitation during June fluctuated widely in the United States: Parts of the Southeast received less than 0.5 inch of rain, whereas parts of Louisiana, Arkansas, and Texas received over 12 inches. The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 1,528,000 cubic feet per second, which was 17 percent above normal and 24 percent above that for May.

The Great Salt Lake, at elevation 4,211.40 feet above sea level on June 30, was in a slow seasonal decline. The maximum lake level for the year, 4,211.85 feet, occurred between June 3 and 8 before a severe windstorm caused a breach in a mineral-recovery pond dike on June 8.

Alaska's Hubbard Glacier, which surged during winter 1985–86, dammed Russell Fiord on June 1. A lake as large as Lake Powell (24 million acre-feet) could form within 2 years if the rate of ice damming continues to exceed the rate of water-level rise.

Contents of 78 percent of the index reservoirs were at or above average at the end of June. The seven-reservoir system in Maine, the Baltimore municipal system in Maryland, High Rock Lake in North Carolina, and Keystone Reservoir in Oklahoma were the only sites that reported significant decline in contents during June and below-average contents at the end of June.

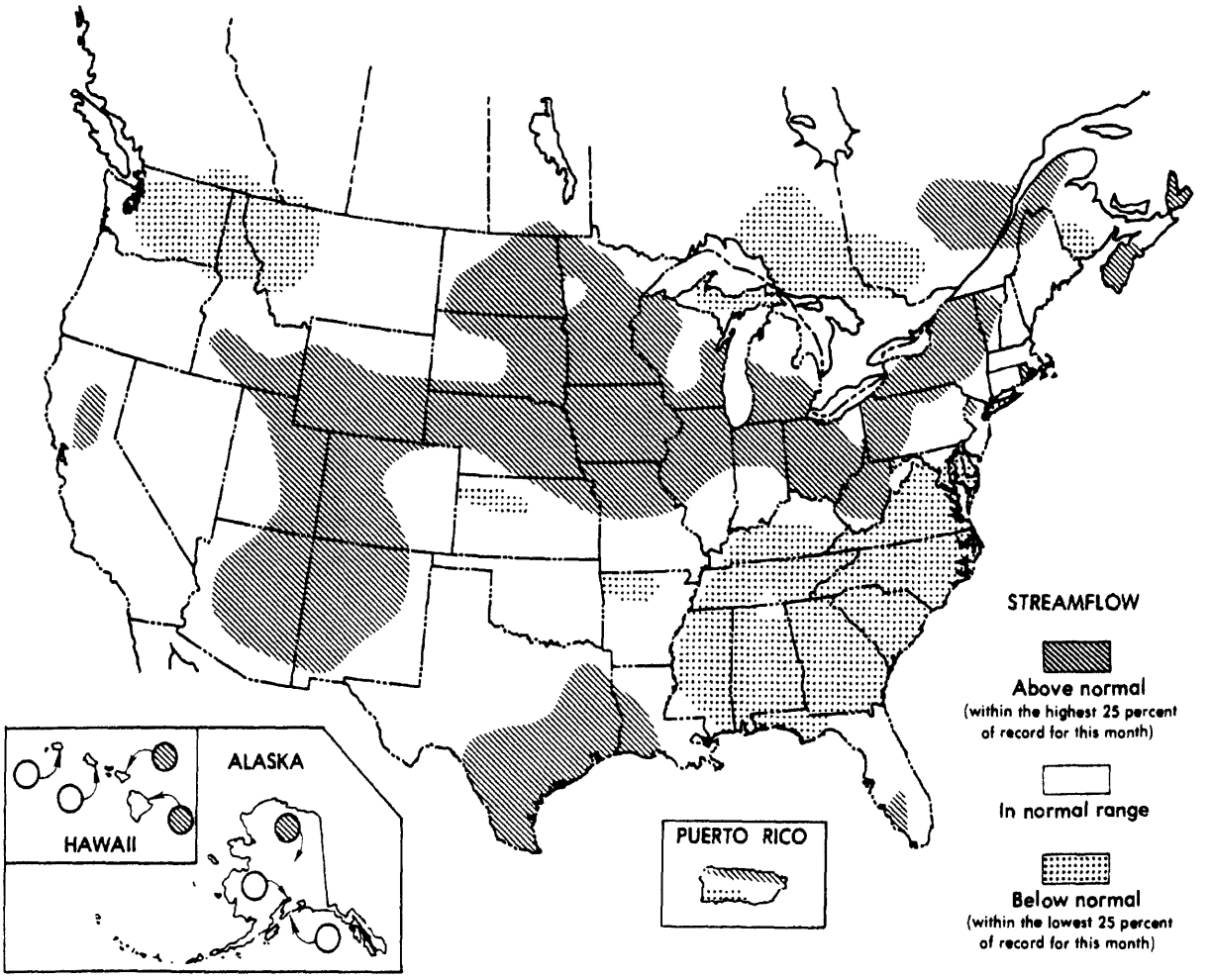


Figure 11. Streamflow during July 1986.

July 1986

Record low flows for July occurred at 11 index stations in the Southeast and one index station in Canada. Drought conditions in the Southeast intensified as below-average precipitation fell in most of the area south of a line from Maryland to Texas. July streamflow at the 16 index stations in the Carolinas, Georgia, and Alabama averaged 36 percent of normal. In sharp contrast to drought conditions in the Southeast, streamflow was in the above-normal range in a broad, irregular band arcing from Arizona to Vermont, but the only record high for July occurred in New Mexico. About 77 percent of the 192 index stations in the United States and southern Canada had flows in the normal to above-normal range compared with the 74 percent for the preceding month. The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 1,061,000 cubic feet per second, which was 9 percent above normal but 31 percent below that for June. In mid-July, toxic blooms of blue-green algae occurred in Hebgen Lake in the southwestern part of Montana near Yellowstone National Park. Hebgen Lake has had toxic blooms of these algae twice in the past (1977 and 1985), but this is only the fifth time toxic concentrations of blue-green algae have been documented in Montana.

Contents of 69 percent of the index reservoirs were at or above average. Most reservoirs with both below-average contents at the end of July and significant declines in contents during July were located in the Southeast. New July lows for ground-water levels occurred in five wells in Georgia. Alltime lows for ground-water levels occurred in index wells at Savannah, Ga. (U.S. well 6), and Memphis, Tenn. (U.S. well 2).

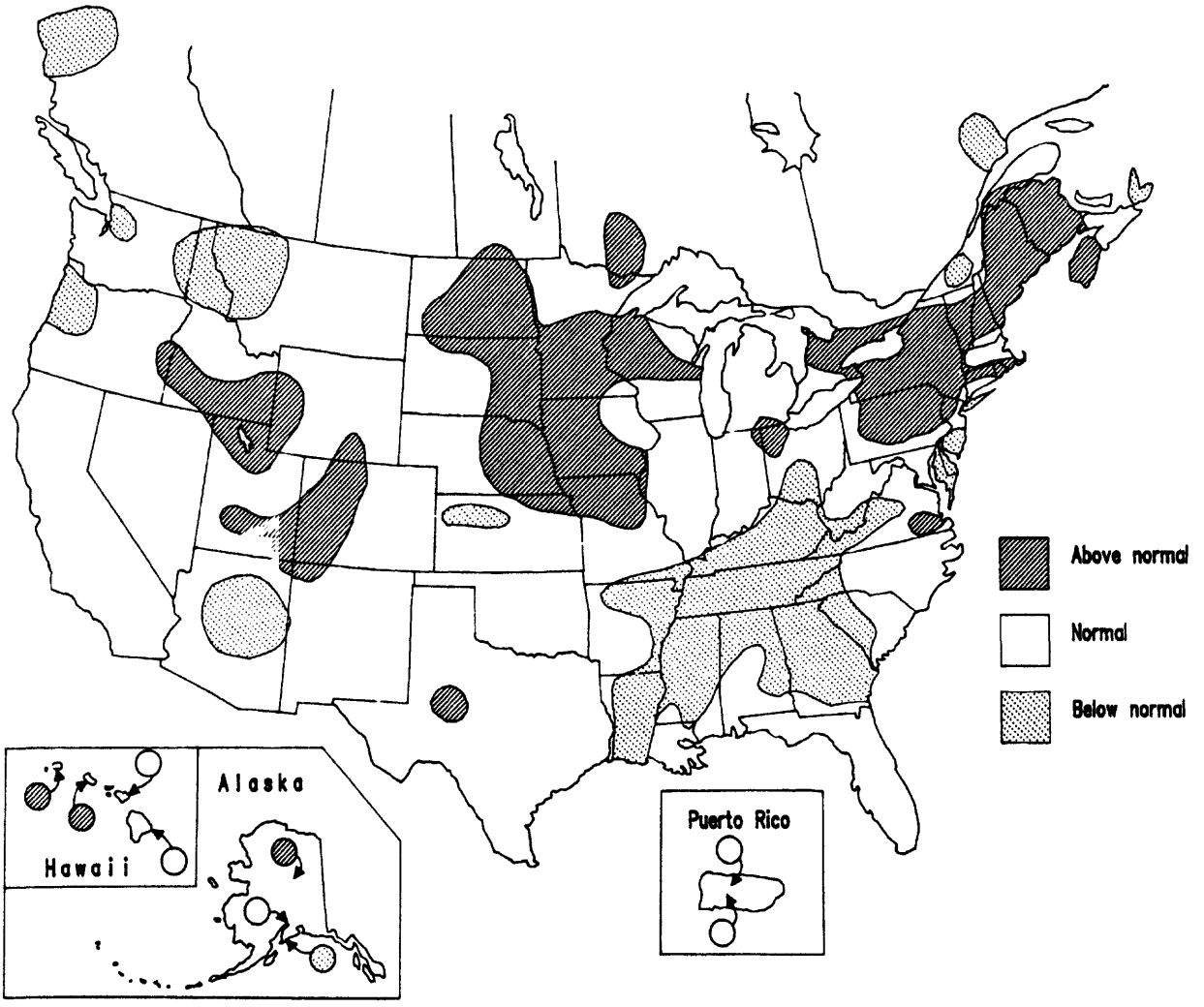


Figure 12. Streamflow during August 1986.

August 1986

Record-low flows for August occurred at index stations in Quebec, Canada, and in Georgia and Alabama. Because monthly discharge of the Apalachicola River at Chattahoochee, Fla., was an alltime low for the 58 years of record at that site, the river was closed to barge traffic early in the month. Streamflow at the 16 index stations in the Carolinas, Georgia, and Alabama averaged about 69 percent of normal during August compared with 36 percent of normal for July.

About 74 percent of the 188 index stations reporting data for August had flows in the normal to above-normal range compared with the 77 percent for last month. The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 786,600 cubic feet per second, which was 6 percent above normal but 26 percent below that for September. Flow in the St. Lawrence River at Cornwall, Ontario, Canada, was above normal for the 19th consecutive month.

The heavy rains of August eased drought conditions in parts of the Southeast; however, in South Carolina, they caused flooding that killed three people on August 18 when about 10.5 inches of rain fell in 7 hours near Newberry. On the evening of August 6 in Milwaukee, Wis., two people drowned after 6.79 inches of rain fell (4 inches in 2 hours), which caused stream and urban flooding. Peak discharge in the Kinnickinnic River at Milwaukee was almost twice that of a 100-year flood.

Contents of 82 percent of the index reservoirs were at or above average for the end of August. Only the Baltimore municipal reservoir system in Maryland, Douglas Lake and the Little Tennessee Projects in the Tennessee Valley, and Buffalo Bill Reservoir in Wyoming recorded below-average contents and a decline of more than 5 percent in contents during August.

Utah's Great Salt Lake declined only 0.30 foot during August and was at an elevation of 4,210.85 feet above sea level on August 31. Alaska's Russell Lake continued to rise behind the ice dam of Hubbard Glacier. An August 11 to 15 survey of terminal-moraine lakes in Oregon's Three Sisters Wilderness Area indicated that conditions at Carver Lake posed a potentially significant hazard. The impounding moraine is steep, unstable, and vulnerable to erosion.

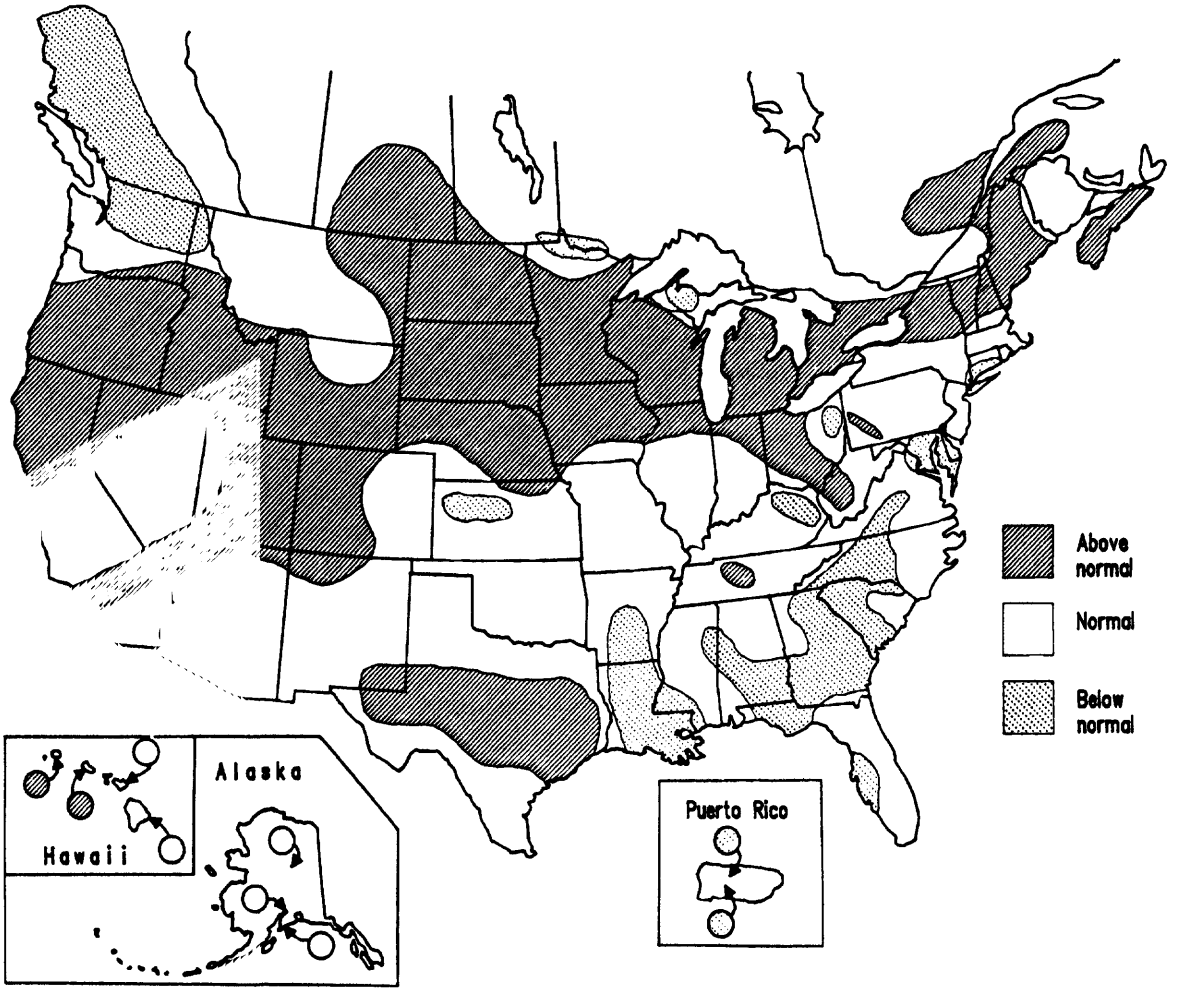


Figure 13. Streamflow during September 1986.

September 1986

Severe flooding began in the central part of Michigan's Lower Peninsula on September 11. Peak discharges on many rivers and streams exceeded both the peak of record and the 100-year flood. On September 12, several dams failed, as did the Flint River dikes in the southern part of the Saginaw County. Flood damages in Michigan were estimated to be $400 million with 27 counties declared State disaster areas and 22 of the 27 counties declared Federal disaster areas. Near monthend, floods occurred in Montana and in a broad band from Oklahoma into western Pennsylvania.

Streamflow was in the normal to above-normal range at 81 percent of the 192 index stations compared with 74 percent for August. Monthly flow of the St. Lawrence River near Cornwall, Ontario, Canada, was the highest for September in 126 years of record. In the Southeast, however, flows were below normal at 14 of the 16 index stations in the Carolinas, Georgia, and Alabama, which reflected the prolonged dry spell in that area of the Nation. Utah's Great Salt Lake was at elevation 4,210.75 feet above sea level on September 30, after declining 0.15 foot between September 1 and 15 and rising 0.05 foot between September 15 and 30.

Alaska's Russell Lake continued to rise behind the dam of Hubbard Glacier and reached an altitude of about 80 feet by the end of the month. Two other glacial events occurred in Alaska during the month. A breakout of Berg Lake, which had been dammed by Steller Glacier, flooded about 50 square miles of an uninhabited area of mostly scrub and brush within the Chugach National Forest. The lake and glacier, which are about 65 miles east of Cordova, are in the Chugach Mountains along Alaska's southern coast. Peters Glacier, which is on the north side of the Denali (Mt. McKinley) massif, surged about 1½ miles. Denali National Park personnel reported that on September 10, the glacier's leading edge was advancing at a rate of 1.5 feet per hour and that a vertical wall of ice at the terminus had attained a height "of at least 150 feet."

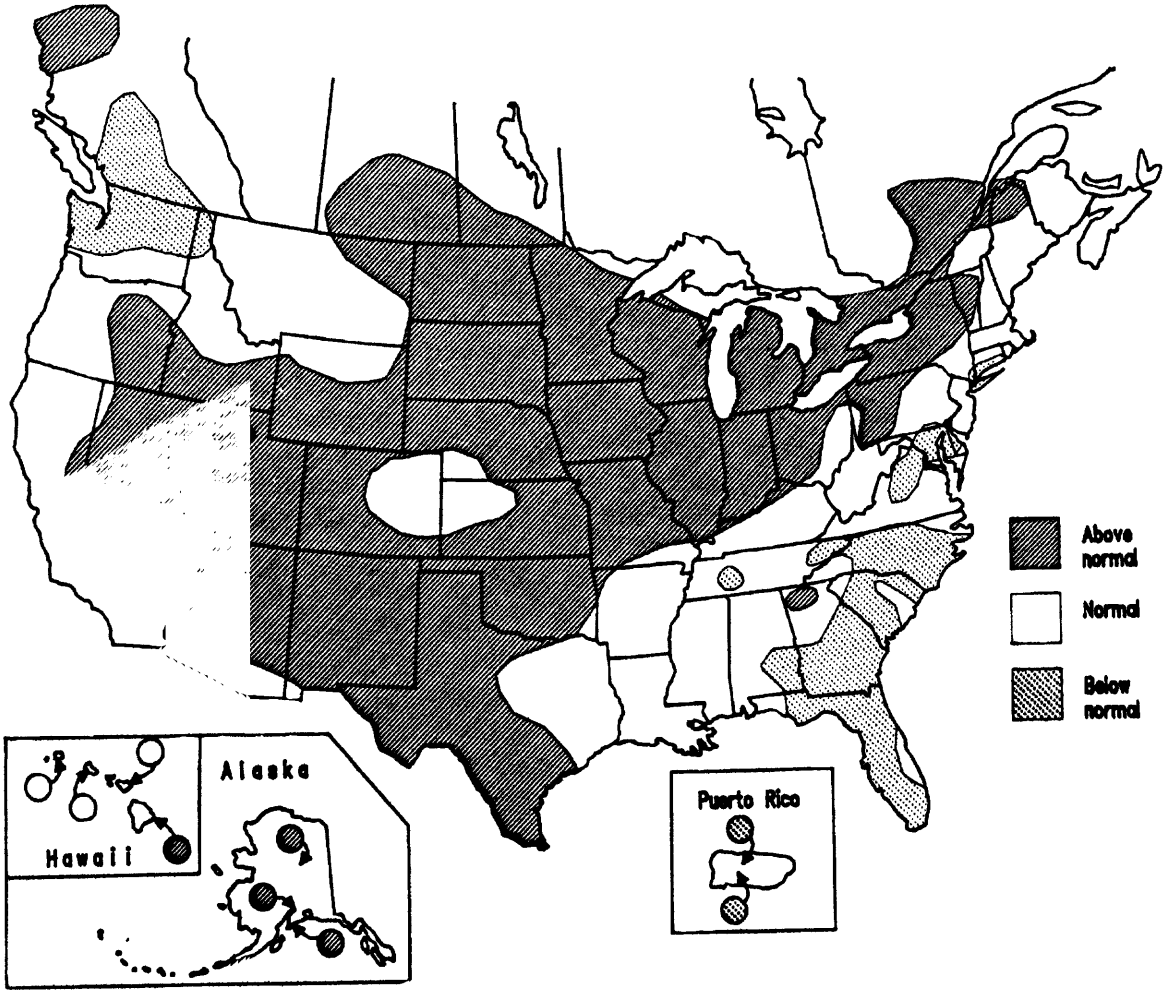


Figure 14. Streamflow during October 1986.

October 1986

A major fall flood in the central Midwest affected large parts of Oklahoma, Kansas, Missouri, Illinois, and parts of adjacent States. As much as 25 inches of rain was reported in north-central Oklahoma from September 29 to October 3. Peak discharges on many rivers and streams exceeded both the peak of record and the 100-year flood. Devastating floods also occurred in south-central Alaska on October 10 and 11 with the areas around Seward, Bradley Lake (at the head of Kachemak Bay, east of Homer), and the Susitna River Valley the hardest hit. Damages were estimated at $15 million to $20 million in Alaska and $100 million in Chicago and its suburbs.

Streamflow was in the normal to above-normal range at 85 percent of the 192 index stations (includes Puerto Rico). Below-normal streamflow persisted in large parts of the Pacific Northwest and the Southeast. Monthly flows were highest of record for October in parts of 10 States and lowest of record for the month in parts of New York, Florida, and Puerto Rico.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged a record-breaking 1,351,500 cubic feet per second, which exceeded the record high set in 1973 of 928,800 cubic feet per second by 45 percent. Although flows in all three rivers were in the above-normal range, flows in the St. Lawrence near Cornwall, Ontario, Canada (126 years of record), and the Mississippi at Vicksburg, Miss. (58 years of record) set records for the month.

Contents of 87 percent of the index reservoirs were near or above average at the end of October. The only reservoirs with below-average contents that also declined significantly during the month were Lake Cushman in Washington and Pend Oreille Lake in Idaho.

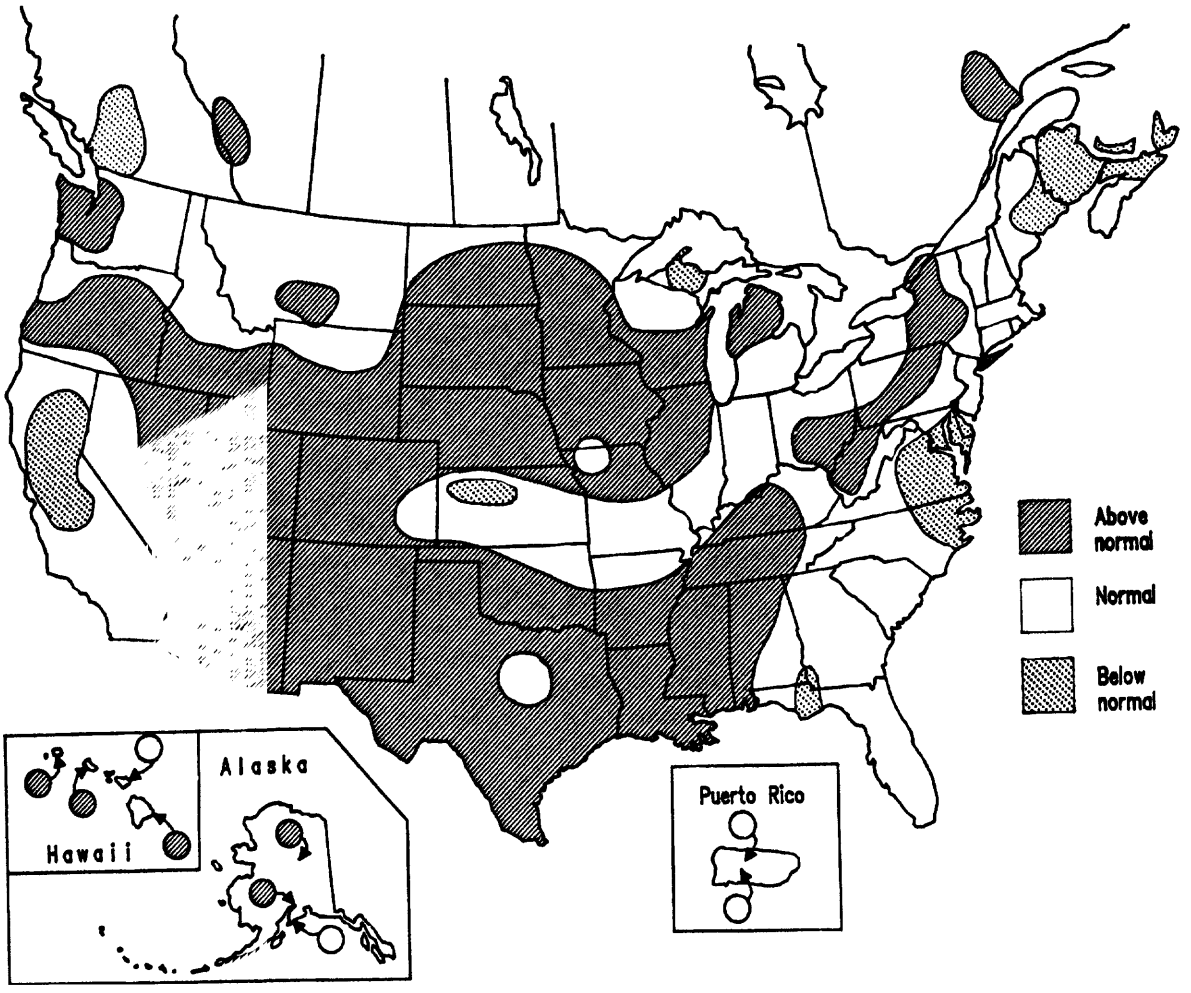


Figure 15. Streamflow during November 1986.

November 1986

Between November 23 and 25, severe floods occurred in Washington State as over 7 inches of rain fell in 24 hours in some areas. For example, the Chehalis River near Grand Mound peaked at 51,100 cubic feet per second, which is a recurrence interval of about 50 years, thus making it one of the four streams that had peak discharges exceeding former peaks of record in the area.

During November, streamflow was in the normal to above-normal range at about 91 percent of the 192 index stations in southern Canada and the United States compared with 85 percent for October. New maximum monthly discharges for November occurred at seven index stations, six of which were west of the Mississippi River.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged a record-breaking 1,234,400 cubic feet per second (3 percent higher than November 1973), which was 85 percent above normal but 9 percent below last month's record-breaking combined flow. Monthly flow in the St. Lawrence River at Cornwall, Ontario, Canada (the only station east of the Mississippi with new maximum monthly November discharge), averaged 337,900 cubic feet per second; this was 36 percent above normal, which was the highest flow for November in 126 years of record.

Great Lakes monthly levels for November remained well above average on all the lakes. Contents of 87 percent of the index reservoirs were near or above average at the end of November. Only three reservoirs (First Connecticut Lake in Connecticut, Lewis and Clark Lake in South Dakota, and Pend Oreille Lake in Idaho) had a significant decline in contents during the month as well as below-average contents at the end of the month.

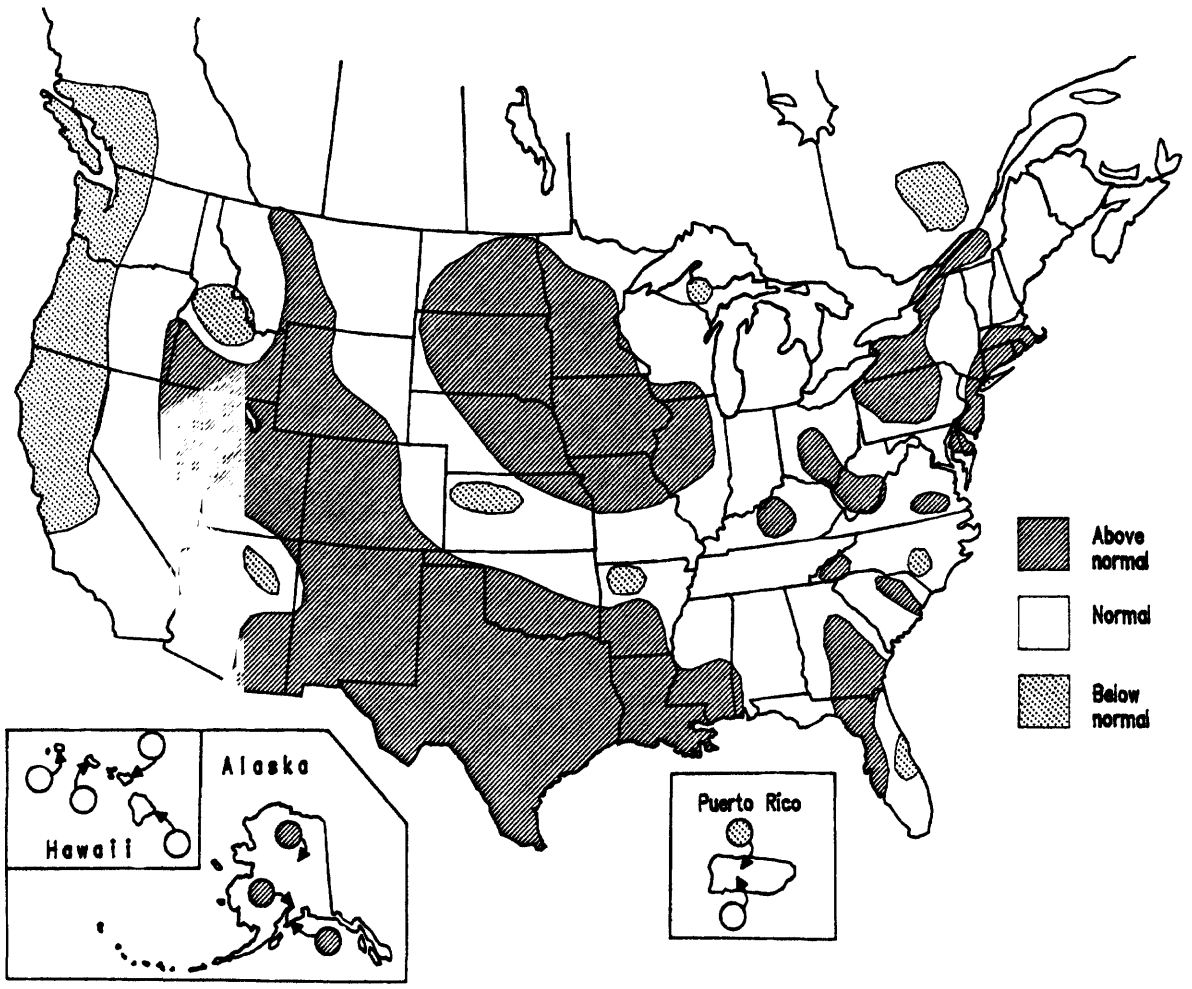


Figure 16. Streamflow during December 1986.

December 1986

Streamflow was in the normal to above-normal range at 89 percent of the 191 index stations in southern Canada, the United States, and Puerto Rico during December compared with about 90 percent for November. With 24.5 percent of the streamflow index stations in the below-normal range, calendar year 1986 was less dry overall than calendar year 1985 when about 36 percent were below normal; the southeastern part of the United States, however, was generally drier in 1986. Most of the Southeast and parts of Oregon, Washington, Idaho, Montana, Kansas, New York, Connecticut, and New Brunswick in Canada were in the below-normal range for both calendar years.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 1,396,800 cubic feet per second. Flow in the St. Lawrence River at Cornwall, Ontario, Canada, was a record-breaking 327,000 cubic feet per second and was above normal for the 23d consecutive month.

Lakes Superior and Erie set new records for highest average annual elevation—602.65 feet in Superior and 574.76 feet in Erie—above sea level. Utah's Great Salt Lake rose 0.15 foot during the month, thus reaching 4,211.20 feet above sea level on December 31.

Contents of 87 percent of the index reservoirs were near or above average at the end of December; this was the same as at the end of November. The only reservoirs with significant declines during the month and significantly below-average contents at the end of the month were Pymatuning reservoir in Pennsylvania, Coeur d'Alene Lake in Idaho, and Lake Cushman in Washington.

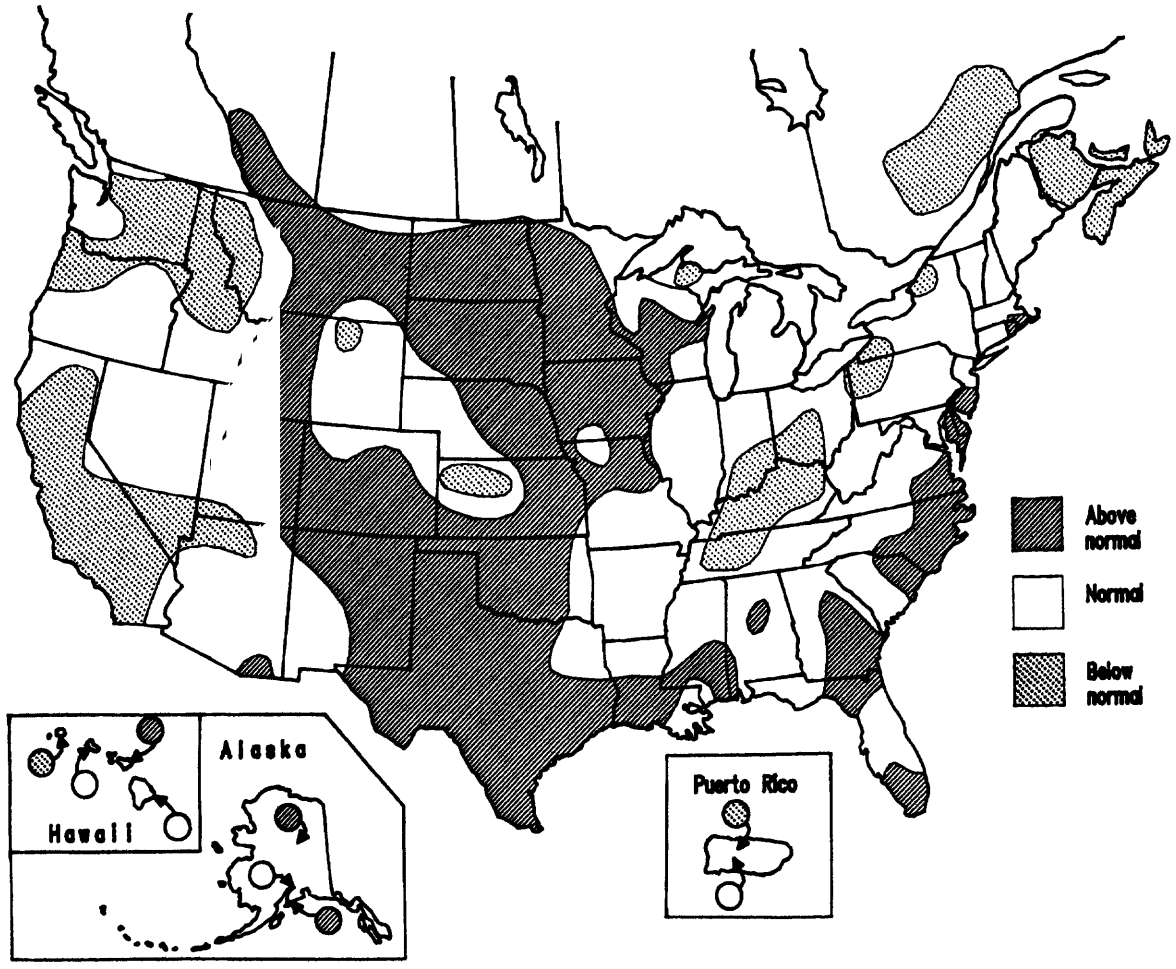


Figure 17. Streamflow during January 1987.

January 1987

Total January streamflow at 190 index streamflow stations was down 27 percent from December flows at those same stations. About 82 percent of the stations reporting for January had flows in the normal to above-normal range, compared with 89 percent for December. Record-high monthly flows occurred at six index stations, most notably the St. Lawrence River at Cornwall, Ontario, Canada—298,700 cubic feet per second. However, the combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—was 4.6 percent below normal and 32 percent below December's flow.

Contents of 85 percent of the index reservoirs were near or above average at the end of January compared with 87 percent at the end of December. The only reservoirs with significant declines in contents during January and significantly below-average contents for the month were the Seven Reservoir System in Maine, Lake Francis in Pennsylvania, the Boise River System and Coeur d'Alene Lake in Idaho, and Lake Chelan in Washington. The Boise River reservoirs contained only 6 percent of capacity, which was an alltime low.

Of the Great Lakes, Lake Erie averaged a January record high of 574.62 feet above sea level. The elevation of Utah's Great Salt Lake was at 4,211.40 feet above sea level after rising 0.20 foot during the month.

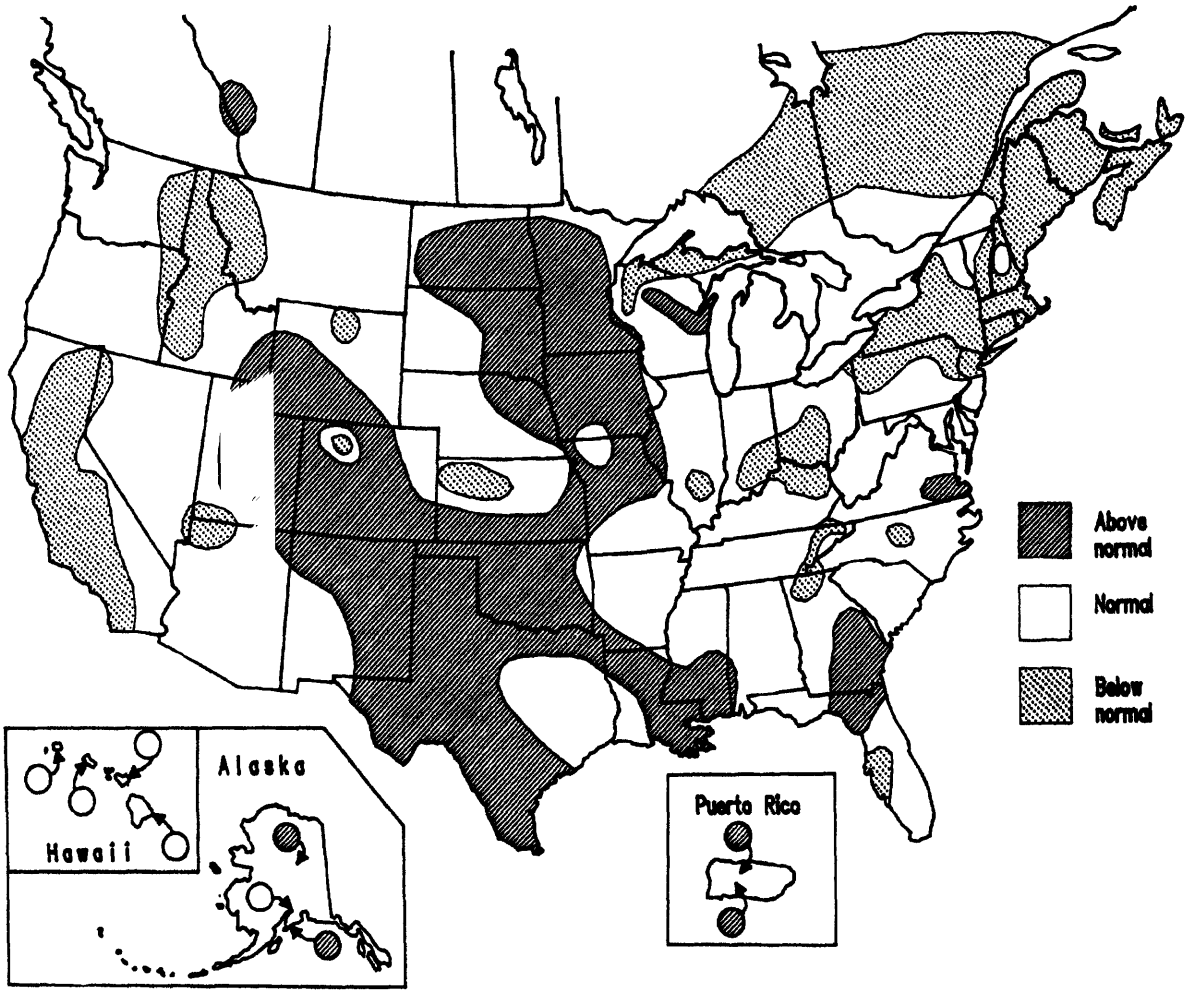


Figure 18. Streamflow during February 1987.

February 1987

Streamflow generally decreased in much of the East, generally increased in the midcontinent, and changed variably in the West. Total February streamflow at the 191 index stations in southern Canada, the United States, and Puerto Rico was up 5.1 percent from that for January but 3 percent below normal for the month. Streamflow was in the normal to above-normal range at about 72 percent of the 191 stations, compared with the 82 percent for the preceding month. New February extremes occurred at six streamflow index stations: record-high monthly flows at four index stations and record-low monthly flows at two index stations. The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 949,000 cubic feet per second, which was 4.6 percent below normal and 32 percent below January's flow.

February precipitation was above average over most of the conterminous United States: Total precipitation exceeded 6 inches in 28 cities. Record-high monthly totals were recorded at 13 cities, and record-low monthly totals at 11 cities.

February elevations for the Great Lakes were lower than those for the preceding month and February 1986, except for Lake Ontario, which averaged 0.10 foot higher than the preceding month and 0.20 foot higher than in February 1986. Utah's Great Salt Lake rose 0.25 foot during the month, thus reaching an elevation of 4,211.65 feet above sea level on February 28; this was only 0.20 foot below last year's record high (June 3–8) of 4,211.85 feet above sea level.

Contents of 83 percent of the index reservoirs were near or above average at the end of February compared with 85 percent at the end of January. Contents of Idaho's Boise River reservoirs increased to 67 percent of maximum (slightly above the end-of-February average) after being at an alltime low of 6 percent of maximum at the end of January.

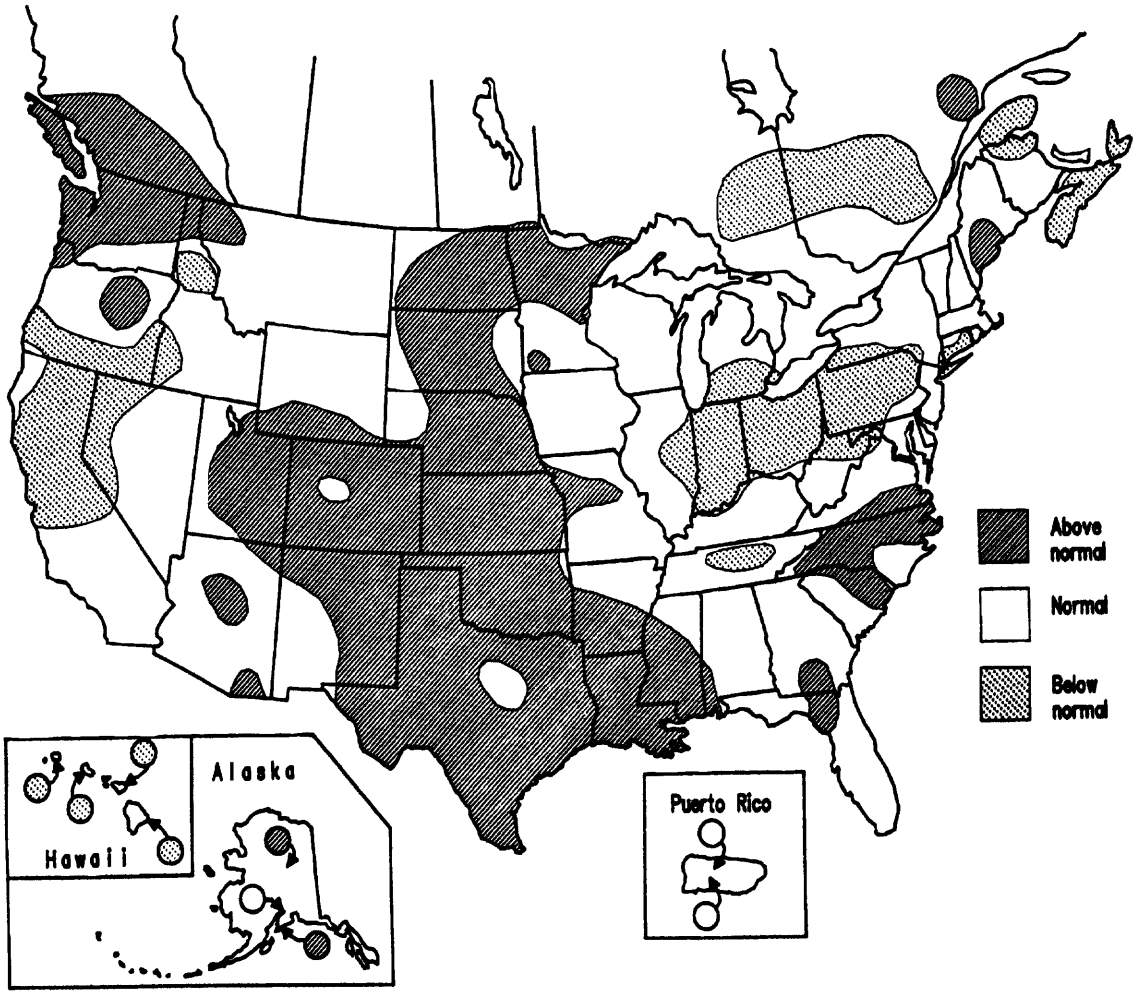


Figure 19. Streamflow during March 1987.

March 1987

March streamflow generally increased seasonally in the conterminous United States, changed variably in southern Canada, and decreased in Alaska, Hawaii, and Puerto Rico. Streamflow was in the normal to above-normal range at about 66 percent of the 190 index stations in southern Canada, the United States, and Puerto Rico, compared with the 72 percent for February. In Nebraska, floods that exceeded previous peaks of record occurred at four stream-gaging stations, but no damage was reported. The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 1,441,500 cubic feet per second, which was 22.1 percent above normal and 46.6 percent above the flow in February.

March elevations for the Great Lakes were lower than those for both the preceding month and March 1986 but continued to be above average. Utah's Great Salt Lake equaled last year's record high of 4,211.85 feet above sea level on March 31 after rising 0.20 foot during the month.

March precipitation fluctuated widely in the United States. Amounts exceeding 200 percent of average fell in most of Florida and several areas west of the Mississippi River, but less than 50 percent of average fell in a fairly large contiguous area in the East and several smaller areas in the West.

Contents of 87 percent of the index reservoirs were near or above average at the end of March compared with 83 percent at the end of February. The only reservoirs or reservoir systems that reported significant declines during the month and significantly below-average contents at the end of the month were the six index reservoirs in Nova Scotia and Allard reservoir in Quebec, Canada, Narrows in North Carolina, and Ross and Chelan in Washington.

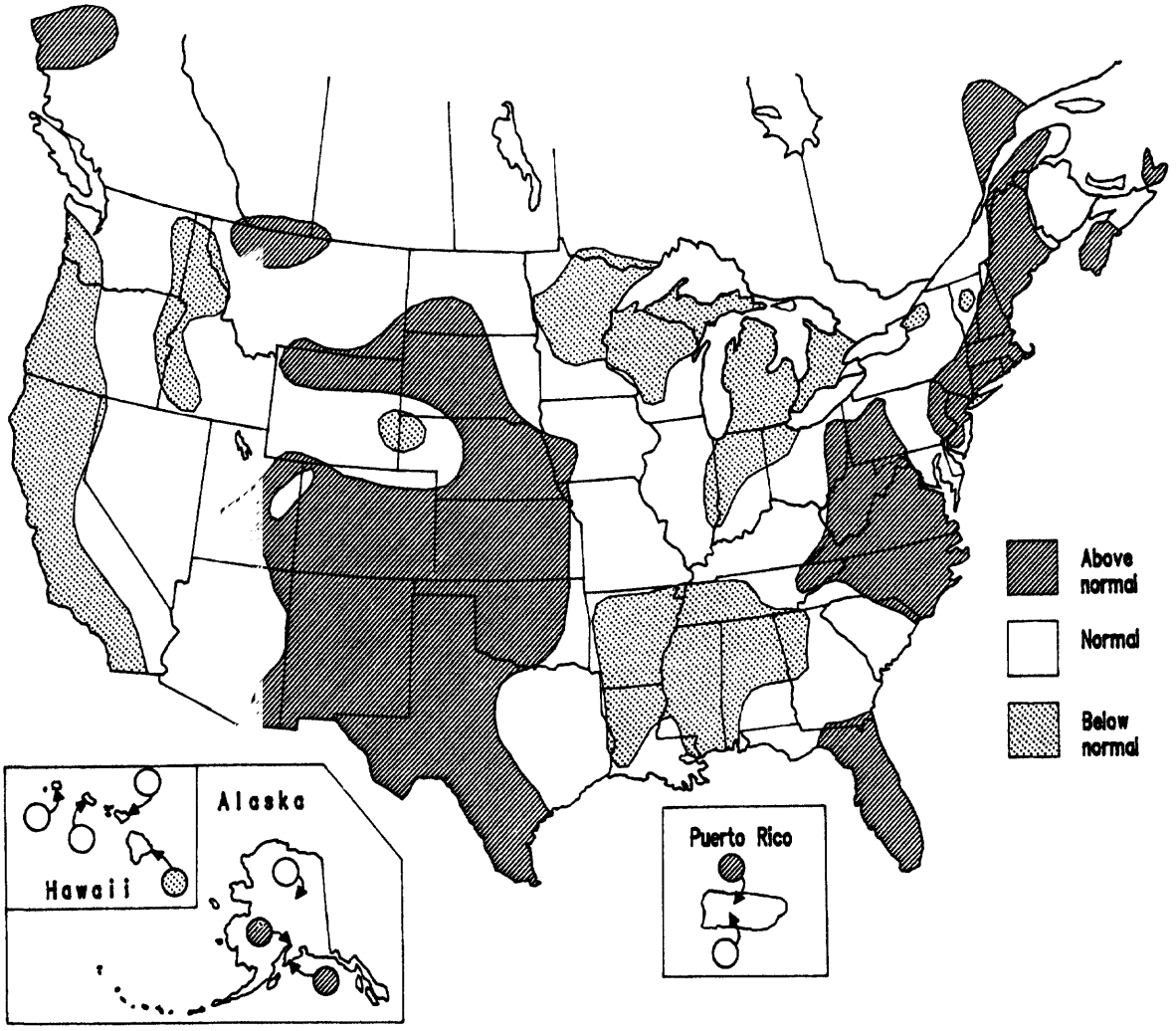


Figure 20. Streamflow during April 1987.

April 1987

Heavy rains combined with melting snow to cause record flooding in Maine, which was declared a Federal disaster area on April 8. Preliminary damage estimates were in excess of $60 million. Record floods also occurred in Florida and some flooding occurred in southern Virginia. The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 1,396,900 cubic feet per second, which was 0.2 percent below normal and 3.1 percent below the March flow.

Although April precipitation was well above average in parts of New Mexico and adjacent States, in part of Kansas, and in several areas in the East, it was below average over most of the United States. The Governor of Idaho declared a state of emergency in Ada, Canyon, Elmore, Washington, Blaine, and Adams Counties in anticipation of a shortage of irrigation water this summer.

April elevations for the Great Lakes were lower than those of April 1986 but remained above average. The level of Utah's Great Salt Lake fell 0.15 foot during April, reaching 4,211.70 feet above sea level on April 30.

An April 16 landslide on the west bank of the Snake River Canyon near Hagerman, Idaho, caused about $1.5 million damage to a pumping plant. The Hagerman fossil beds, which are considered to be the most complete assemblage of Pliocene fauna in the world, were also damaged. The slide was possibly caused by the long-term buildup of a locally perched aquifer in fine-grained sedimentary material above a thin layer of basalt. Movement occurred when gravity overcame the cohesiveness of the saturated mass.

Contents of 89 percent of the index reservoirs were near or above average at the end of April compared with 87 percent at the end of March. The only reservoirs with significant declines in contents during the month and significantly below-average contents at the end of the month were Keystone in Oklahoma and Possum Kingdom in Texas.

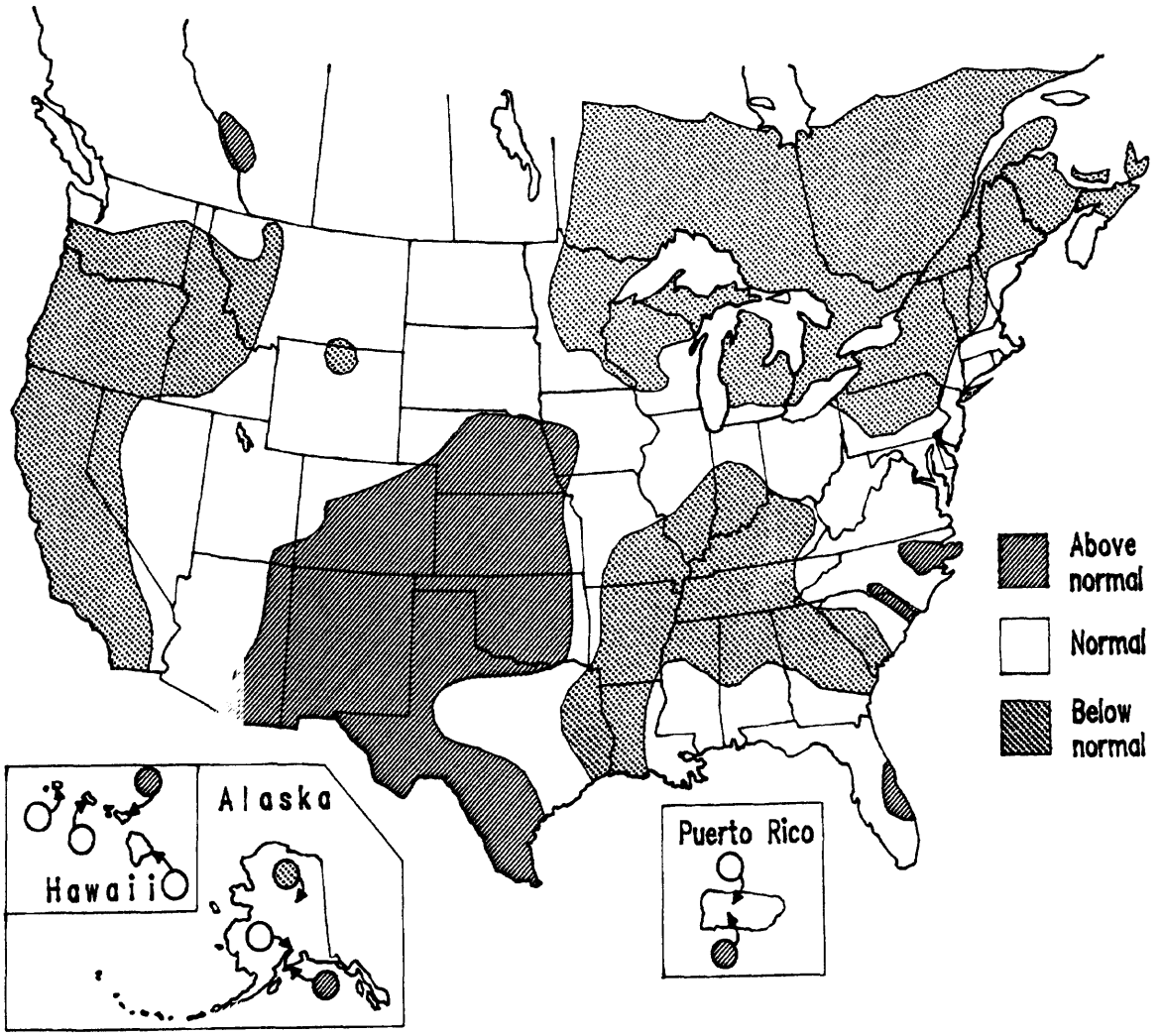


Figure 21. Streamflow during May 1987.

May 1987

Heavy rains near the end of May caused record flooding in parts of Iowa, Oklahoma, and Texas, which continued into June in some areas. Three people drowned during the floods, two in Oklahoma and one in Texas. No damage estimates are available. The worst flooding in Iowa was in the Nishnabotna River basin in the southwestern part of the State where about 1,100 people were evacuated from Red Oak. The main east-west line of the Burlington Railroad (also used by Amtrak) was closed by flooding near Emerson, and the Governor of Iowa declared Mills, Montgomery, Fremont, and Page Counties disaster areas. In Oklahoma, 10–13 inches of rain fell between May 26 and 28 and caused severe flooding in the central and western parts of the State. Peaks of record were exceeded at nine gaging stations, and the 100-year flood was exceeded at four of those stations. Several bridges were washed out, and State highways were closed by flood waters. The floods in Texas began after 5–8 inches of rain in 24 hours fell in some areas at monthend and continued into June. A pipeline ruptured during the flooding, spilling an unknown volume of crude oil into the Red River.

In contrast, streamflow was in the normal to above-normal range at only about 58 percent of the 191 index stations in southern Canada, the United States, and Puerto Rico, after generally decreasing in most of southern Canada and the United States compared with 76 percent of stations last month. This is about the same percentage of stations with flow in the normal to above-normal range as in May 1986, but the combined flow of the 190 sites reporting data for May 1986 and 1987 was lower in the latter: 2,372,340 cubic feet per second for May 1987 versus 2,819,060 cubic feet per second for May 1986. The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged a below-normal 1,255,600 cubic feet per second, which was 17.2 percent below normal and 10.1 percent below last month's flow.

Contents of 85 percent of the index reservoirs were near or above average at the end of May compared with 87 percent at the end of April. Only one reservoir, Shasta Lake in California, recorded a significant decline during the month and significantly below-average contents at the end of the month.

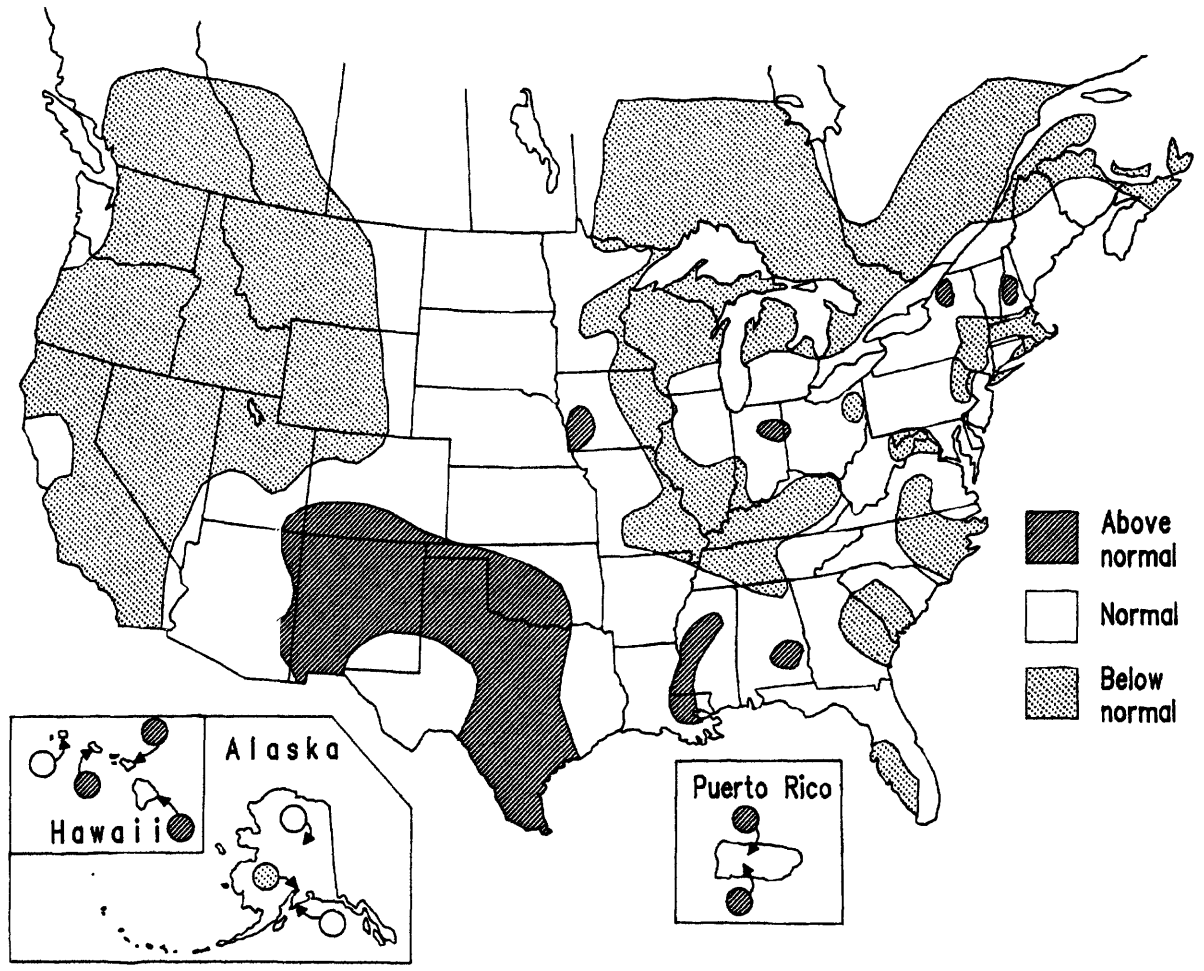


Figure 22. Streamflow during June 1987.

June 1987

Heavy rains from late May through early June caused significant flooding in Texas. A San Antonio resident drowned when her car was swept off a road by flood waters. A flood-ruptured pipeline northeast of Wichita Falls dumped an unknown volume of crude oil into the Red River.

Streamflow was in the normal to above-normal range at about 58 percent of the 191 index stations in southern Canada, the United States, and Puerto Rico, which was about the same percentage of stations with flow in the normal to above-normal range as the preceding month. Total June flow was 2,083,780 cubic feet per second, which was about 22 percent below normal, about 12 percent below last month's total flow, and the lowest for June in the last 5 years. Some areas in which flows were persistently above normal have now had two or more consecutive months of below-normal flows. New minimums occurred at 10 index stations, and new maximums occurred at 3 index stations as flow generally decreased in most of southern Canada and the United States. The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged a below-normal 1,051,400 cubic feet per second, which was 22.3 percent below normal and 16.3 percent below May's flow.

January through June temperatures were well above average over most of southern Canada and the United States. Precipitation was below average in much of the same area in the United States where temperatures were above average.

The level of Utah's Great Salt Lake declined 0.40 foot during June, thus reaching 4,211.20 feet above sea level on June 30. The lake level has fallen 0.65 foot since the record-equaling March 30, 1987, seasonal high of 4,211.85 feet above sea level.

Contents of 81 percent of the index reservoirs were near or above average at the end of June compared with 85 percent at the end of May. The six Nova Scotia, Canada, reservoirs; Wanaque, N.J.; Lake Wallenpaupack, Pa.; Lake Francis Case in S. Dak.; the four Boise River reservoirs, Idaho; and Pine Flat and Shasta Lake, Calif., had significant declines in contents during the month and significantly below-average contents at the end of the month.

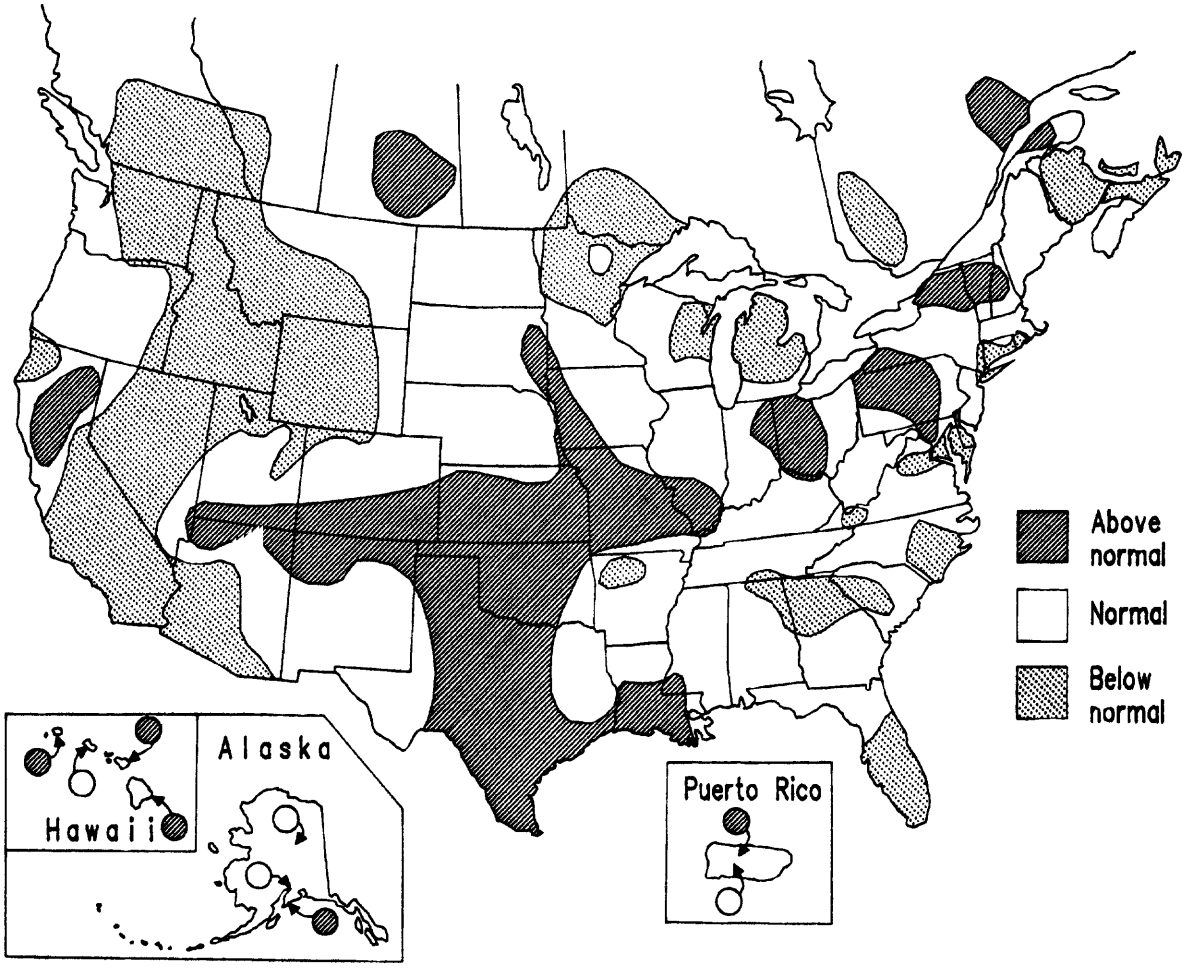


Figure 23. Streamflow during July 1987.

July 1987

Heavy rains of 4–6 inches in 24 hours on July 1–2 caused flooding that resulted in estimated damages of $30 million in north-central Ohio. No record-high peak discharges were reported, but on July 3, the Olentangy River at Claridon, Ohio (drainage area 157 square miles), peaked at 13,700 cubic feet per second, which was about 1.5 times the discharge for the 100-year flood but 1,200 cubic feet per second less than the January 1959 peak of record. In Minneapolis, Minn., where precipitation had been below average through mid-July, 8.96 inches of rain fell in 24 hours on July 23–24; this exceeded the 100-year, 24-hour rainfall by about 3 inches. Total precipitation for the week ending July 25 was 14.49 inches, which was double that recorded for the period January 1–July 18, 1987. Two people were killed, many highways were flooded for days, and high winds or tornadoes damaged at least 50 homes. Peak discharges on several streams in the area are estimated to have exceeded peaks of record and the 100-year flood, but recurrence interval and discharge data are not available.

Streamflow was in the normal to above-normal range at about 69 percent of the 191 index stations in southern Canada, the United States, and Puerto Rico compared with the 58 percent for June. Total July flow was only about 17,500 cubic feet per second more than in July 1985, which was the lowest July in the 1983–87 period. The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged a below-normal 875,900 cubic feet per second, which was 9.5 percent below normal and 17.7 percent below the flow for June.

July elevations for the Great Lakes were lower than those for July 1986. The level of Utah's Great Salt Lake declined 0.50 foot during July, thus reaching 4,210.70 feet above sea level on July 31. Contents of 78 percent of the index reservoirs were near or above average at the end of July compared with 81 percent at the end of June.

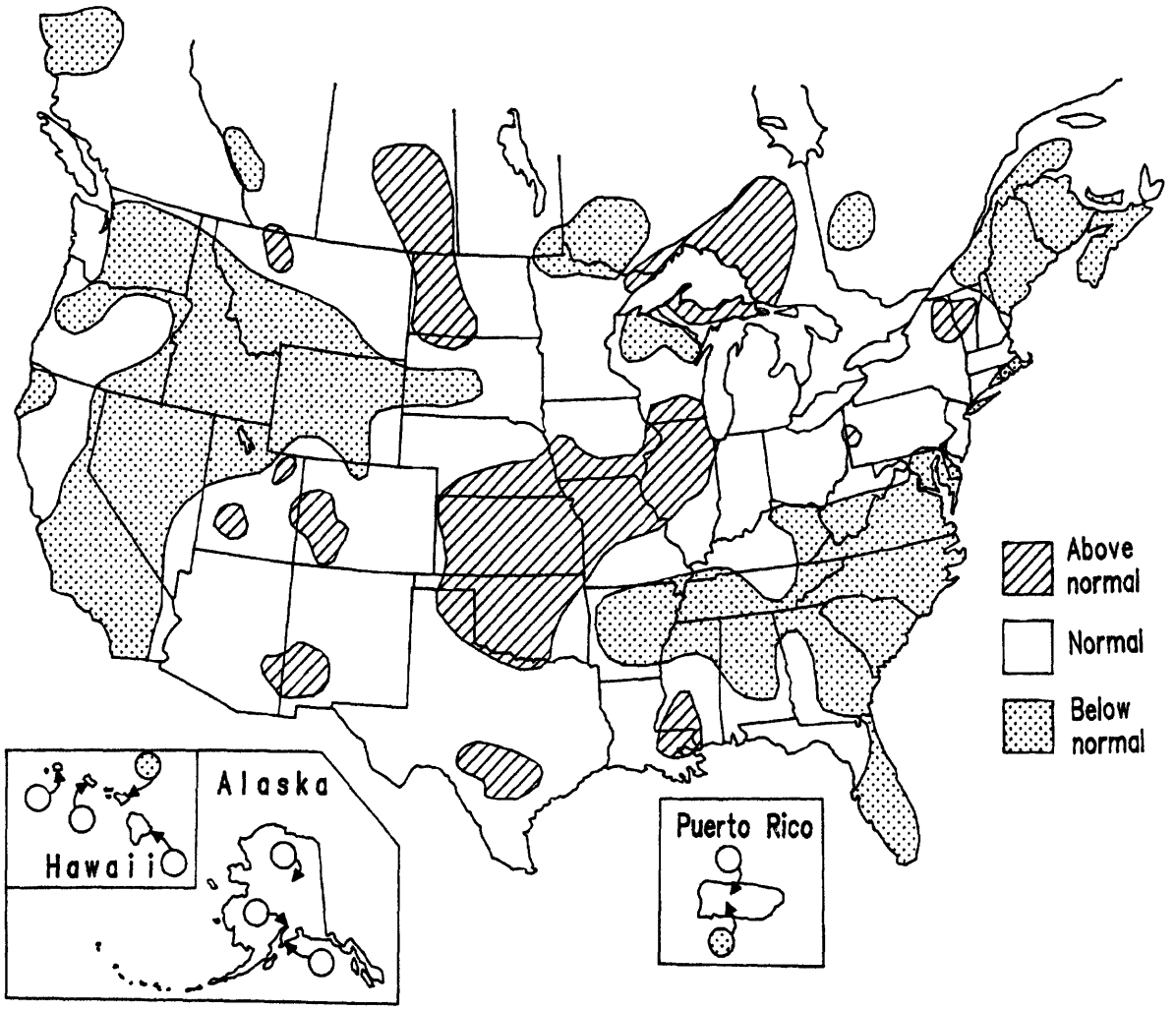


Figure 24. Streamflow during August 1987.

August 1987

Severe flooding occurred in Cook and Du Page Counties in northeastern Illinois on August 14–15, and minor flooding occurred in southwestern Iowa on August 25–26. Flows generally increased from July to August in only two States, Arizona and Michigan. Streamflow generally changed variably in Alaska, Hawaii, New Mexico, Louisiana, Mississippi, Florida, Georgia, North Carolina, New Jersey, Connecticut, Illinois, Iowa, and Minnesota. Flow generally decreased in the rest of southern Canada and the United States.

Streamflow was in the normal to above-normal range at 59.7 percent of the 191 index stations in southern Canada, the United States, and Puerto Rico compared with the 58 percent for the preceding month. This is the lowest percentage of stations with flow in the normal to above-normal range for August in the last 5 years. Total August flow, which was about 176,520 cubic feet per second, was the lowest for August in the last 5 years and 12.3 percent below that of August 1985, which was the second lowest August during the period.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged a below-normal 643,500 cubic feet per second, which was 12.8 percent below normal and 26.5 percent below July's flow. Flow in the Columbia River at The Dalles, Oreg., set a record low for August after decreasing by about 41 percent from that for July and was in the below-normal range for the third consecutive month.

August elevations for the Great Lakes ranged from 0.86 foot (Lake Erie) to 1.70 feet (Lake Ontario) lower than those for August 1986. The level of Utah's Great Salt Lake declined 0.60 foot during August, thus reaching 4,210.10 feet above sea level on August 31.

Contents of 74 percent of the index reservoirs were near or above average at the end of August compared with 78 percent at the end of July. Eighteen reservoirs or reservoir systems had significant declines in contents during the month and significantly below-average contents at the end of the month.

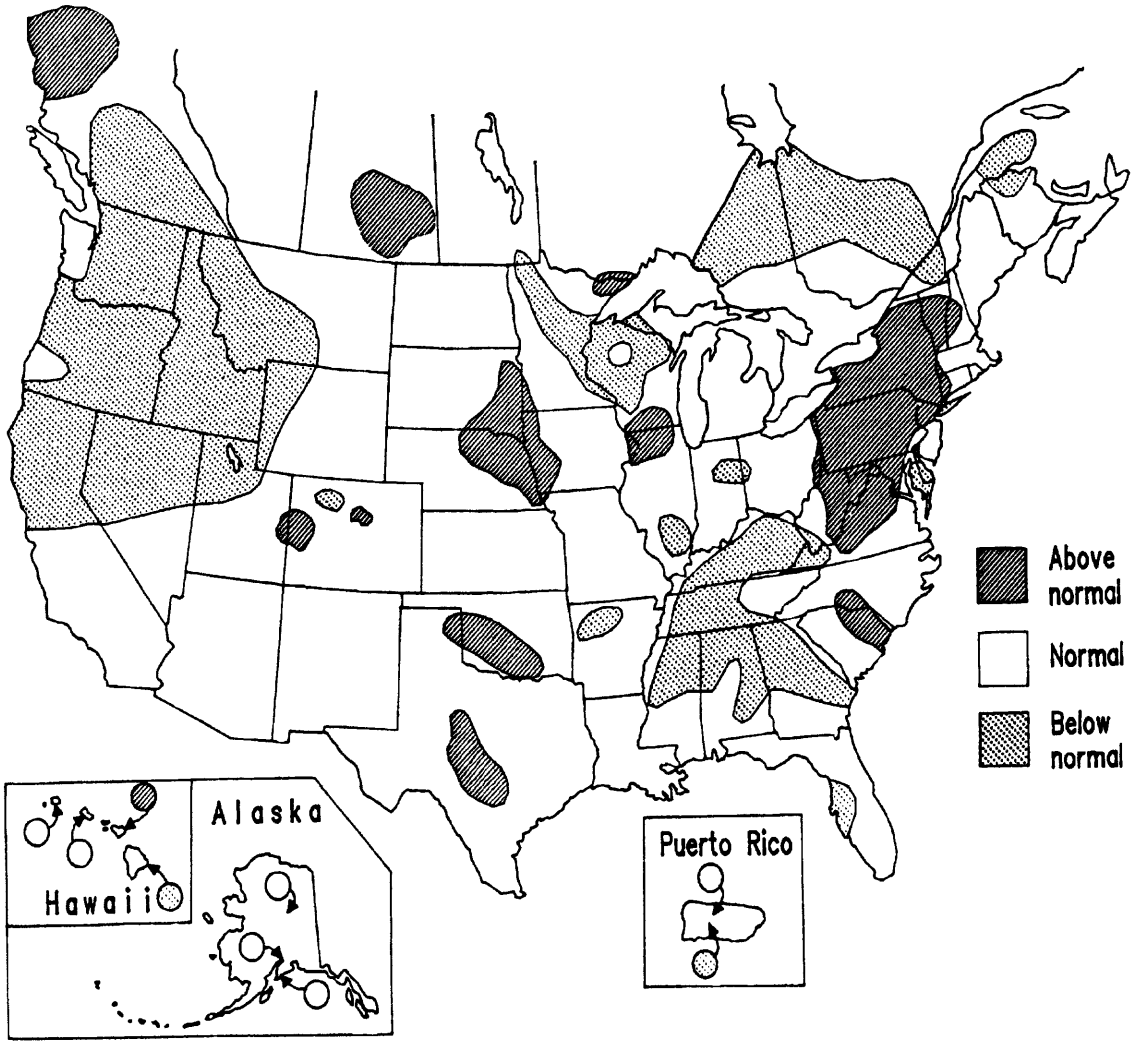


Figure 25. Streamflow during September 1987.

September 1987

Heavy rains from September 8 to 10 caused flooding in the southwestern part of Virginia, but only three sites had peaks of record. In contrast, streamflow in Idaho, Washington, and Oregon was near or at record lows for September at many stations as drought conditions persisted in those States. Flows in eastern Washington were the lowest since 1977.

Streamflow was in the normal to above-normal range at 72.2 percent of the 190 index stations in southern Canada, the United States, and Puerto Rico compared with the 59.7 percent for the preceding month. This is the lowest percentage of stations with flow in the normal to above-normal range for September in the last 5 years but is the highest percentage of stations in those ranges since April 1987 (76 percent).

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged a normal 617,900 cubic feet per second in spite of decreasing about 4 percent from August to September and was about 3 percent below normal. The monthly flow of 65,300 cubic feet per second (67 percent of normal) in the Columbia River at The Dalles, Oreg., was the lowest in 108 years of record and was about 8,900 cubic feet per second less than the previous September minimum (1973); this flow set a record low for the second consecutive month after the almost 25-percent decrease from the August flow and was in the below-normal range for the fourth consecutive month. Flow in the St. Lawrence River at Cornwall, Ontario, Canada, decreased by about 4 percent from that for August and was in the normal range after 31 consecutive months in the above-normal range.

The combined flow of the three largest rivers of the United States averaged 1,101,000 cubic feet per second, in the normal range for the 1987 water year. The annual flow of 309,000 cubic feet per second on the St. Lawrence River at Cornwall, Ontario, Canada, was the highest for the 108 years of record, the previous record of 308,200 cubic feet per second (1973) was exceeded by only 800 cubic feet per second, or 0.3 percent.

September elevations for the Great Lakes ranged from 0.74 foot for Lake Erie to 1.63 feet for Lake Ontario lower than those for September 1986. Besides these two lakes, levels declined slightly from last month at the master gages on Lakes Superior and Huron. The level of Utah's Great Salt Lake declined 0.60 foot during September; 4,210.10 feet above sea level was reached on September 30.

Several jokulhlaups (outbursts of water), perhaps sediment-laden, came from the South Tahoma Glacier on the southwest side of Mount Rainier in Washington on September 23. In a separate but related event, a series of almost continuous rock avalanches from the nearly vertical headwall above Tahoma Glacier occurred beginning midmonth.

Contents of 78 percent of the index reservoirs were near or above average at the end of September compared with 74 percent at the end of August.

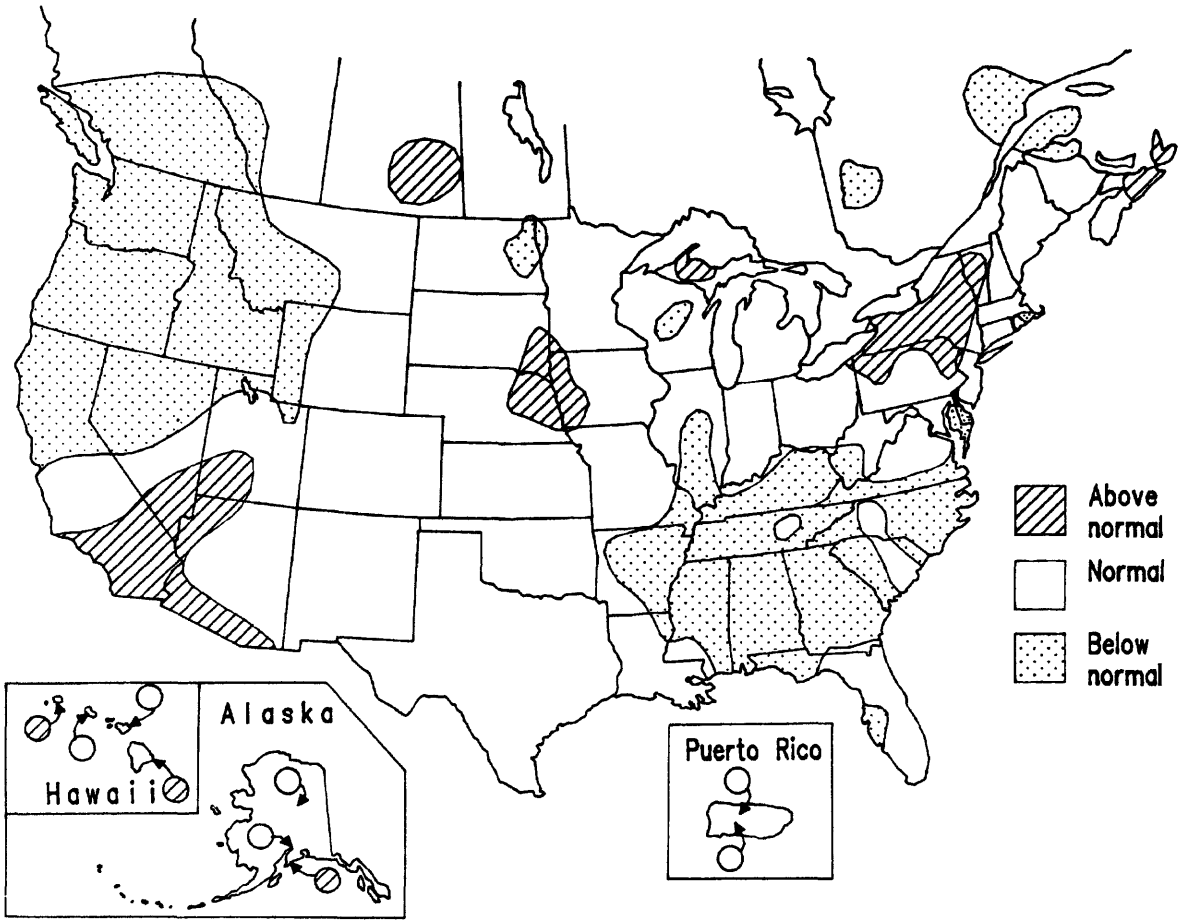


Figure 26. Streamflow during October 1987.

October 1987

Streamflow in Montana, Idaho, Washington, and Oregon was near or at record lows for October at many stations as drought conditions persisted in those States during what is usually the wet time of year. New October minimums occurred at 12 index stations, 8 of which were in those four States. In sharp contrast, rains from storm cells generated as remnants of Hurricane Floyd crossed southern Florida at midmonth increased daily flows of two streams by over 600 percent in no more than 5 days. Streamflow in parts of California, Arizona, Utah, and Nevada increased into the above-normal range during the month.

Streamflow was in the normal to above-normal range at 66.3 percent of the 190 index stations in southern Canada, the United States, and Puerto Rico, compared with the 72.2 percent for the preceding month. Total October flow of 1,027,440 cubic feet per second was 13.6 percent below normal, 17.8 percent below last month's total, and the lowest for October in the last 5 years. The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged a below-normal 551,400 cubic feet per second (about 14 percent below normal) after decreasing about 11 percent from September to October.

October elevations for the Great Lakes declined from September at the master gages on Lakes Superior, Huron, Erie, and Ontario. Levels were also significantly below October 1986 levels. The level of Utah's Great Salt Lake declined 0.15 foot and reached 4,209.45 feet above sea level on October 31. The lake level declined 2.40 feet from the March 30, 1987, seasonal high of 4,211.85 feet above sea level.

Contents of 76 percent of the index reservoirs were near or above average at the end of October compared with 78 percent at the end of September.

Short-term soil (crop) moisture changes were generally favorable during the month with the exception of three large areas that remained abnormally to excessively dry—Pacific Northwest, southern Texas and small parts of adjacent States, and Alabama and parts of adjacent States. A large area from extreme northern Virginia to southern Maine was wet. The Palmer drought-severity index (long-term) changed little from September to October in spite of the favorable short-term changes during October.

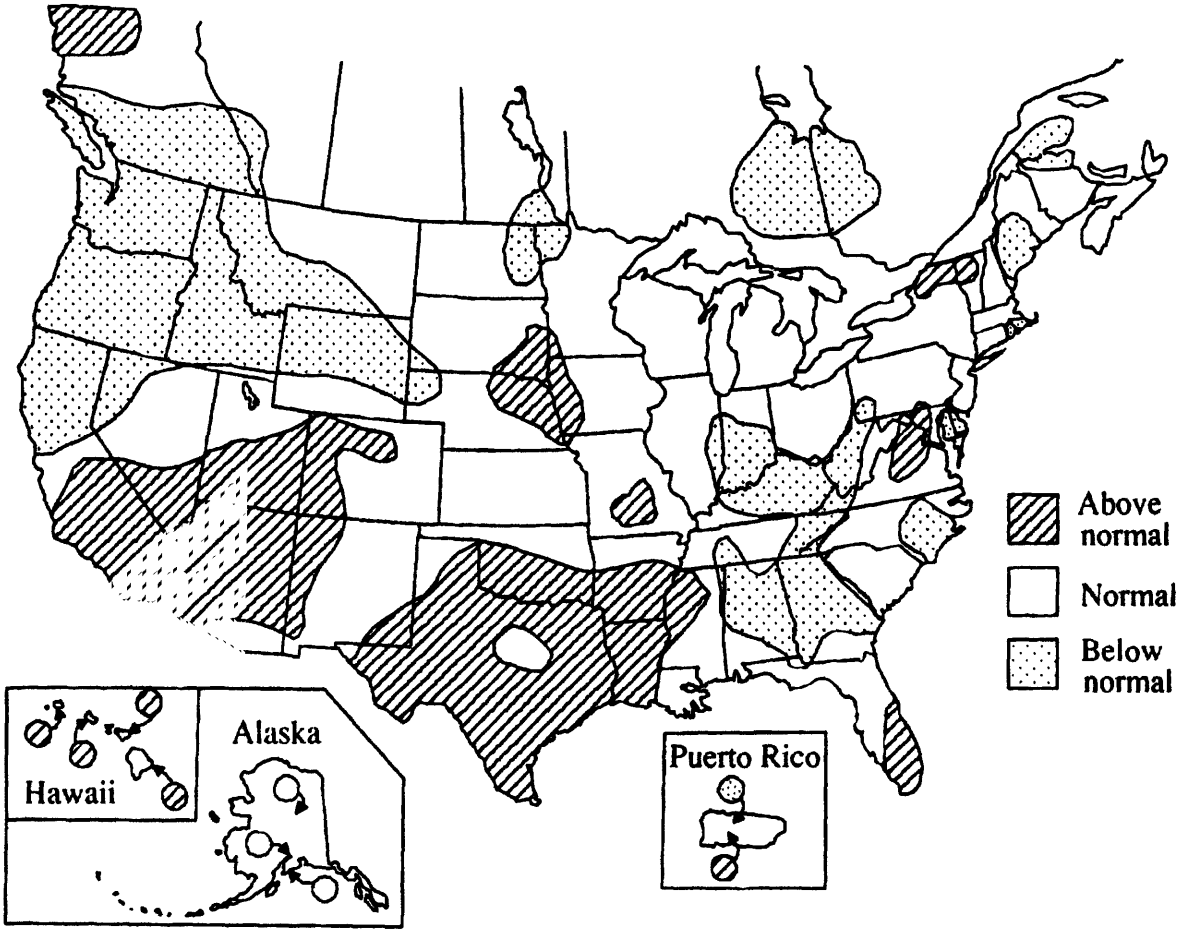


Figure 27. Streamflow during November 1987.

November 1987

Heavy rains totaling 16 to 18 inches on November 15–16 caused severe floods in central Louisiana on November 16. Peak discharge at two gaging stations exceeded both the 100-year flood and the previous flood of record; peak discharge exceeded the flood of record, but not the 100-year flood at five other gages.

Below-normal streamflow persisted in Washington and Oregon; most of Idaho; parts of Montana, Wyoming, Nevada, and California; parts of the Southeast; and several small areas in southern Canada and the northern United States. Streamflow was in the normal to above-normal range at 73.2 percent of the 190 index stations in southern Canada, the United States, and Puerto Rico compared with the 66.3 percent for the preceding month. This is the lowest percentage of stations with flow in the normal to above-normal range for November in the last 6 years. Total November flow of 1,116,280 cubic feet per second was 13.6 percent below normal, 17.8 percent below last month's total, and the lowest for November in the last 6 years.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged a below-normal 561,100 cubic feet per second (about 15 percent below normal) after decreasing about 2 percent from October to November. Flows in the Mississippi and the St. Lawrence Rivers were in the normal range, but flow in the Columbia River at The Dalles, Oreg., was in the below-normal range for the sixth consecutive month.

November elevations for the Great Lakes were below those for October and November 1986 at the master gages on Lakes Superior, Huron, Erie, and Ontario. The level of Utah's Great Salt Lake did not change during November, remaining at 4,209.45 feet above sea level throughout the month.

Contents of 70 percent of the index reservoirs were near or above average at the end of November compared with 76 percent at the end of October.

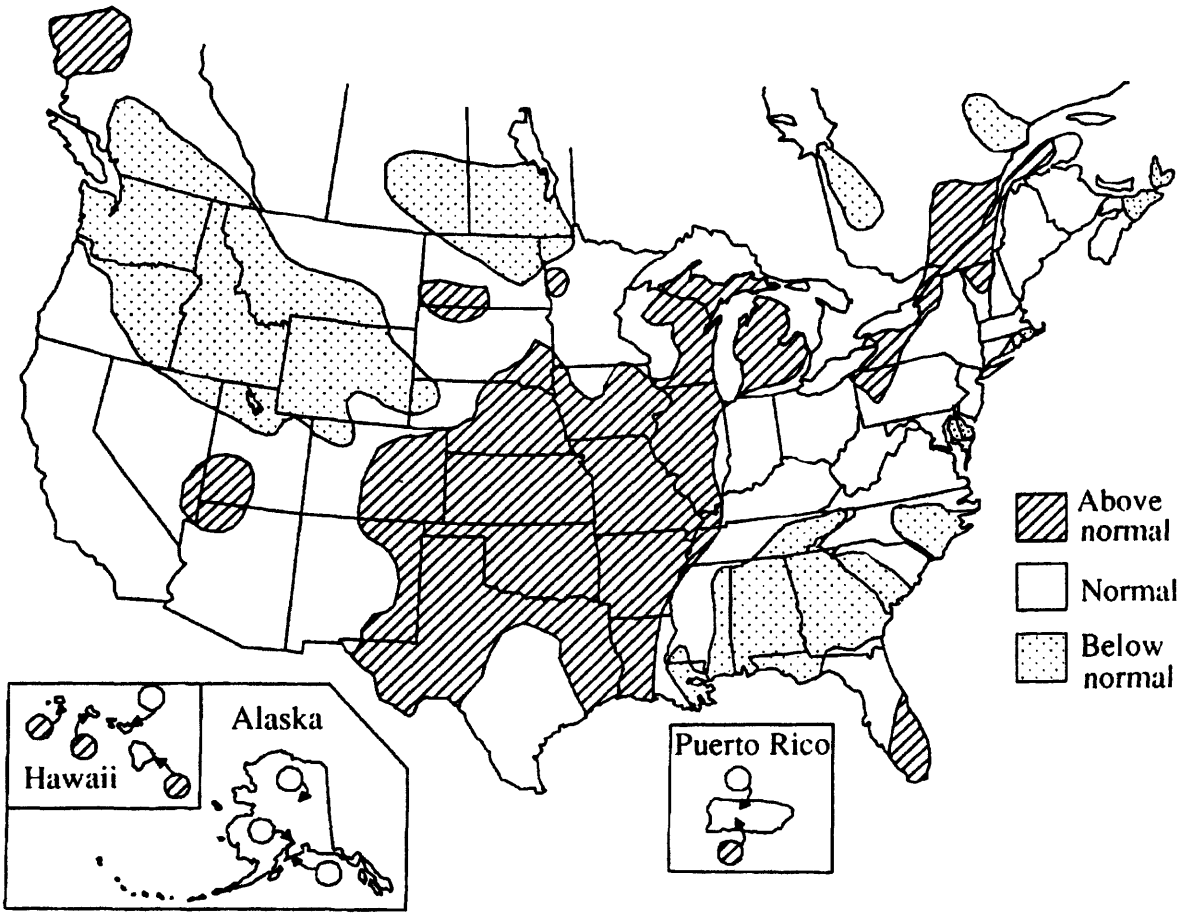


Figure 28. Streamflow during December 1987.

December 1987

Heavy rains of as much as 15 inches between December 24 and 27 caused flooding in northeastern Arkansas and western Tennessee. In Hawaii, a week of thunderstorms and high winds that began on December 11, as well as a New Year's Eve storm, caused flooding.

Streamflow was in the normal to above-normal range at 75 percent of the 191 index stations in southern Canada, the United States, and Puerto Rico, compared with the 73 percent for the preceding month. Total December flow was the lowest for that month in the last 6 years. There were no lows, but new highs occurred at one index station each in Oklahoma, Florida, and Puerto Rico.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—was in the normal range after increasing about 43 percent from November to December. The combined flow, however, was the lowest for December in the last 6 years.

December elevations at the four master gages on the Great Lakes declined from the preceding month at one gage each on Lakes Superior and Huron, and increased from last month at one gage each on Lakes Erie and Ontario. The level of Utah's Great Salt Lake declined to a seasonal low of 4,209.35 feet above sea level on December 20, then rose to 4,209.40 feet by December 31.

Contents of 75 percent of the index reservoirs were near or above average at the end of December compared with 70 percent at the end of November.

For calendar year 1987, streamflow was in the normal to below-normal range in most of the United States and southern Canada. About 87 percent of the 191 index sites had flows in 1987 in the normal to below-normal range compared with about 68 percent for calendar year 1986.

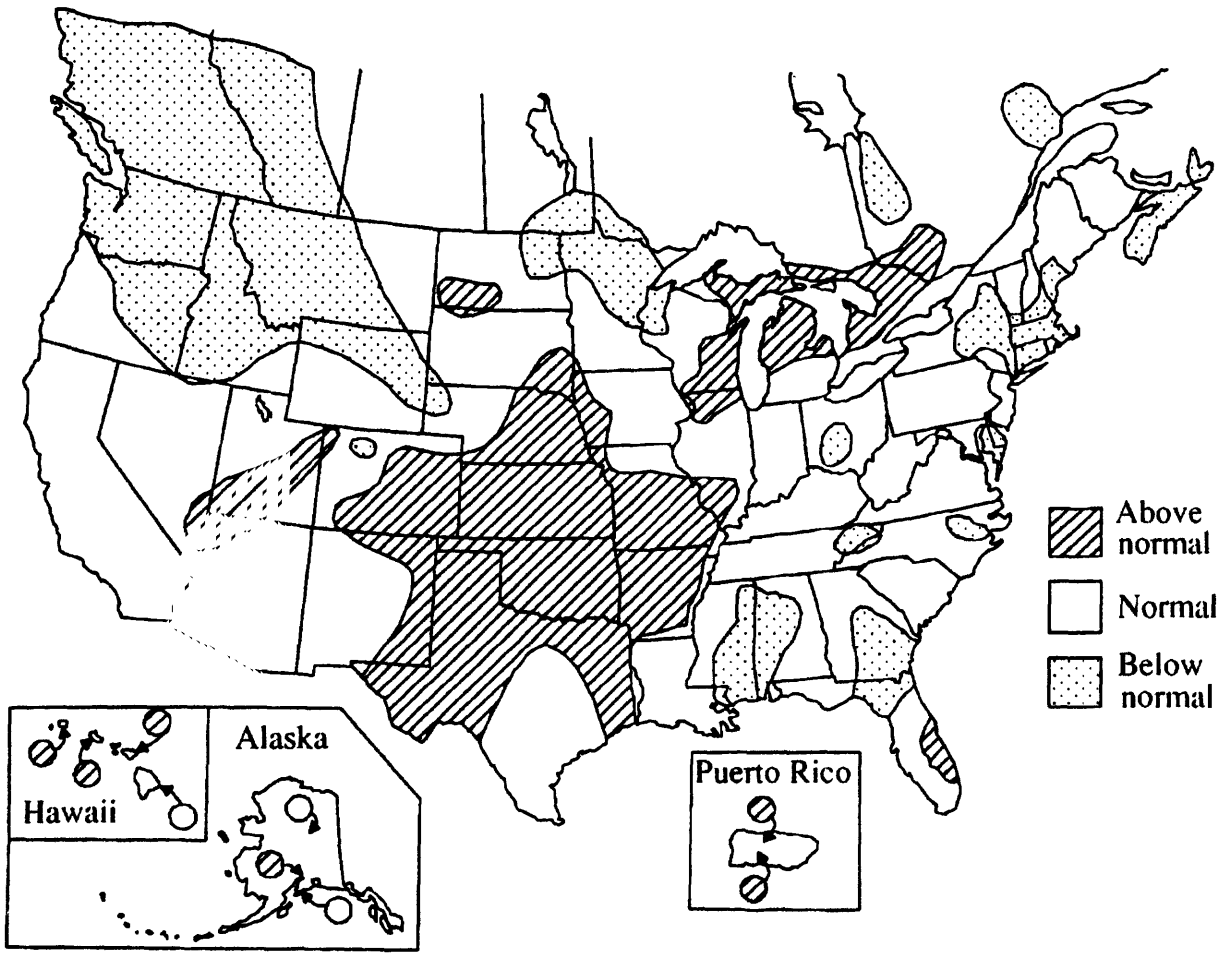


Figure 29. Streamflow during January 1988.

January 1988

Streamflow was in the normal to above-normal range at 72 percent of the 191 index stations in southern Canada, the United States, and Puerto Rico compared with the 75 percent for the preceding month. Total January flow of 1,558,950 cubic feet per second for the 181 index stations in the conterminous United States and southern Canada was 8.2 percent above normal and 21 percent above December's total.

Below-normal streamflow persisted in a large area from southern British Columbia, Canada, to northwestern Nebraska and also in several smaller areas. Flows decreased into the below-normal range in a large area of southwestern Canada and Montana, several other small areas adjacent to those of persistent below-normal flows, and some larger areas centered on northeastern Minnesota and Massachusetts. Above-normal streamflow persisted in a large area centered on Kansas and Oklahoma and in several smaller areas, the largest of which was centered on Lake Michigan. Flows increased into the above-normal range in several small areas, the largest of which was in Ontario and Quebec, Canada, north and east of Lake Huron.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged an above-normal 1,214,800 cubic feet per second (about 22 percent above normal), which was an increase of about 51 percent from December to January. Flow in the Columbia River at The Dalles, Oreg., was in the below-normal range for the eighth consecutive month after decreasing by about 2 percent from December to January.

January elevations at the four master gages on the Great Lakes were in the average range for the first time since October 1982. Levels declined from those of the preceding month at all four gages and were also lower than those of January 1987. The level of Utah's Great Salt Lake rose 0.05 foot during the month and was at 4,209.50 feet above sea level on January 31; this was 1.90 feet lower than on January 31, 1987.

Contents of 74 percent of the index reservoirs were near or above average at the end of January compared with 75 percent at the end of December.

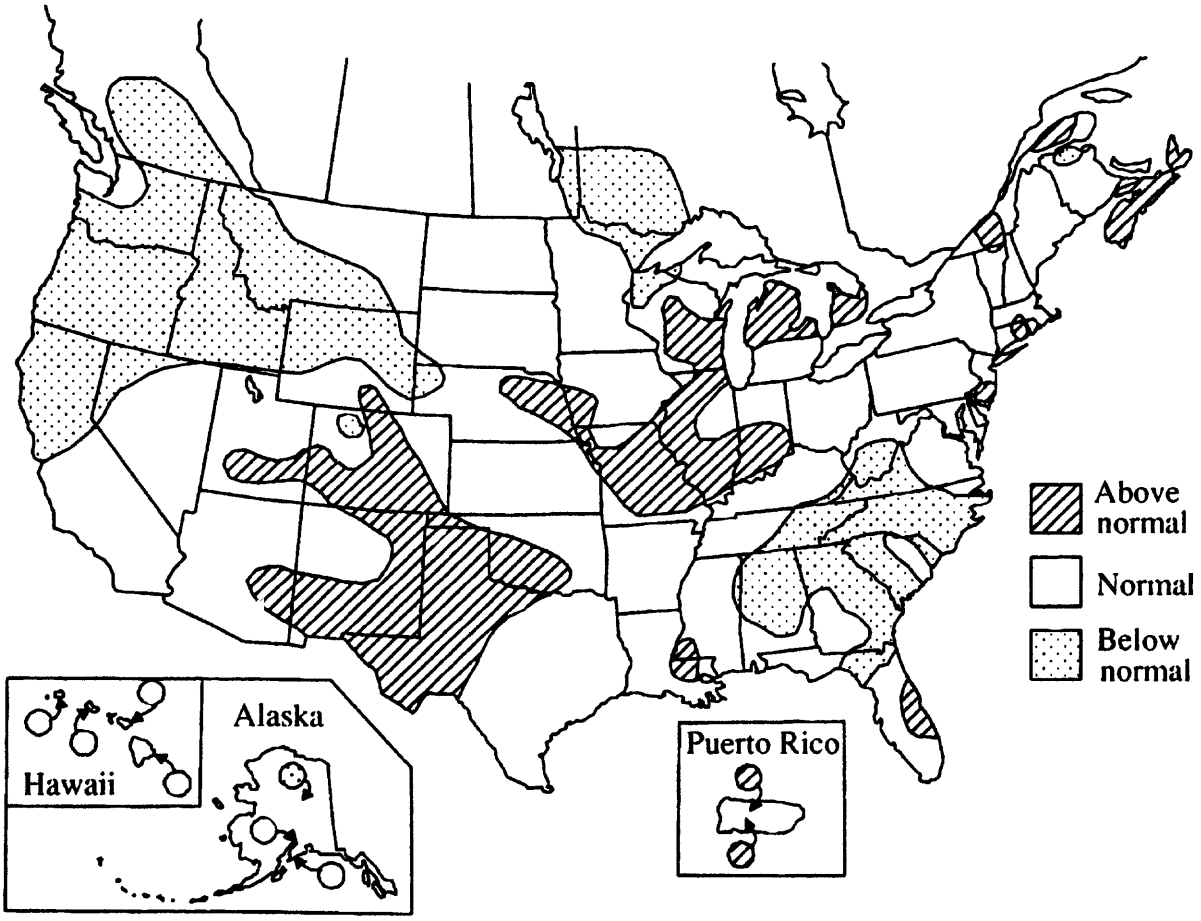


Figure 30. Streamflow during February 1988.

February 1988

Low streamflow persisted in the Pacific Northwest for the 11th consecutive month as most of the West had an unusually dry February. Monthly flows were in the below-normal range at 15 of the 17 index streamflow stations in Montana, Idaho, Washington, and Oregon. The only other area in which similar dry conditions have occurred during the same period was in those States from the Mississippi River east to the Atlantic Ocean and south from the Ohio River-Pennsylvania State line.

Streamflow was in the normal to above-normal range at 75 percent of the 190 index stations in southern Canada, the United States, and Puerto Rico, about the same as the 74 percent of 191 index stations for the preceding month. This was the second lowest percentage of stations with flow in the normal to above-normal range for February in the last 6 years. Below-normal streamflow persisted in the Southeast and in a large area from southern British Columbia, Canada, to northwestern Nebraska, and flows moved into the below-normal range to the southwest of that area. Above-normal streamflow persisted in one large area centered on western Texas and in several smaller areas, the two largest of which were centered on western Iowa and Lake Michigan. Only one February low (Niobrara River above Box Butte Reservoir, Nebr.) and one February high (Rio Grande De Manati at Highway 2 near Manati, P.R.) occurred at streamflow index stations.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—was in the normal range after decreasing by 4 percent from January to February. Flow in the Columbia River at The Dalles, Oreg., however, was below normal for the ninth consecutive month.

February elevations at the four master gages on the Great Lakes were in the average range except on Lake Erie, which rose into the above-average range. The level of Utah's Great Salt Lake was 4,209.55 feet above sea level on February 29.

Contents of 74 percent of the index reservoirs were near or above average at the end of February; this was about the same as at the end of January (75 percent). Ten reservoirs or reservoir systems recorded significant declines in contents during the month and significant below-average contents at the end of the month.

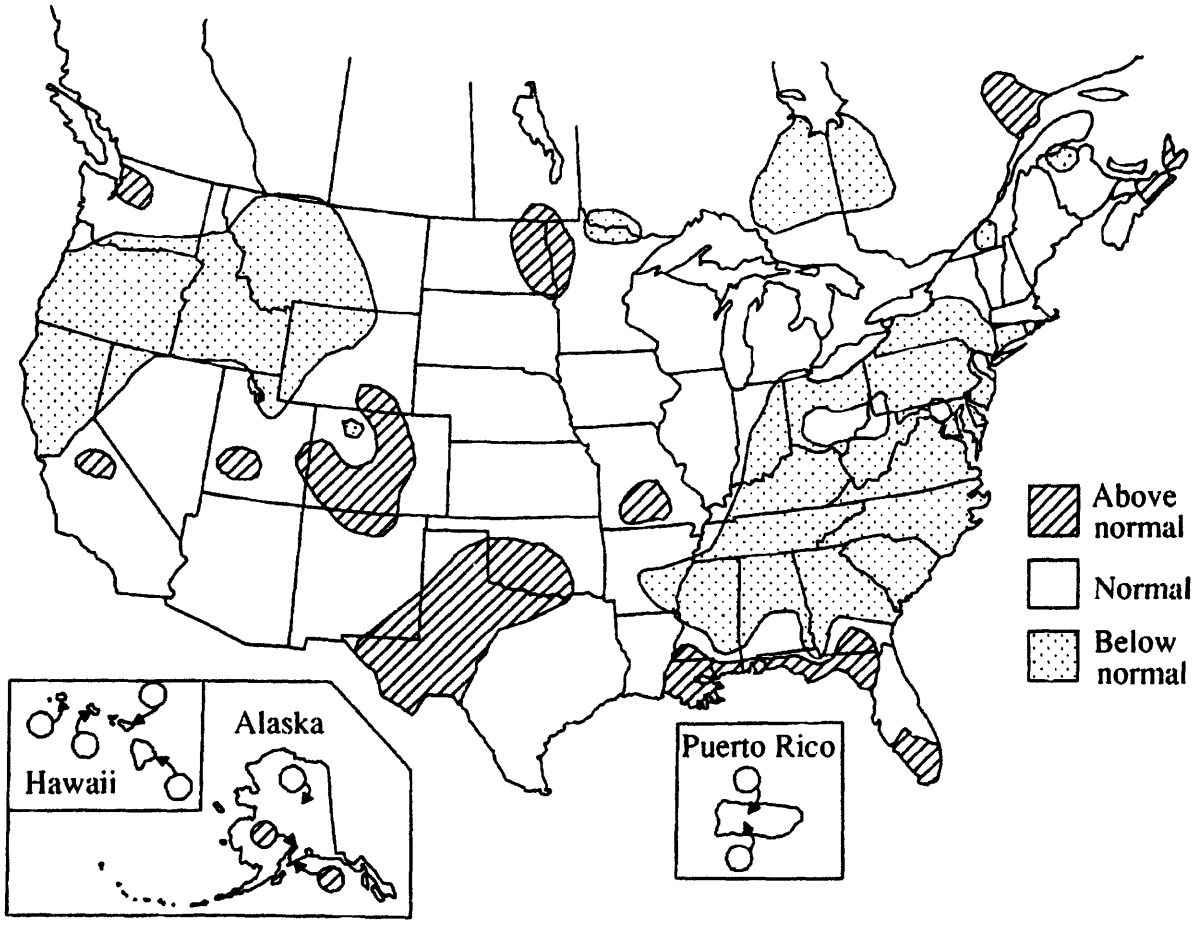


Figure 31. Streamflow during March 1988.

March 1988

For the 12th consecutive month, drought persisted in the Pacific Northwest where total streamflow at the 17 index stations in the States of Oregon, Washington, Idaho, and Montana was 35 percent below normal in spite of above-average precipitation in parts of that area during March. In the Southeast, total streamflow at the 39 index stations was 54 percent below normal after decreasing by 12 percent from that for February. Streamflow for fall-winter 1988 was below normal in most of the West and in most of the Southeast.

Streamflow was in the normal to above-normal range at only 58 percent of the index stations in southern Canada, the United States, and Puerto Rico; it was the lowest percentage of stations with flow in the normal to above-normal range for March in the last 6 years. Total March flow for the index stations in the conterminous United States and southern Canada was 23 percent below normal and the lowest for March in the last 6 years.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—was 13 percent below normal after a 12 percent decrease from February to March and was the lowest for March in the last 6 years. Flow in the Columbia River at The Dalles, Oreg., was below normal for the 10th consecutive month.

March elevations at the four master gages on the Great Lakes were lower than those for March 1987. The elevation of Utah's Great Salt Lake was 4,209.50 feet above sea level on March 31. Lake level had been at 4,209.55 feet above sea level from February 15 to March 26.

Contents of 60 percent of the index reservoirs were near or above average at the end of March compared with the 74 percent at the end of February. Contents of all reservoirs in South Carolina, Georgia, Alabama, and the Tennessee Valley, however, were lower than in March 1986, which preceded the summer drought in that area.

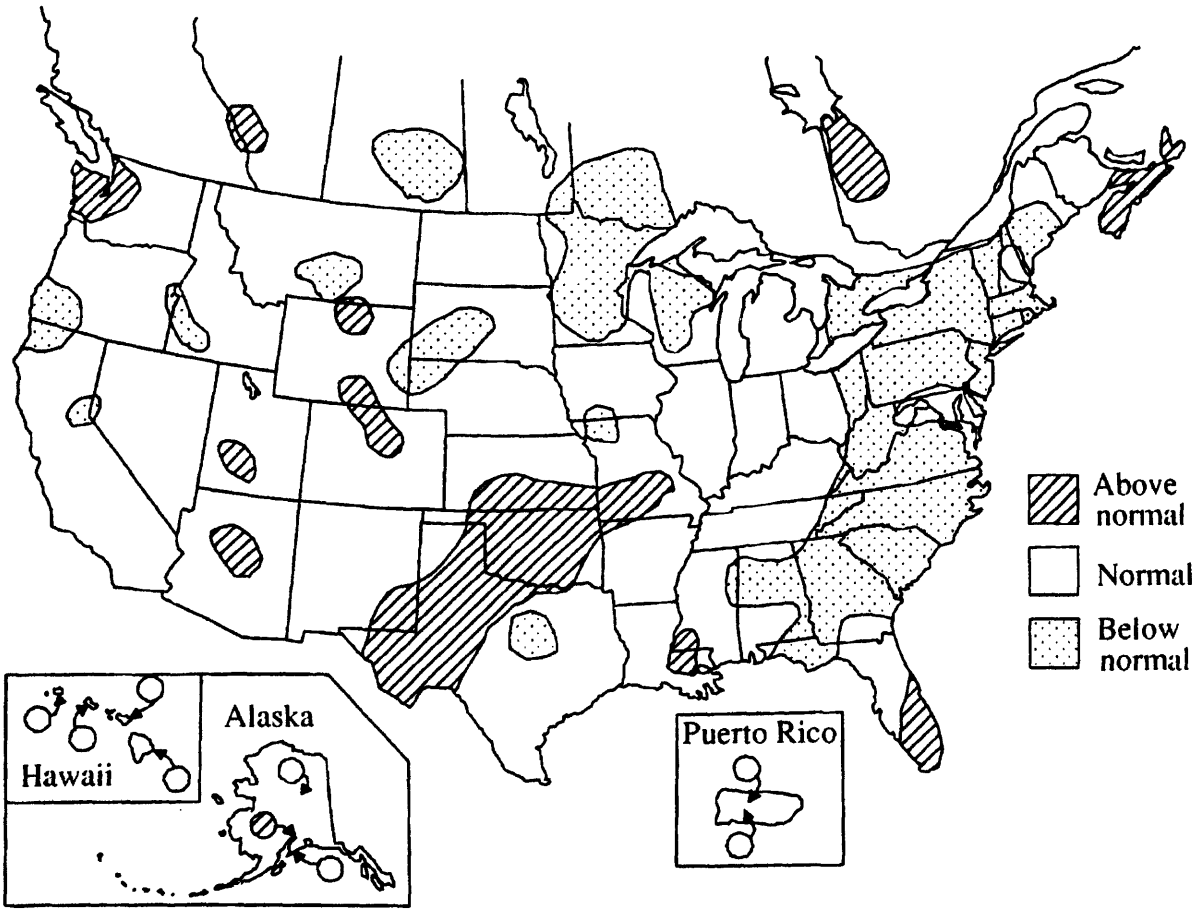


Figure 32. Streamflow during April 1988.

April 1988

April streamflow increased in two of the three areas in the West where streamflow has been below normal for several months and also increased in the Southeast after above-average precipitation fell in much of both areas during April. For example, total April streamflow at the 17 index stations in the States of Oregon, Washington, Idaho, and Montana increased 126 percent but was still 6 percent below normal. In California, total streamflow at the six index stations was 27 percent below normal after a 40-percent increase from March to April. In Nevada and Utah (Great Basin only), total streamflow at the four index stations decreased 10 percent from March to April and was 47 percent below normal. In the Southeast, total streamflow at the 39 index stations was 40 percent below normal after increasing 4 percent from that for March.

Streamflow was in the normal to above-normal range at 66 percent of the index stations in southern Canada, the United States, and Puerto Rico; it was the second lowest percentage of stations with flow in the normal to above-normal range for April in the last 6 years. Total flow for the 181 index stations in the conterminous United States and southern Canada was 13 percent below normal and the lowest for April in the last 6 years.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—was 8 percent below normal, which was a 26-percent increase from March to April. The combined flow was the second lowest for April in the last 6 years.

April elevations at the four master gages on the Great Lakes were lower than those for April 1987 but were in the average range. On April 30, the elevation of Utah's Great Salt Lake was 4,209.45 feet above sea level, which was 0.05 foot lower than on April 1.

Contents of 63 percent of the 100 index reservoirs were near or above average for the end of April compared with the 60 percent in those categories for March. Below-average contents, however, persisted in 11 of 25 index reservoirs or reservoir systems in the West and in 8 of 16 in the Southeast.

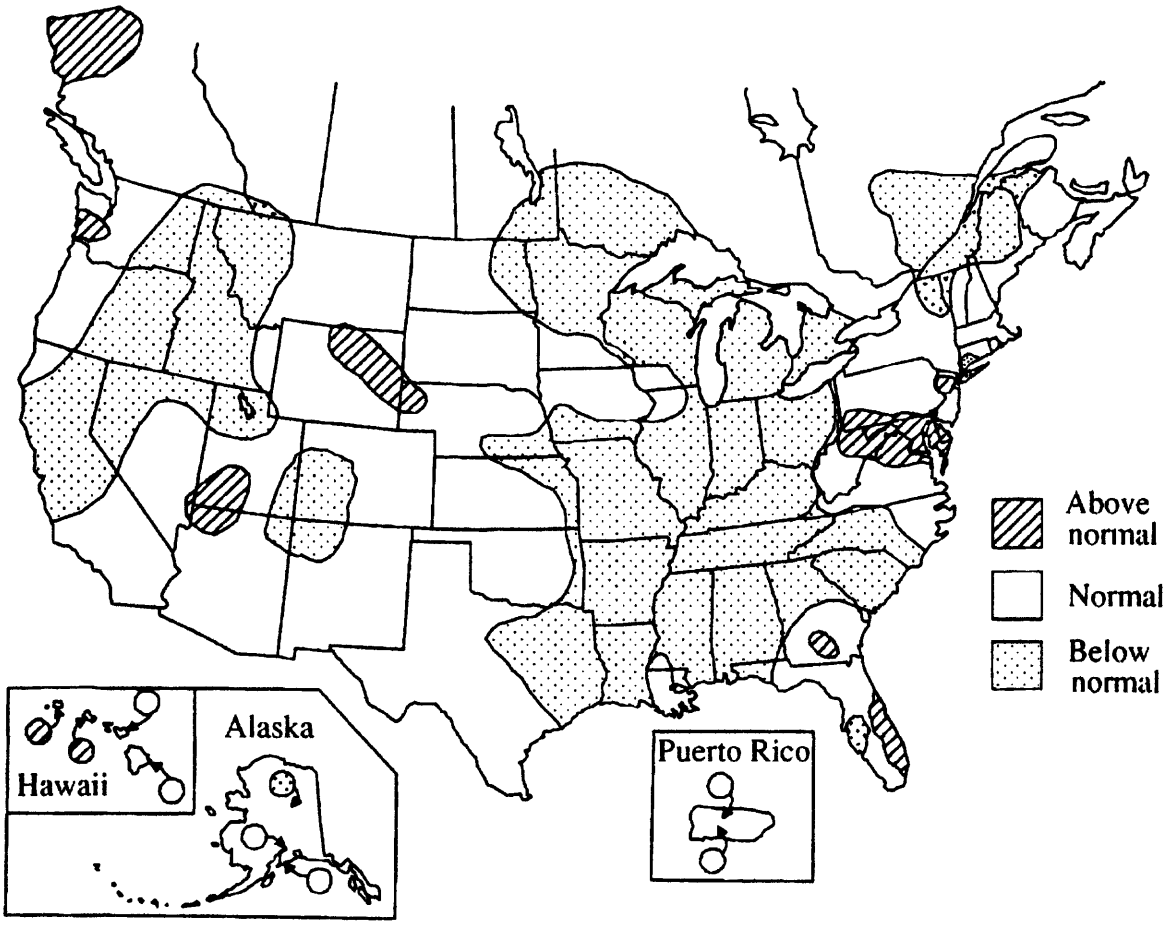


Figure 33. Streamflow during May 1988.

May 1988

May streamflow was below normal in all four areas affected by drought: the Pacific Northwest States, California, the Great Basin areas of Nevada and Utah, and the Southeast. Streamflow was in the normal to above-normal range at 54 percent of the index stations in southern Canada, the United States, and Puerto Rico compared with the 66 percent for the preceding month—the lowest percentage of stations with flow in the normal to above-normal range not only for May, but also for any month in the last 6 years. Total flow for the 181 index stations in the conterminous United States and southern Canada was the lowest for May in the last 6 years.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—was in the below-normal range and the second lowest for May for the period of combined record (60 years). Individually, flow in all three rivers was in the below-normal range for the month. Flow in the Mississippi River at Vicksburg, Miss., was also the second lowest since 1941. Flow in the St. Lawrence River at Cornwall, Ontario, Canada, was in the below-normal range (with respect to the 1951–80 reference period) for the first time since July 1967.

May elevations at the four master gages on the Great Lakes were in the average range, except on Lake Superior where the elevation was in the below-average range for the first time since March 1982. The elevation of the Great Salt Lake in Utah declined 0.35 foot during May.

Monthend contents of 62 percent of the index reservoirs were in the average or above-average range for May compared with the 63 percent at the end of April. May 1988 monthend contents of many reservoirs were lower than those of May in previous drought years—May 1987 in the West and May 1986 in the Southeast.

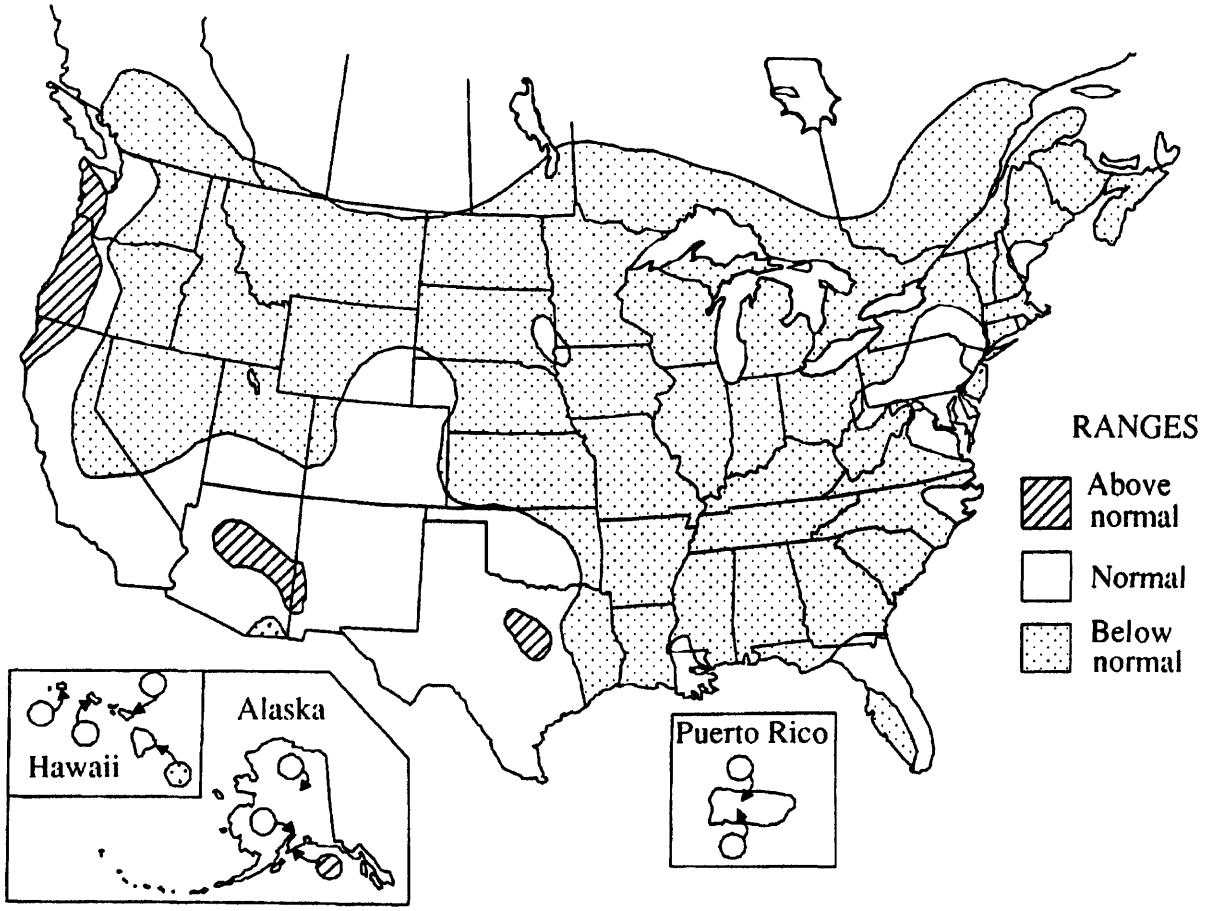


Figure 34. Streamflow during June 1988.

June 1988

Streamflow was in the normal to above-normal range at only 32 percent of the 190 index stations in southern Canada, the United States, and Puerto Rico compared with the 54 percent of 191 index stations during the preceding month. Total June flow of 1,497,600 cubic feet per second for the 180 index stations in the conterminous United States and southern Canada was 43 percent below normal, a 30 percent decrease in streamflow from May to June and the lowest for June in the last 6 years. Below-normal streamflow occurred in 60 percent of southern Canada and the conterminous United States during June compared with 38 percent for May.

The intensity of the present drought is shown by the occurrence of June record lows at 33 streamflow index stations in southern Canada and the conterminous United States; 31 of them were at sites east of the Mississippi River and included the gaging station Mississippi River at Vicksburg, Miss. In six areas that have been affected by drought—the Great Basin areas of Utah and Nevada, California, the Pacific Northwest, the Northern Great Plains, the Western Great Lakes States, and the Southeast—June streamflow increased from that for May only in California (by only 6 percent). Streamflow remained below normal in all six areas.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged a record low of 744,700 cubic feet per second (45 percent below normal) after a 22 percent decrease from May to June. Of 45 "large rivers" (including the Big Three), only two had June flows that were above normal (Willamette River at Salem, Oreg., and Tanana River at Nenana, Alaska), and flow in 38 of the 45 decreased from May to June.

June elevations at the four master gages on the Great Lakes were in the average range on Lakes Huron and Erie and in the below-average range on Lakes Superior and Ontario. The elevation of Utah's Great Salt Lake continued to decline and fell 0.40 foot during the month.

In southern Canada and the conterminous United States, monthend contents of the index reservoirs were below average for June at 45 of the 100 reporting sites. In the West, the below-average contents were at most sites in North Dakota, Montana, Idaho, Wyoming, California, and Nevada. In the Southeast, the sites were in North Carolina, the Tennessee Valley, South Carolina, Georgia, and Alabama.

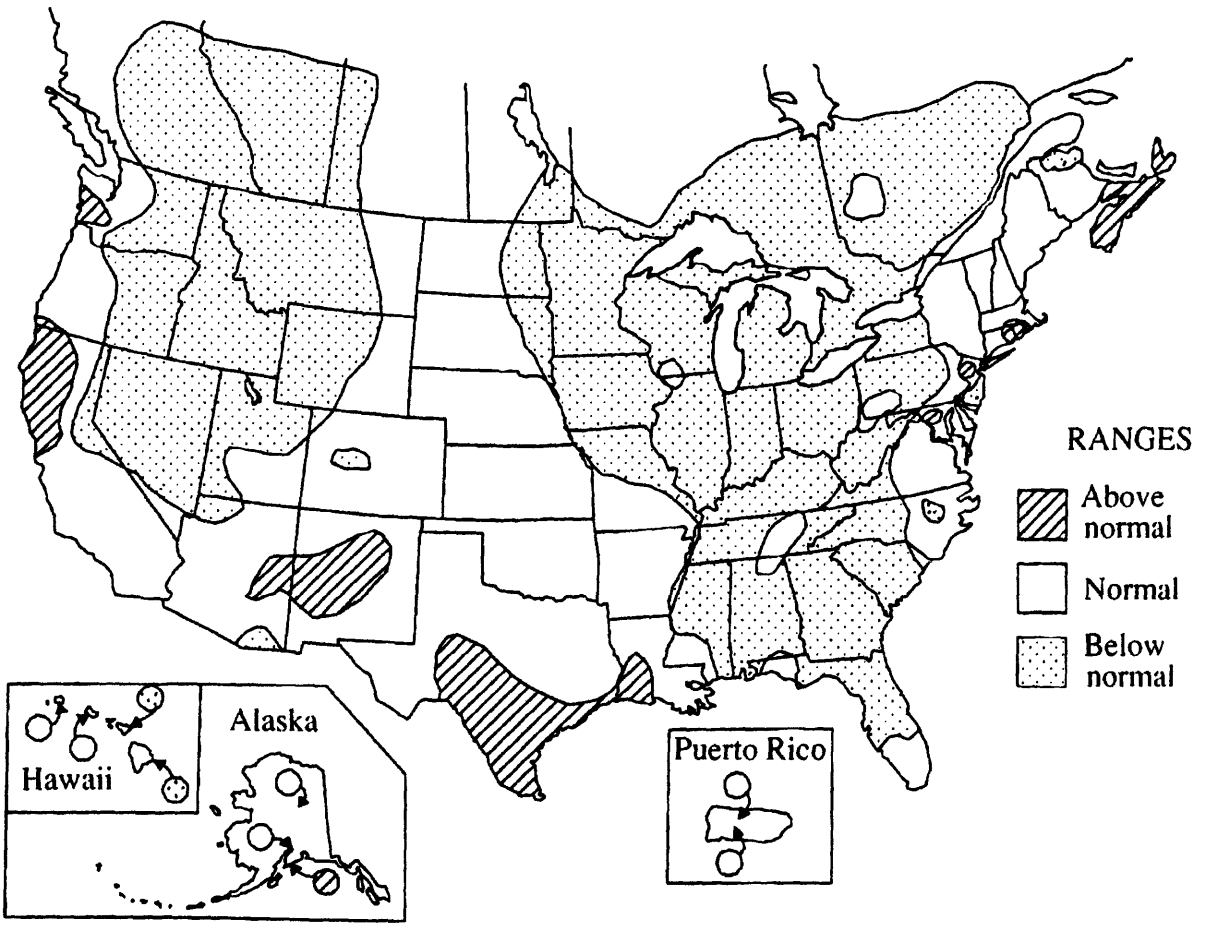


Figure 35. Streamflow during July 1988.

July 1988

Streamflow was in the normal to above-normal range at only 48 percent of the 190 index stations in southern Canada, the United States, and Puerto Rico and was the lowest percentage of stations with flow in the normal to above-normal range for July in the last 6 years. Total July flow of 1,053,800 cubic feet per second for the 180 index stations in the conterminous United States and southern Canada was 42 percent below normal, which was a 30-percent decrease in streamflow from June to July and the lowest for July in the last 6 years. Below-normal streamflow occurred in 50 percent of southern Canada and the conterminous United States during July compared with 60 percent for June. Only 13 July record lows occurred compared with 33 June record lows. There was also one July record high, the St. Mary's River at Stillwater, Nova Scotia, Canada.

In six areas that are affected by the current drought—the Great Basin areas of Utah and Nevada, California, the Pacific Northwest, the Northern Great Plains, the Western Great Lakes States, and the Southeast—July streamflow increased from that for June only in California and only by 5 percent. Streamflow was above normal only in California (38 percent); flow in the other five areas was well below normal. The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged a July record low of 527,200 cubic feet per second (46 percent below normal) after a 29-percent decrease from June to July.

July elevations at the four master gages on the Great Lakes declined from those for June. The elevation of Utah's Great Salt Lake was 4,208.05 feet above sea level on July 30, after declining 0.65 foot during the month.

Monthend reservoir contents for July 1988 were in the below-average range at 42 of 100 reporting sites, which was about the same as for June. These reservoirs are located in New York, the Tennessee Valley, the Dakotas, Montana, Wyoming, Idaho, California, and Nevada.

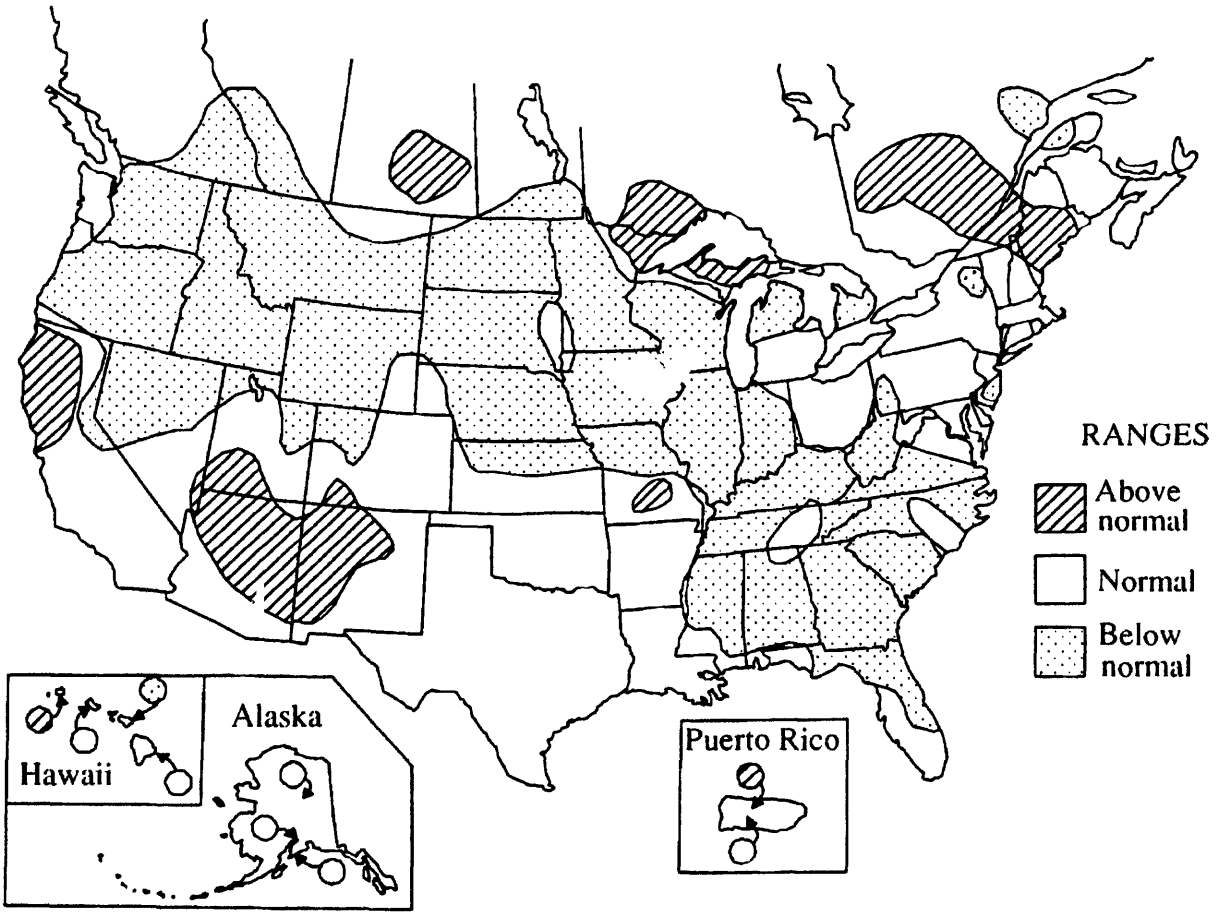


Figure 36. Streamflow during August 1988.

August 1988

Streamflow was in the normal to above-normal range at 48 percent of the 190 index stations in southern Canada, the United States, and Puerto Rico, which was the same as last month. Total August flow for the 180 index stations in the conterminous United States and southern Canada was 28 percent below normal. Below-normal streamflow occurred in 40 percent of southern Canada and the conterminous United States compared with 50 percent for July and 60 percent for June. Only 7 monthly lows occurred during August compared with 13 monthly lows during July. There was also one August record high, Gila River near Gila, N. Mex.

August streamflow decreased from that for July in the six areas that are affected by the current drought—the Great Basin areas of Utah and Nevada, California, the Pacific Northwest, the Northern Great Plains, the Western Great Lakes States, and the Southeast. Streamflow was again above normal only in California (34 percent); flow in the other five areas was well below normal.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—was 31 percent below normal and the third lowest for August in 59 years of record. Of the three rivers, the St. Lawrence at Cornwall, Ontario, Canada, had the highest individual flow, which was greater also than that of the Mississippi River for the third consecutive month.

August elevations at the four master gages on the Great Lakes declined from those for July and were significantly lower than those for August 1987. The elevation of Utah's Great Salt Lake declined 0.65 foot to 4,207.40 feet above sea level on August 31.

Monthend index reservoir contents for August 1988 were in the below-average range at 39 of 100 reporting sites compared with 42 of 100 during July 1988. August 1988 contents were lower than those of August 1987 at 48 of the 100 sites.

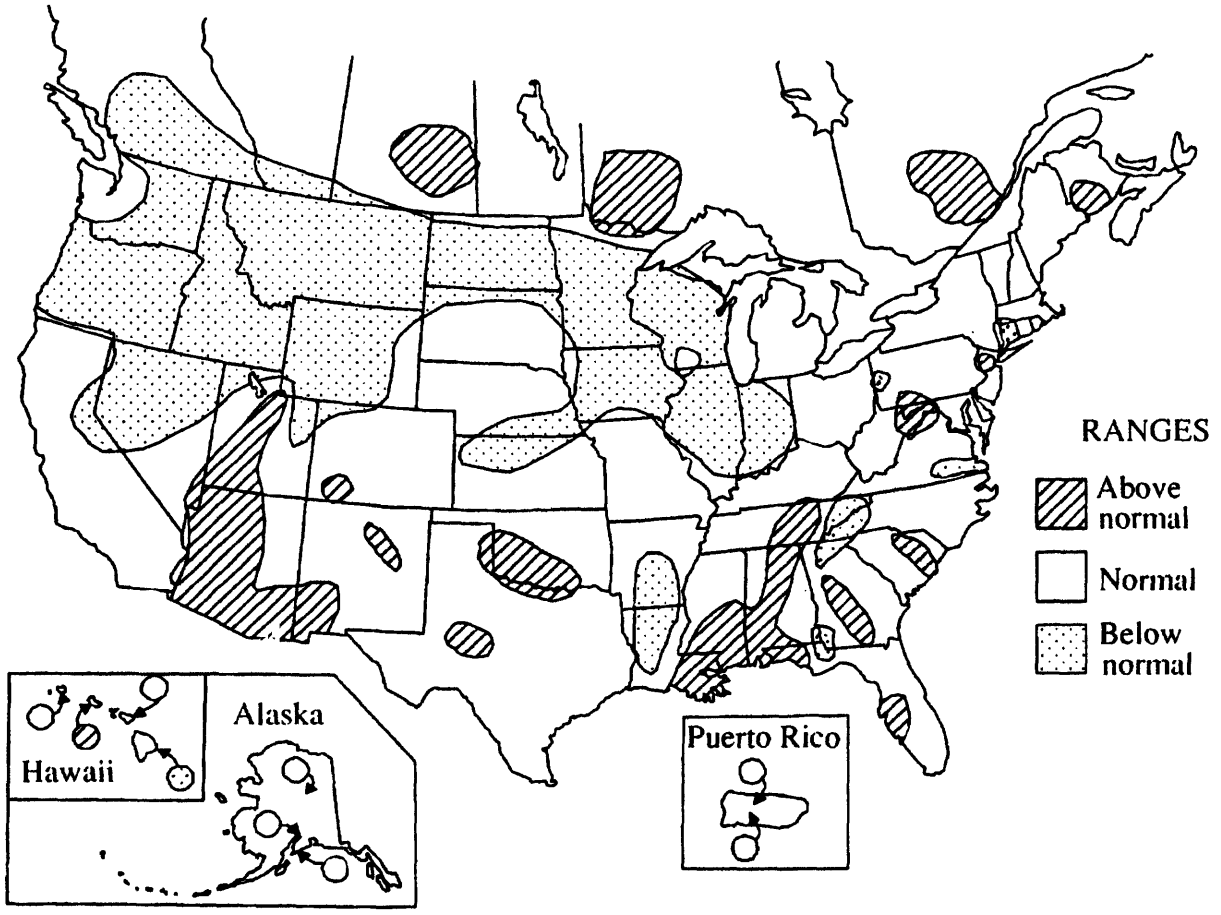


Figure 37. Streamflow during September 1988.

September 1988

Streamflow was in the normal to above-normal range at 68 percent of the 191 index stations in southern Canada, the United States, and Puerto Rico compared with 48 percent of 190 stations during the preceding month. Total flow for the 181 index stations in the conterminous United States and southern Canada was 15 percent below normal and the lowest for September in the last 6 years after a 1-percent increase in streamflow from August to September. This was the seventh consecutive month of below-normal total streamflow in southern Canada and the conterminous United States. Below-normal streamflow occurred in 27 percent of the area of southern Canada and the conterminous United States compared with 39 percent for August. Eight monthly lows, including one alltime low, occurred during September compared with seven monthly lows, including two alltime lows, during August.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—was the third lowest for September in 59 years of record. Flow in the Columbia River at The Dalles, Oreg., was the lowest for September in 109 years of record. Flow in the Mississippi River was the second lowest for September for the period of record (59 years). Flow in the St. Lawrence River at Cornwall, Ontario, Canada, was in the normal range.

September elevations at the four master gages on the Great Lakes declined from those for August at three of four sites; only the elevation on Lake Superior rose. Levels were in the average range on Lakes Huron and Erie and below average on Lakes Superior and Ontario. The elevation of Utah's Great Salt Lake declined 0.55 foot during the month and was 4,206.85 feet above sea level on September 30.

Monthend index reservoir contents for September 1988 were in the below-average range at 34 of 100 reporting sites compared with 39 of 100 sites during August 1988. These reservoirs are located in the Western States and in States east of the Mississippi River.

For the 1988 water year as a whole, the areal extent of streamflow in the below-normal range nearly doubled during the second half of the year—from 28 (fall-winter) to 55 percent (spring-summer). Below-normal streamflow occurred in 45 percent of the area of southern Canada and the conterminous United States for the water year, which was about the same as in 1977 and 1981. These 3 years are essentially tied for the third driest year in the last 68 years, as measured by the areal extent of below-normal streamflow. Only the 1931 (66 percent) and 1934 (63 percent) water years were drier.

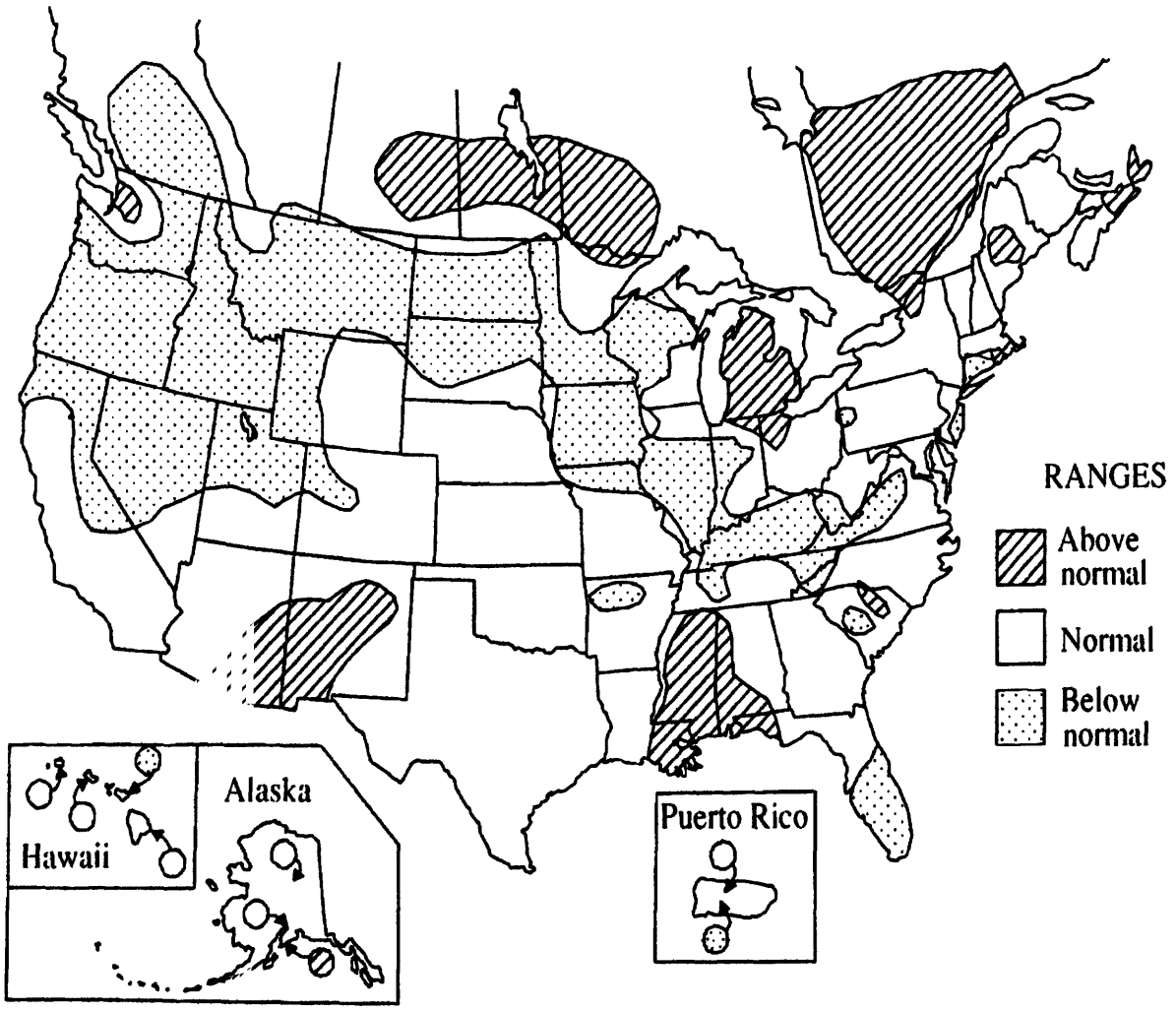


Figure 38. Streamflow during October 1988.

October 1988

Streamflow was in the normal to above-normal range at 65 percent of the 191 index stations in southern Canada, the United States, and Puerto Rico compared with 68 percent of 191 stations during the preceding month. Total October flow for the 181 index stations in the conterminous United States and southern Canada was 15 percent below normal and the lowest flow for October in the last 7 years. This was the eighth consecutive month of below-normal total streamflow in southern Canada and the conterminous United States. Below-normal streamflow occurred in 28 percent of the area of southern Canada and the conterminous United States during October compared with 27 percent during September. Only three monthly lows occurred during October, however, compared with eight monthly lows during September.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—was in the below-normal range and 22 percent below normal during October after a 9-percent increase from September to October. Only the flow in the St. Lawrence River at Cornwall, Ontario, Canada, was in the normal range and was greater than the flow in the Mississippi River for the fifth consecutive month.

October elevations at the four master gages on the Great Lakes declined from those for September at all four sites. All were in the average range except for Lake Superior, which was below average for the sixth consecutive month. The elevation of Utah's Great Salt Lake declined 0.25 foot during the month and was 4,206.60 feet above sea level on October 31. The level is 2.85 feet lower than at the end of October 1987.

Monthend index reservoir contents for October 1988 were in the below-average range at 39 of 100 reporting sites compared with 34 of 100 during September 1988. Only in Canada, South Carolina, Alabama, and Texas did most reservoirs have higher contents at the end of October 1988 than at the end of October 1987. Lake Tahoe, which straddles the California-Nevada State line, had no usable storage left at the end of the month.

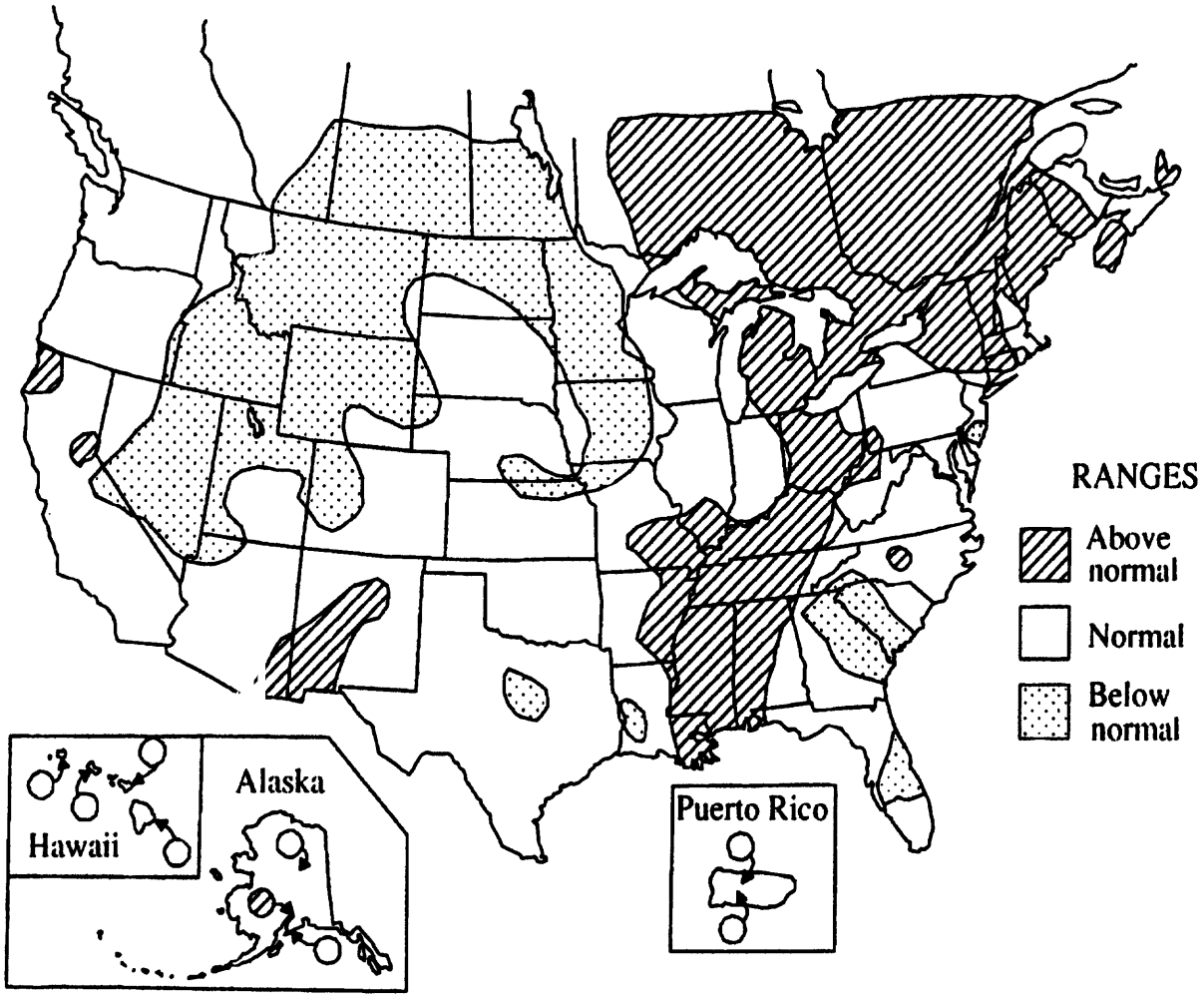


Figure 39. Streamflow during November 1988.

November 1988

Streamflow was in the normal to above-normal range at 80 percent of the 189 index stations in southern Canada, the United States, and Puerto Rico compared with 65 percent of 191 stations during the preceding month. Total November flow for the 180 index stations in the conterminous United States and southern Canada was 11 percent above normal. Below-normal streamflow occurred in 22 percent of the area of southern Canada and the conterminous United States during November compared with 28 percent during October.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged a normal-range 664,100 cubic feet per second (less than 1 percent below normal) during November after a 32-percent increase from October to November. Individual flows of all three rivers were in the normal range.

November elevations at the four master gages on the Great Lakes declined from those for October except on Lake Superior. The monthly means were in the average range on all four lakes. The elevation of Utah's Great Salt Lake declined 0.10 foot to 4,206.50 feet above sea level on November 15, and remained at that level through November 30.

Monthend index reservoir contents for November 1988 were in the below-average range at 28 of 100 reporting sites compared with 39 of 100 during October 1988. Lake Tahoe, which straddles the California-Nevada State line, had no usable storage for the second consecutive month.

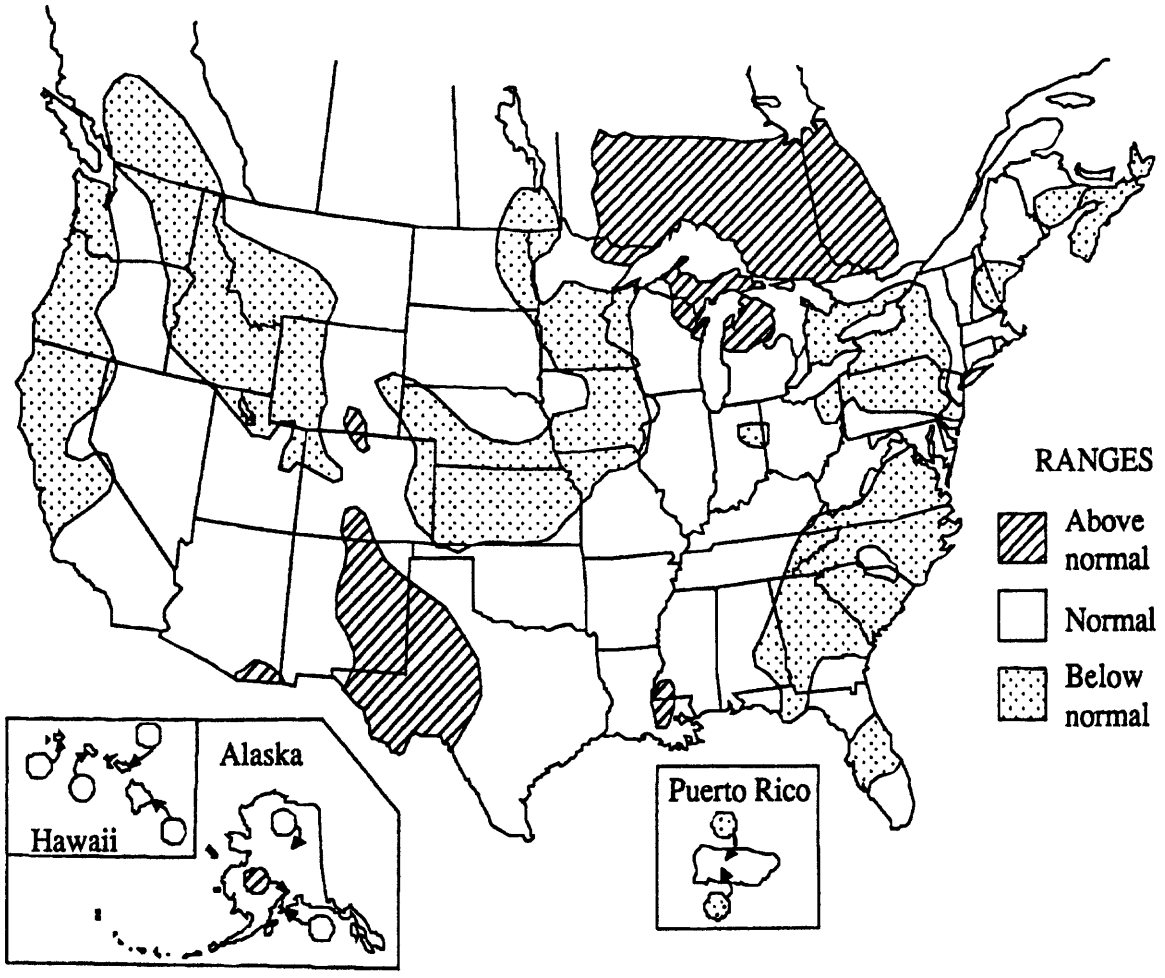


Figure 40. Streamflow during December 1988.

December 1988

Streamflow was in the normal to above-normal range at 60 percent of the 191 index stations in southern Canada, the United States, and Puerto Rico compared with 80 percent during the preceding month. This is the lowest percentage of stations with flow in the normal to above-normal range for December in the last 7 years and a 6-percent decrease from November to December. Total December flow for the 179 index stations in the conterminous United States and southern Canada was 17 percent below normal, also the lowest for December in the last 7 years. Below-normal streamflow occurred in 26 percent of the area of southern Canada and the conterminous United States during December compared with 22 percent during November and a high of 60 percent during June.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—was in the normal range during December after a 14 percent increase from November to December. Only one December low occurred: flow in the Etowah River at Canton, Ga. (398 cubic feet per second) was 59 percent below normal and the lowest flow in 61 years of record.

December elevations at the four master gages on the Great Lakes declined from those for November except on Lake Huron. The monthly means were in the average range on all four lakes. The elevation of Utah's Great Salt Lake declined 0.05 foot to 4,206.45 feet above sea level on December 15, and remained at that level through December 31.

Monthend index reservoir contents for December 1988 were in the below-average range at 32 of 100 reporting sites compared with 28 of 100 during November 1988. Lake Tahoe, which straddles the California-Nevada State line, had no usable storage for the third consecutive month.

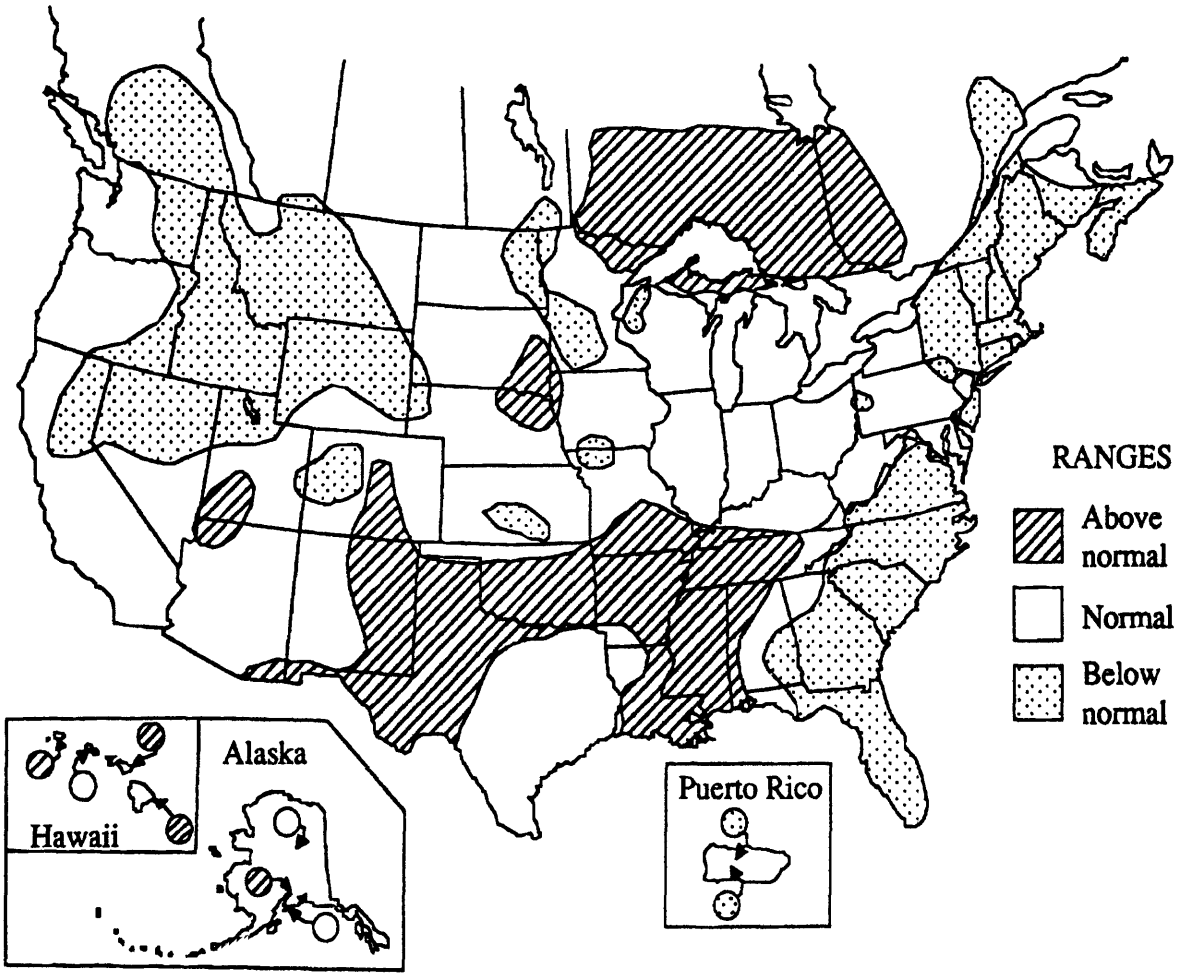


Figure 41. Streamflow during January 1989.

January 1989

Streamflow was in the normal to above-normal range at 61 percent of the 191 index stations in southern Canada, the United States, and Puerto Rico during January. Total flow for the 181 index stations in the conterminous United States and southern Canada was 9 percent above normal after a 50-percent increase in streamflow from December to January.

January streamflow ranged from 50 percent below normal (California) to 31 percent above normal (Western Great Lakes) in five areas affected by drought (California, Northern Great Plains, Pacific Northwest, Western Great Lakes, Southeast). The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—was 13 percent above normal and in the above-normal range during January. Individually, flow in the St. Lawrence was below normal for the first time since May 1988, below normal in the Columbia for the second consecutive month, and above normal in the Mississippi for the first time since January 1988.

In southwestern Florida, the South Florida Water Management District imposed further water-use restrictions on January 16, 1989, in parts of Lee and Collier Counties. Water levels in all freshwater aquifers in southwest Florida were at or near historical lows.

Monthend index reservoir contents for January 1989 were in the below-average range at 33 of 97 sites compared with 32 of 100 during December 1988. Storage in the 153 major reservoirs in California was only 2.9 million acre-feet greater than on February 1, 1977; 1977 was the driest year of record in that State. About half of that increased storage was in reservoirs built since 1977. Lake Tahoe (California-Nevada) had no usable storage for the fourth consecutive month.

Contents of the New York City reservoir system were only 56 percent of maximum at the end of January. Diversions of water from New York City's Delaware River basin reservoir system were reduced to 70 percent of the maximum usually allowed. Allowable diversions by New Jersey communities from the Delaware River were also reduced to 70 percent of the usual maximum.

Mean January elevations at the four master gages on the Great Lakes were in the average range, except on Lake Ontario where the level was in the below-average range. Utah's Great Salt Lake rose 0.05 foot to 4,206.50 feet above sea level on January 31.

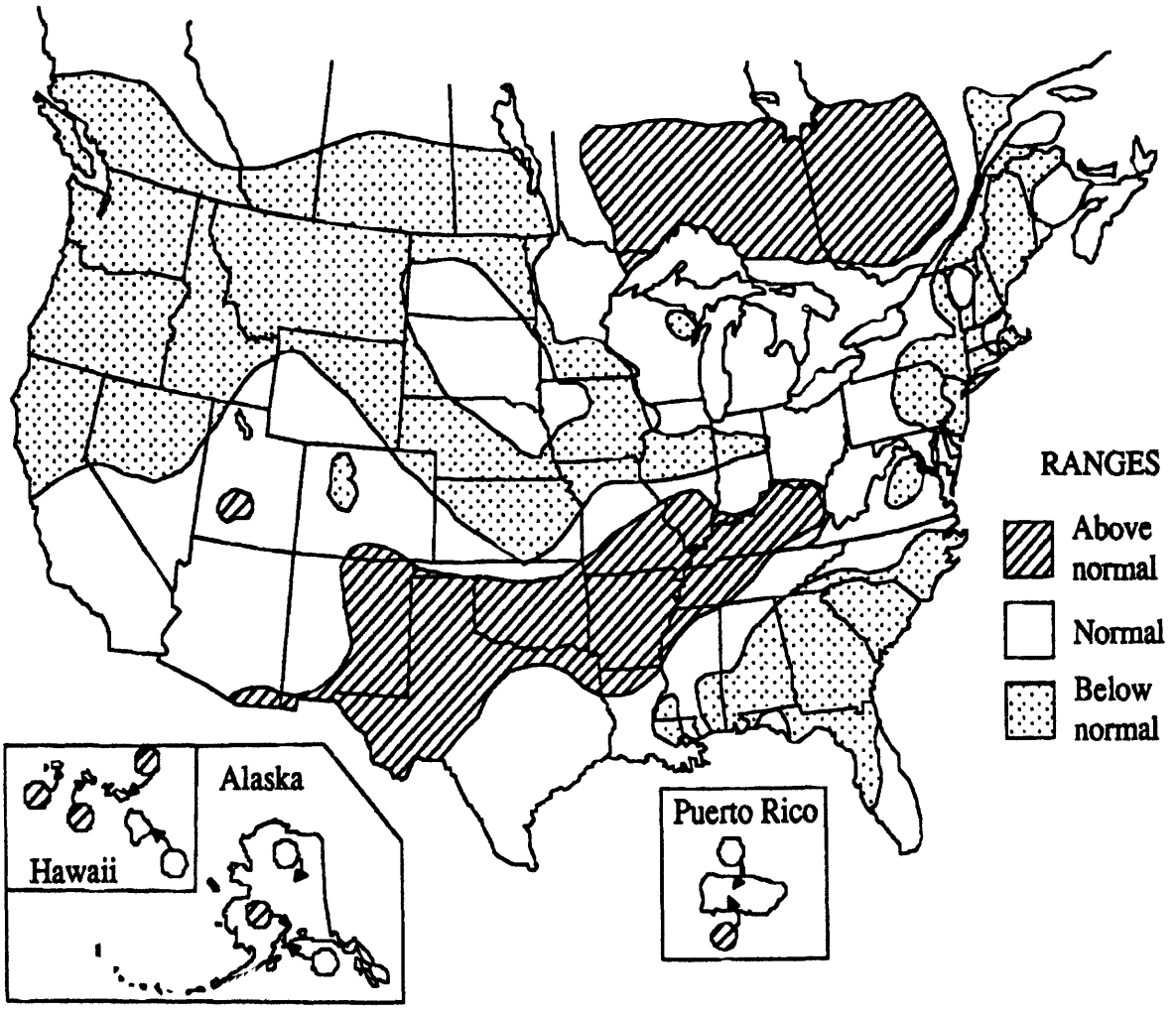


Figure 42. Streamflow during February 1989.

February 1989

Hydrologic drought continued to affect some parts of the United States in spite of above-average precipitation over a large area of the Nation. Storage remained well below the average for this time of year in California's major reservoirs, and the runoff outlook was below average. Soil moisture was generally very low in Oregon and Washington, whereas the snowpack was above average (120–160 percent) in Oregon and below average (85–90 percent) in Washington. These mixed conditions cited for Oregon and Washington also occurred in other Western States. Storage in the New York City reservoir system remained below average, and streamflow in the Southeast decreased despite heavy rains over inland areas during February. For example, heavy rains February 13 to 16 caused flooding in west-central Kentucky. Estimated peak discharges with recurrence intervals of about 100 years occurred on the Rolling Fork (Salt River basin) and the Kentucky River downstream from Lock 6.

Streamflow was in the normal to above-normal range at 61 percent of the index stations in southern Canada, the United States, and Puerto Rico during February; this was the lowest percentage for February in the last 7 years. Total February flow in the conterminous United States and southern Canada was 5 percent above normal after a 5-percent increase in streamflow from January to February. Below-normal streamflow occurred in 36 percent of southern Canada and the conterminous United States during February compared with 25 percent during January.

February streamflow ranged from 66 percent below normal (California) to 11 percent above normal (Western Great Lakes) in the five areas affected by drought. Flow was the same as during January in the Northern Great Plains, but decreases in the other four areas ranged from 5 percent in the Southeast to 20 percent in California. Five new monthly low flows occurred during the month: one each in New York, South Carolina, Georgia, Florida, and Nebraska.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—was in the normal range during February, but 4 percent less than during January. Flow in the St. Lawrence and the Mississippi Rivers was in the normal range. Flow in the Columbia River was 42 percent below normal and in the below-normal range for the third consecutive month.

Monthend index reservoir contents for February 1989 were in the below-average range at 34 of 100 sites compared with 33 of 97 during January 1989; this included most reservoirs in Nova Scotia in Canada, Maryland, the Dakotas, Montana, Wyoming, Idaho, Washington, California, and Nevada. Lake Tahoe had no usable storage for the fifth consecutive month. February 1989 contents were significantly lower than those of February 1988 at 40 of the 100 sites, including most sites in the Dakotas, Montana, Wyoming, California, Nevada, and Texas. In the Southeast, only 2 of the 10 index reservoirs had contents that were less than those of February 1986; 1986 was the most recent year of drought in the Southeast before 1988.

February elevations at the four master gages on the Great Lakes were in the average range, except on Lake Ontario where the level was in the below-average range for the second consecutive month. Utah's Great Salt Lake rose 0.10 foot during February.

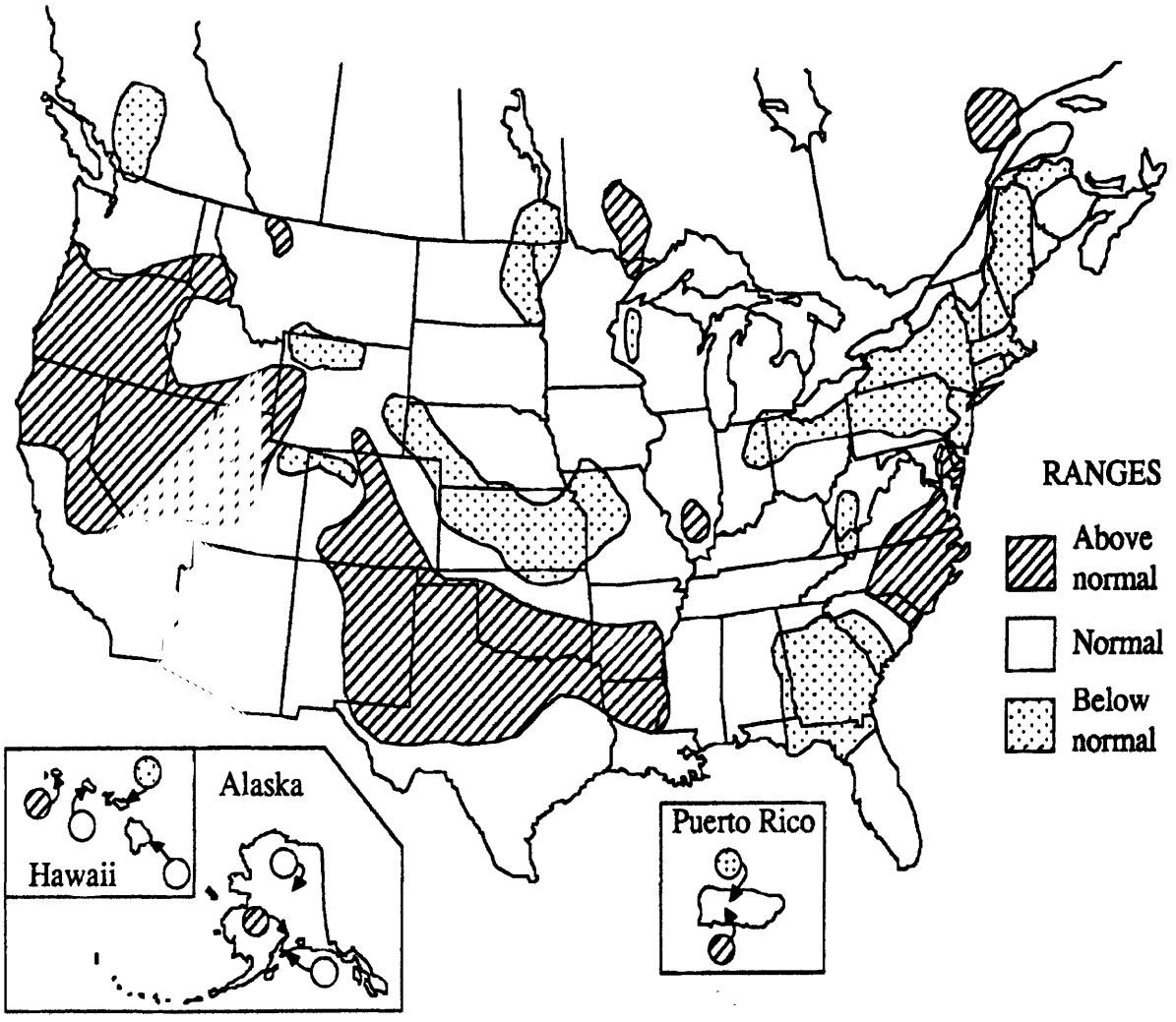


Figure 43. Streamflow during March 1989.

March 1989

Hydrologic drought continued to affect some parts of the United States in spite of above-average precipitation over a large area of the Nation. Storage remained well below the average for this time of year in some major reservoirs in California, Washington, Idaho, Montana, New York, South Carolina, and Georgia. Water-use restrictions remained in effect in parts of California, New York, New Jersey, and Florida.

Streamflow was in the normal to above-normal range during March at 75 percent of the 189 index stations compared with 61 percent during February and was the third lowest March flow in the last 7 years. Total flow for the 179 index stations in the conterminous United States and southern Canada was 11 percent above normal. Below-normal streamflow occurred in 12 percent of southern Canada and the conterminous United States compared with 36 percent during February.

March streamflow ranged from 30 percent below normal (Northern Great Plains) to 46 percent above normal (California) in the five areas affected by drought. Flow increased from that during February in all five areas. The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—was in the above-normal range during March. Flows in the St. Lawrence and Columbia Rivers were in the normal range. Flow in the Mississippi River was in the above-normal range.

Monthend index reservoir contents were in the below-average range at 33 of 100 reporting sites. Lake Tahoe had 12 percent of maximum contents in storage, which was a significant improvement over last month's condition (no usable storage for five consecutive months). Contents of the New York City reservoir system were only 60 percent of the March average.

March elevations at the four master gages on the Great Lakes were in the average range except on Lake Ontario, which was below average for the third consecutive month. Utah's Great Salt Lake was at 4,206.80 feet above sea level on March 31, which was 2.70 feet lower than at the end of March 1988.

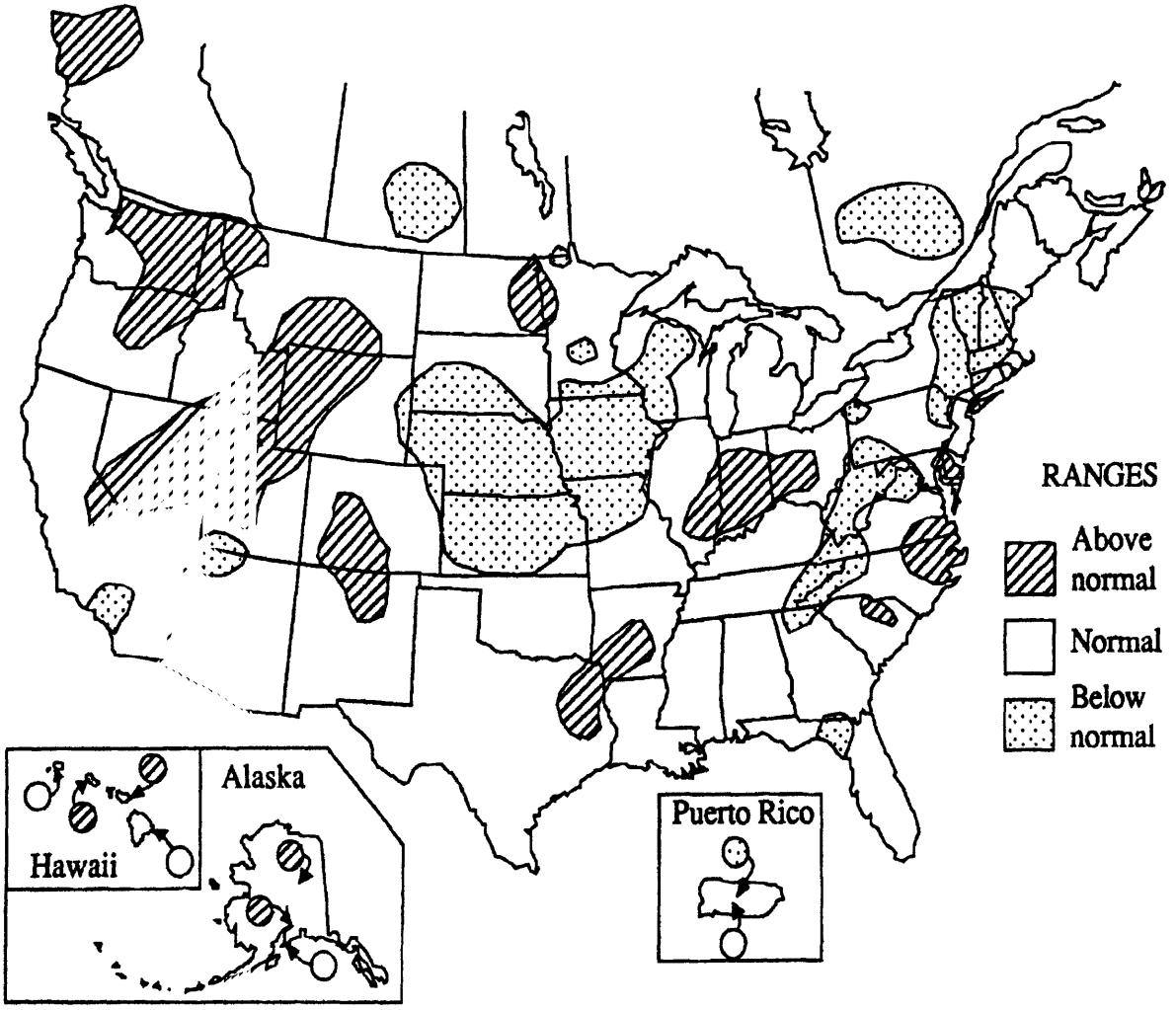


Figure 44. Streamflow during April 1989.

April 1989

Flooding occurred along the Red River of the North during early April. The peak flood stage at Wahpeton, N. Dak., exceeded that of the 1897 flood of record, but the peak discharge was less than in 1897.

Streamflow was in the normal to above-normal range at 76 percent of the index stations in southern Canada, the United States, and Puerto Rico during April compared with 75 percent of the stations during March. Total April flow for the index stations in the conterminous United States and southern Canada was 2 percent above normal after an 8-percent increase in streamflow from March to April. Below-normal streamflow occurred in 13 percent of southern Canada and the conterminous United States during April compared with 12 percent during March.

April streamflow ranged from 15 percent below normal (Northern Great Plains) to 41 percent above normal (California) in the five areas affected by the drought of 1988. Flow decreased from that during March in California and the Southeast but increased from that during March in the other areas (Pacific Northwest, Northern Great Plains, Western Great Lakes).

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—was in the normal range and 6 percent above normal during April. Flow in only one river, the St. Lawrence, was in the below-normal range.

Monthend index reservoir contents were in the below-average range at 30 of 100 reporting sites. Usable storage in Allard Reservoir in Quebec, Canada, increased from none at the end of March to 90 percent of the average for the month at the end of April. Storage in Lake Tahoe increased to 20 percent of maximum, which was a significant improvement over previous months. Contents of the New York City reservoir system were only 71 percent of the April average.

April elevations at the four master gages on the Great Lakes were in the average range except on Lake Ontario, where the level was in the below-normal range for the fourth consecutive month. Utah's Great Salt Lake declined 0.15 foot during the month and was 2.80 feet lower than at the end of April 1988.

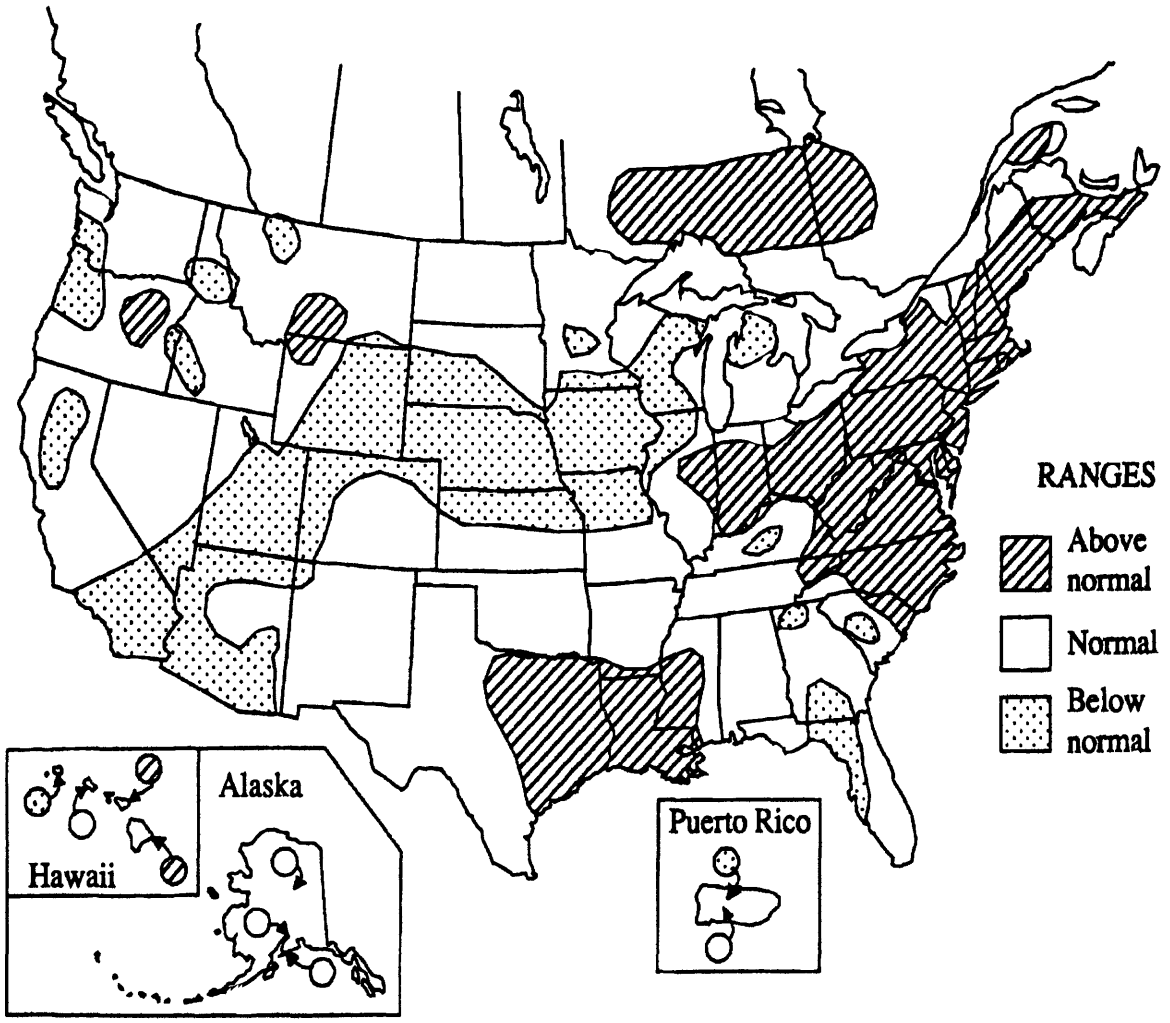


Figure 45. Streamflow during May 1989.

May 1989

Severe flooding, which was caused by heavy rain, occurred mostly in the central and eastern parts of Texas. Several people were killed in floods in Ohio after heavy rain on May 25–26, but the flooding was much less severe than that in Texas. Heavy rains fell in Ohio and southern Michigan on May 31.

Drought continued in parts of the West and Midwest, but most of the East was wet. Water-withdrawal and water-use restrictions ended in New York City and the Delaware River basin after 6 inches of rainfall between May 1 and 11.

Streamflow was in the normal to above-normal range at 74 percent of the 190 index stations in southern Canada, the United States, and Puerto Rico during May compared with 76 percent of 191 stations during April and 54 percent of 191 stations during May 1988. Total May flow for the index stations in the conterminous United States and southern Canada was 2 percent above normal after a 5-percent increase in streamflow from April to May and 48 percent more than the flow during May 1988. Below-normal streamflow occurred in 18 percent of southern Canada and the conterminous United States during May compared with 13 percent during April. New monthly extremes occurred at 21 index stations during May: 6 lows (5 west of the Mississippi River) and 15 highs (all in the East) compared with 4 new extremes last month.

May streamflow ranged from 36 percent below normal (California) to 54 percent above normal (Southeast) in the five areas affected by drought in 1988. Flow decreased from that during April in California and the Northern Great Plains but increased from that during April in the other three areas (Pacific Northwest, Western Great Lakes, Southeast).

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—was 11 percent below normal and in the below-normal range during May. Flow in the Columbia was in the normal range; flows in the Mississippi and St. Lawrence were below normal.

Monthend index reservoir contents were in the below-average range at only 25 of 100 reporting sites. Contents of the New York City reservoir system increased into the average range for May. Only six reservoirs (with maximum contents of at least 1,000,000 acre-feet) had monthend contents in the below-average range and also lower than last year: Lake Sakakawea, N. Dak.; Fort Peck, Mont.; Ross and Franklin D. Roosevelt Lakes, Wash.; and Lake Berryessa, Calif.

May elevations at the four master gages on the Great Lakes were in the average range. Utah's Great Salt Lake declined 0.15 foot, was 0.30 foot below the seasonal high in April, and was also 2.60 feet lower than at the end of May 1988.

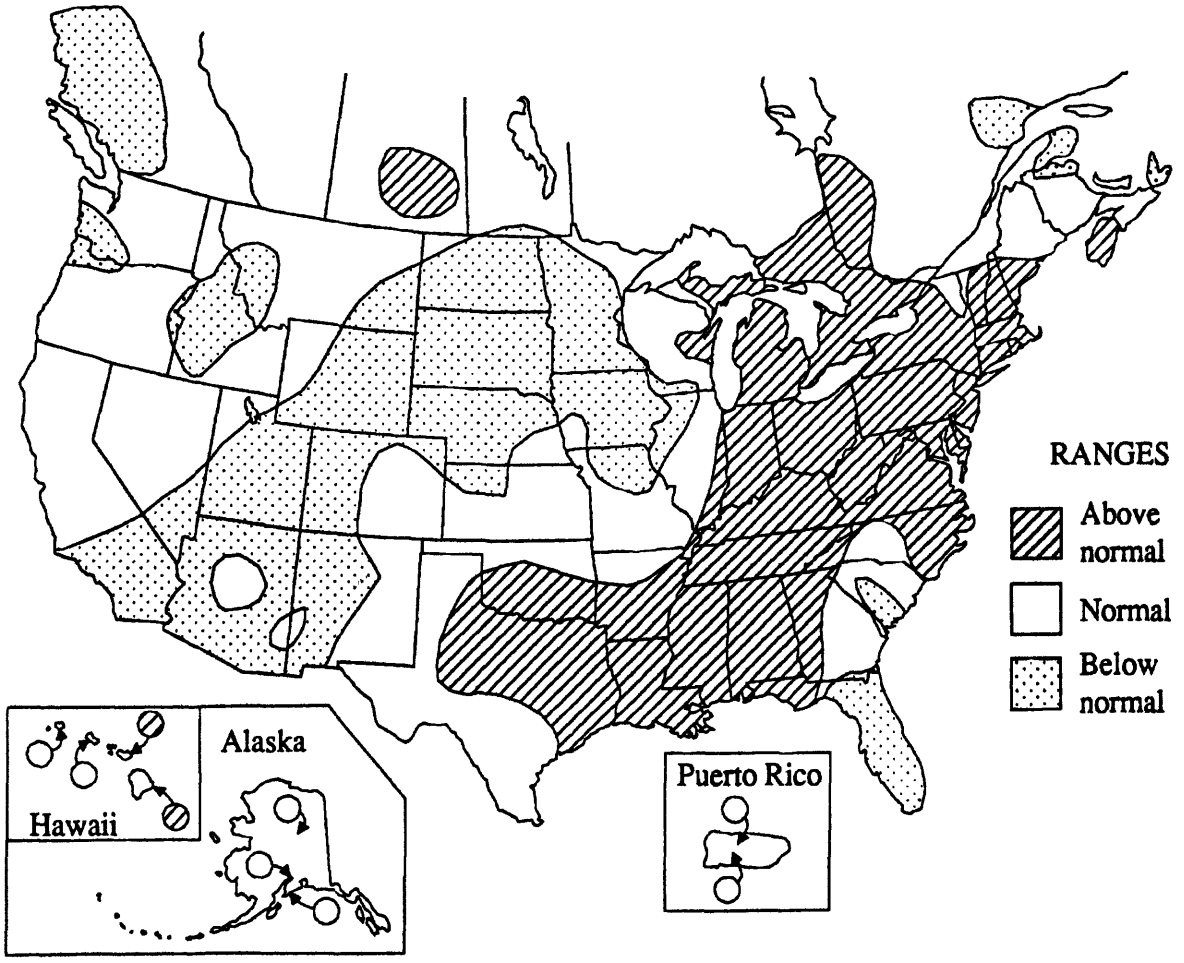


Figure 46. Streamflow during June 1989.

June 1989

Heavy rains caused floods in parts of Florida, Alabama, Louisiana, Texas, Michigan, Pennsylvania, and New York. The most severe and damaging floods occurred on June 8–9 when 3 to 15 inches of rain fell on Florida's panhandle and on the area east of Mobile Bay in Alabama (Baldwin County), which caused several streams to exceed either peaks of record or the 100-year flood. Three people were killed in the Eastpoint area of the Florida panhandle when a tornado went through the area on June 9. Up to 16 inches of rain from Tropical Storm Allison fell in the Houston (Harris County), Tex., area from June 24 to 27; flood records set before 1989 were exceeded at seven stations during the resulting June 26–27 floods.

Hydrologic drought persisted in parts of the Central and Western United States. Total June flow for the 191 index stations in the conterminous United States and southern Canada was 14 percent above normal; this was a 6-percent decrease in streamflow from May to June. New monthly extremes occurred at 12 index stations during June compared with 22 new extremes last month. The only new low was in the Saline River near Russell, Kans.; it was the lowest June flow in 37 years and the second consecutive month of record monthly low flow. Flow at this site was indicative of the prolonged drought in the Central Great Plains. June streamflow ranged from 32 percent below normal to 126 percent above normal in the five areas affected by the drought of 1988. Flow decreased from the May totals in all five areas. The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—was 3 percent above normal and in the normal range during June, which was 4 percent more than during May.

Monthend index reservoir contents were in the below-average range at 30 of 100 reporting sites, including most reservoirs in Nebraska, the Dakotas, Wyoming, Montana, Washington, California, and Nevada. The only large reservoirs with contents in the below-average range and lower than last year were in the Dakotas, Wyoming, Montana, Washington, and California.

Great Lakes levels rose seasonally and were above average except on Lake Huron. The level of Lake Ontario rose 2.70 feet since March 1989 and was almost a foot higher than the level during June 1988. The elevation of Utah's Great Salt Lake declined seasonally and was 2.70 feet lower than at the end of June 1988.

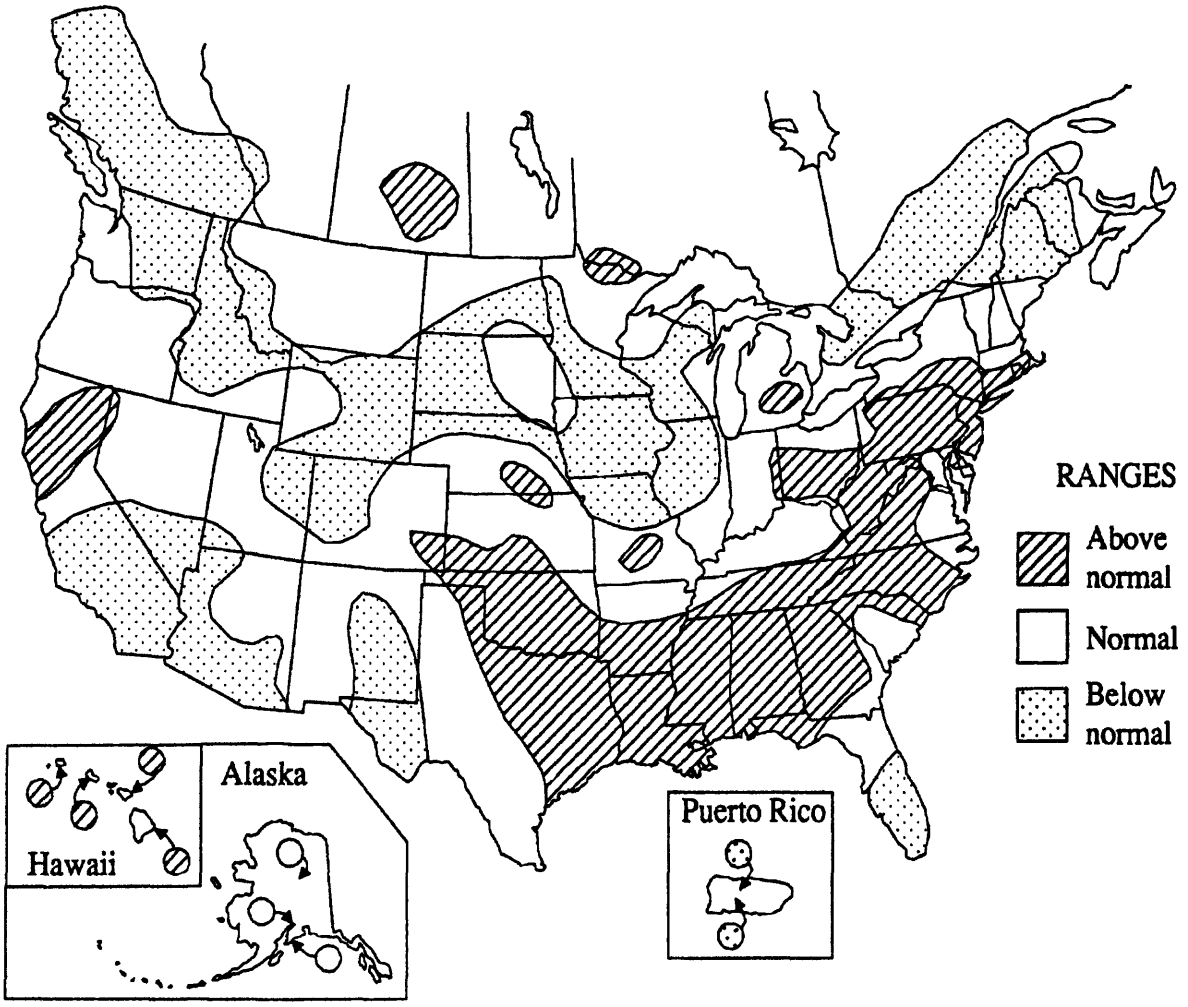


Figure 47. Streamflow during July 1989.

July 1989

Heavy rains caused floods that exceeded previous peaks of record and the 100-year recurrence interval on some streams in northern New Castle County in Delaware. Three persons drowned, and damages in the county were estimated to be about $5 million.

Hydrologic drought continued in parts of the Central and Western United States during July. Streamflow was in the normal to above-normal range at 68 percent of the index stations in southern Canada, the United States, and Puerto Rico during July compared with 73 percent during June. Below-normal streamflow occurred in 29 percent of southern Canada and the conterminous United States during July compared with 27 percent during June. Total July flow for the index stations in the conterminous United States and southern Canada was 16 percent above normal after a 28-percent decrease in streamflow from June to July. New monthly extremes occurred at 10 index stations during July compared with 12 new extremes during June.

July streamflow ranged from 39 percent below normal (Northern Great Plains) to 214 percent above normal (Southeast) in the five areas affected by the drought of 1988. Flow increased from that during June in California and the Southeast and decreased in the other three areas (Pacific Northwest, Northern Great Plains, and Western Great Lakes).

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 18 percent above normal and in the above-normal range during July. Flow in the Columbia was below normal for the second consecutive month. Flow in the Mississippi was above normal for the second consecutive month.

Monthend index reservoir contents for July 1989 were in the below-average range at 32 of 100 reporting sites compared with 30 of 100 during June 1989. About the same number of reservoirs had contents in the above-average range.

July elevations at the four master gages on the Great Lakes were in the average range. Utah's Great Salt Lake declined 0.65 foot to 4,205.35 feet above sea level on July 31.

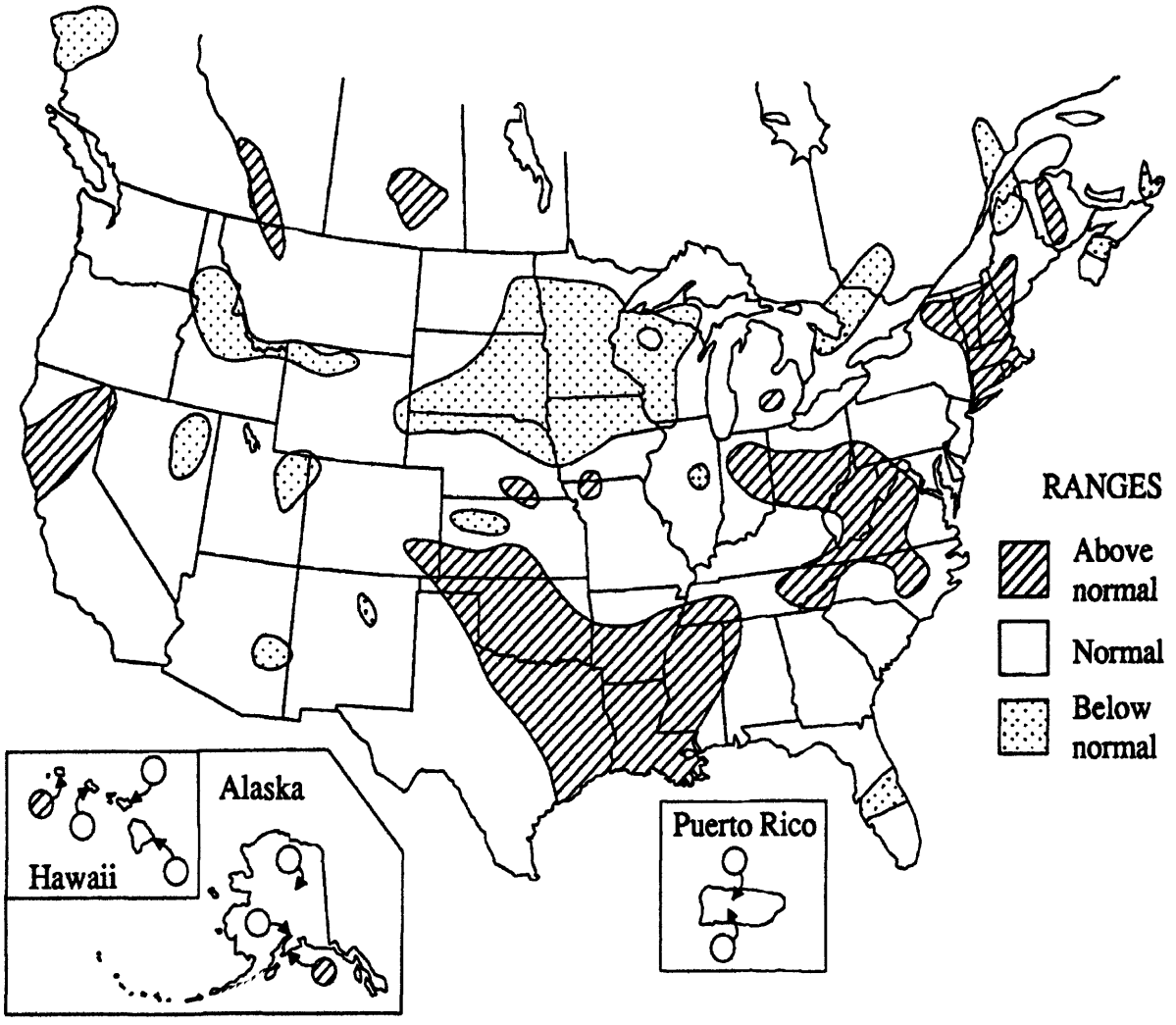


Figure 48. Streamflow during August 1989.

August 1989

Heavy rains on August 25–26 caused severe floods in the Anchorage, Alaska, area from August 26 to 28. Less severe flooding occurred in Seward and the Kĕnai Peninsula Borough. Damages in Anchorage were estimated to be about $5 million, whereas damages in Seward and the Kenai Peninsula Borough were estimated to be about $1 million.

Streamflow was in the normal to above-normal range at 79 percent of the index stations in southern Canada, the United States, and Puerto Rico during August. Below-normal streamflow occurred in only 10 percent of the area of southern Canada and the conterminous United States. Total August flow for the index stations in the conterminous United States and southern Canada was 2 percent below normal after a 39-percent decrease in streamflow from July to August.

August streamflow ranged from 43 percent below normal (Northern Great Plains) to 52 percent above normal (California) in the five areas affected by the drought of 1988. Flow increased from that during July only in California.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 4 percent below normal and was in the normal range. Individual flow in all three rivers was in the normal range.

Monthend index reservoir contents for August were in the below-average range at 31 of 100 reporting sites compared with 32 of 100 during July 1989 and 39 of 100 during August 1988. Most of the reservoirs in Nebraska, the Dakotas, Wyoming, Montana, Idaho, California, Nevada, and Colorado were in this range.

August elevations at the four master gages on the Great Lakes were in the average range for the fourth consecutive month. Utah's Great Salt Lake declined to 4,205.00 feet above sea level on August 31. Lake level has declined 1.80 feet since the seasonal high of May 1–15.

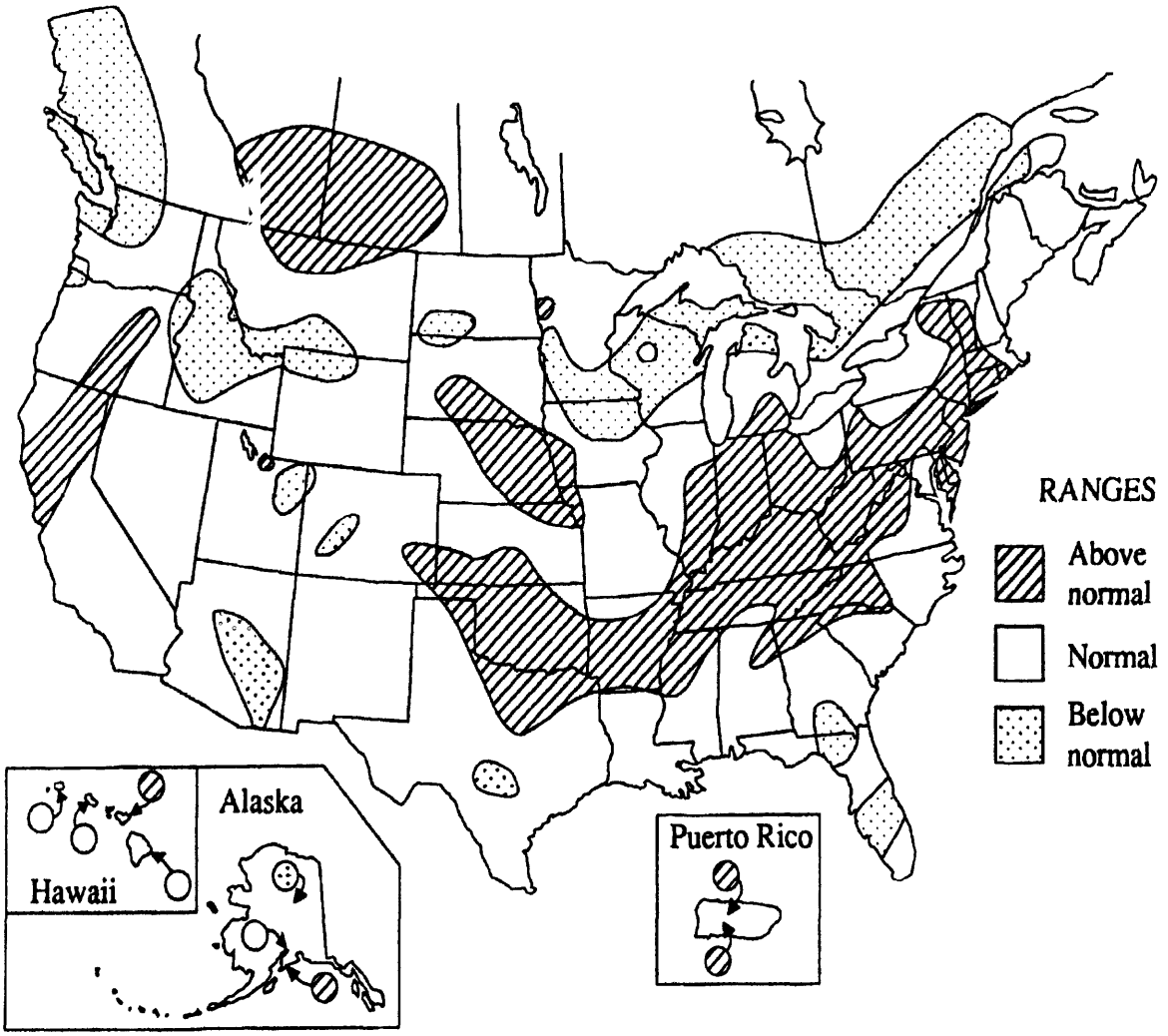


Figure 49. Streamflow during September 1989.

September 1989

On September 15–16, thunderstorms stalled over Fayetteville, N.C., and caused flash floods in which two people drowned. Flooding caused the evacuation of more than 400 homes and more than $10 million in damages to homes, businesses, streets, utilities, and bridges.

On September 17–18, Hurricane Hugo passed over the U.S. Virgin Islands and Puerto Rico and caused 16 deaths and severe wind, rain, and flood damages estimated to be about $4.5 billion to public and private buildings, utilities, and roads. Hugo then moved onshore at Charleston, S.C., September 22, and 29 deaths occurred in the Carolinas because of the storm. Hugo's storm surge peaked at about 16 feet above mean low water in the vicinity of McClellanville (Bull Bay area), about 48 miles up the coast from Charleston. Damage estimates in North Carolina were estimated to be about $6 billion.

On September 24, about 11 inches of rain fell on Jacksonville, Fla. Flooding caused two deaths, the evacuation of parts of the Westside area of the city, and the temporary closing of Interstate Highways 10 and 95.

Streamflow was in the normal to above-normal range at 80 percent of the 190 index stations in southern Canada, the United States, and Puerto Rico during September. Below-normal streamflow occurred in 14 percent of the area of southern Canada and the conterminous United States during September. Total September flow for the 180 index stations in the conterminous United States and southern Canada was 31 percent above normal.

September streamflow ranged from 14 percent below normal (Northern Great Plains) to 198 percent above normal (Western Great Lakes) in the five areas affected by the drought of 1988. Flow increased from that during August in two areas (Northern Great Plains and Western Great Lakes) and decreased in the other three areas (Southeast, Pacific Northwest, and California).

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 28 percent above normal and was in the above-normal range during September. Flow in the Mississippi was again above normal. Flow was normal in the other two rivers.

Monthend index reservoir contents were in the below-average range at 30 of 100 sites compared with 31 of 100 during August 1989. However, 10 reservoirs or reservoir systems had contents in the below-average range and significantly lower contents than last year. These 10 reservoirs are west of the Mississippi River.

Elevations at the four master gages on the Great Lakes were in the average range. Utah's Great Salt Lake declined 0.30 foot during the month.

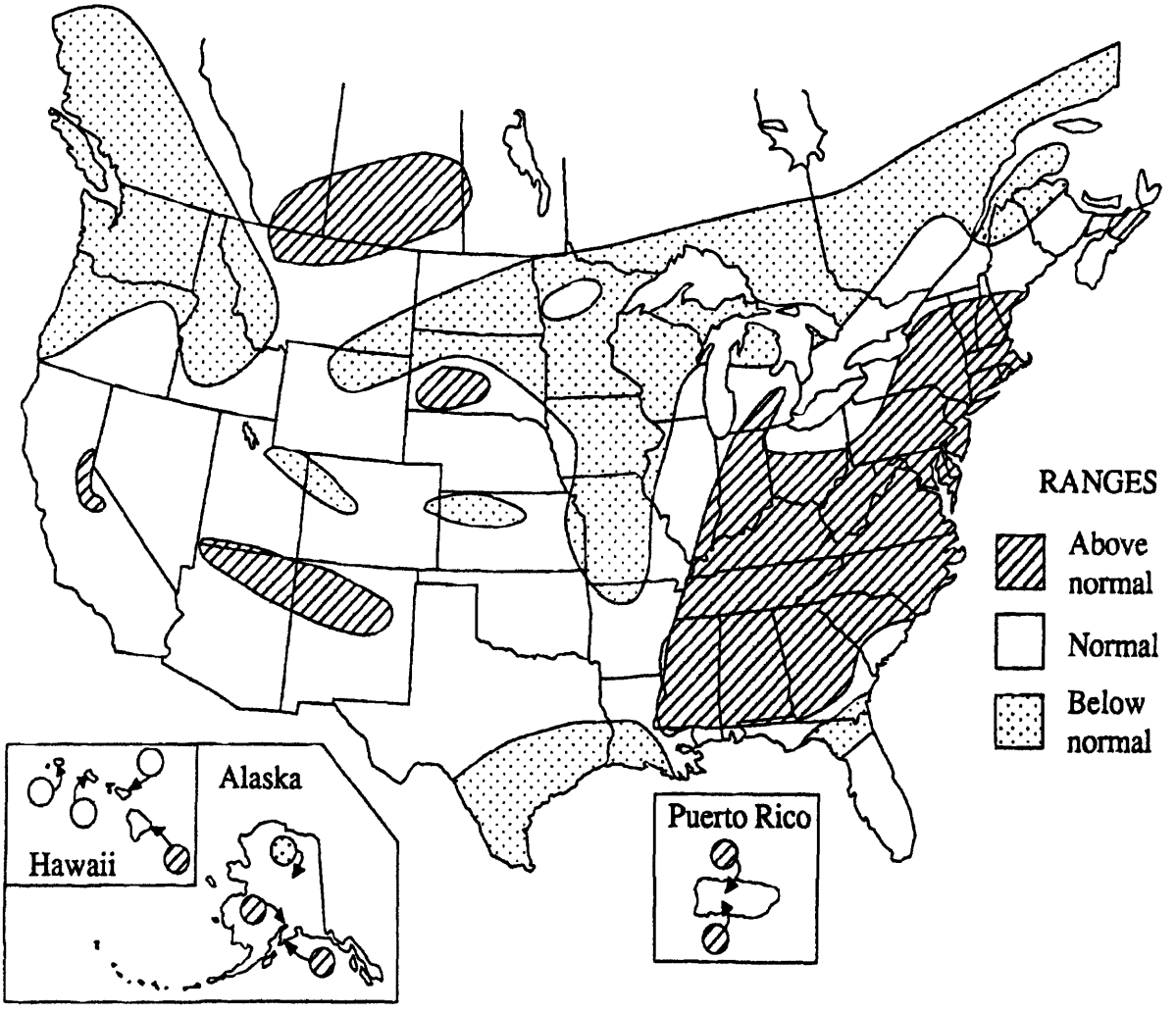


Figure 50. Streamflow during October 1989.

October 1989

Floods occurred in northeastern and north-central Georgia after heavy rains September 30 to October 1. In Florida, urban floods occurred in Melbourne (Brevard County) on October 9, and in St. Augustine (St. Johns County) on October 10. Floods in eastern Kentucky on October 17–18 caused damages estimated to be over $11 million.

Streamflow was in the normal to above-normal range at 73 percent of the 192 index stations in southern Canada, the United States, and Puerto Rico during October. Below-normal streamflow occurred in 29 percent of the area of southern Canada and the conterminous United States compared with 14 percent during September. Total flow for the 182 index stations in the conterminous United States and southern Canada was 24 percent above normal.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—was in the normal range at 21 percent above normal during October but 6 percent less than during September. The only below-normal flow was in the Columbia River.

Monthend index reservoir contents were in the below-average range at 22 of 100 reporting sites. Reservoirs with contents in the below-average range and significantly lower than last year (with maximum contents of at least 1,000,000 acre-feet) were Gouin, Quebec, Canada; International Falcon, Tex.; Lake McConaughy, Nebr.; Lake Oahe, S. Dak.; Fort Peck, Mont.; Pathfinder and associated reservoirs, Wyoming; Bear Lake, Idaho-Utah; and Lake Berryessa, Calif.

October elevations at the four master gages on the Great Lakes were in the average range on all the lakes except Lake Superior, where the level was in the below-average range. Levels declined from those for September on all of the lakes. Utah's Great Salt Lake declined to 4,204.50 feet above sea level.

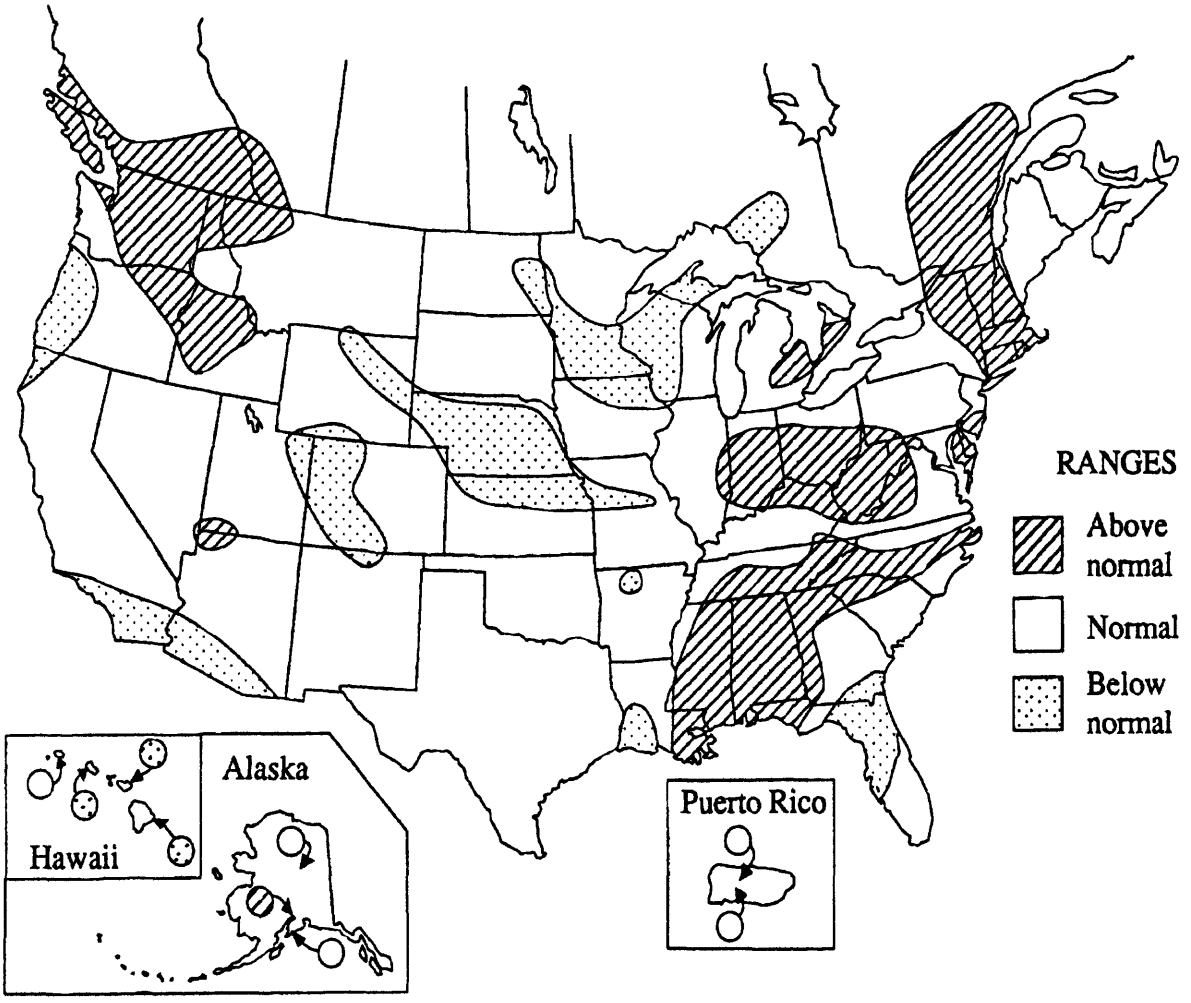


Figure 51. Streamflow during November 1989.

November 1989

Streamflow was in the normal to above-normal range at 79 percent of the 192 index stations in southern Canada, the United States, and Puerto Rico during November. Below-normal streamflow occurred in only 10 percent of the area of southern Canada and the conterminous United States during November. New November low flows occurred at index stations in Nebraska, Kansas, and Iowa. Total November flow for the 182 index stations in the conterminous United States and southern Canada was 21 percent above normal after an 8-percent increase in flow from October to November.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—was 18 percent above normal and in the normal range during November. Flows in the Columbia and St. Lawrence Rivers were above normal, and flow was normal in the Mississippi River.

Monthend index reservoir contents were in the below-average range at 33 of 100 reporting sites compared with 22 of 100 during October. Contents were in the above-average range at 45 reservoirs. Reservoirs with contents in the below-average range and significantly lower than last year were the same ones as reported in October.

November elevations at the four master gages on the Great Lakes were in the average range on all the lakes except Lake Superior, which was at the upper limit of the below-average range. Levels declined from those for October on all of the lakes. Utah's Great Salt Lake declined 0.10 foot to 4,204.40 feet above sea level on November 30.

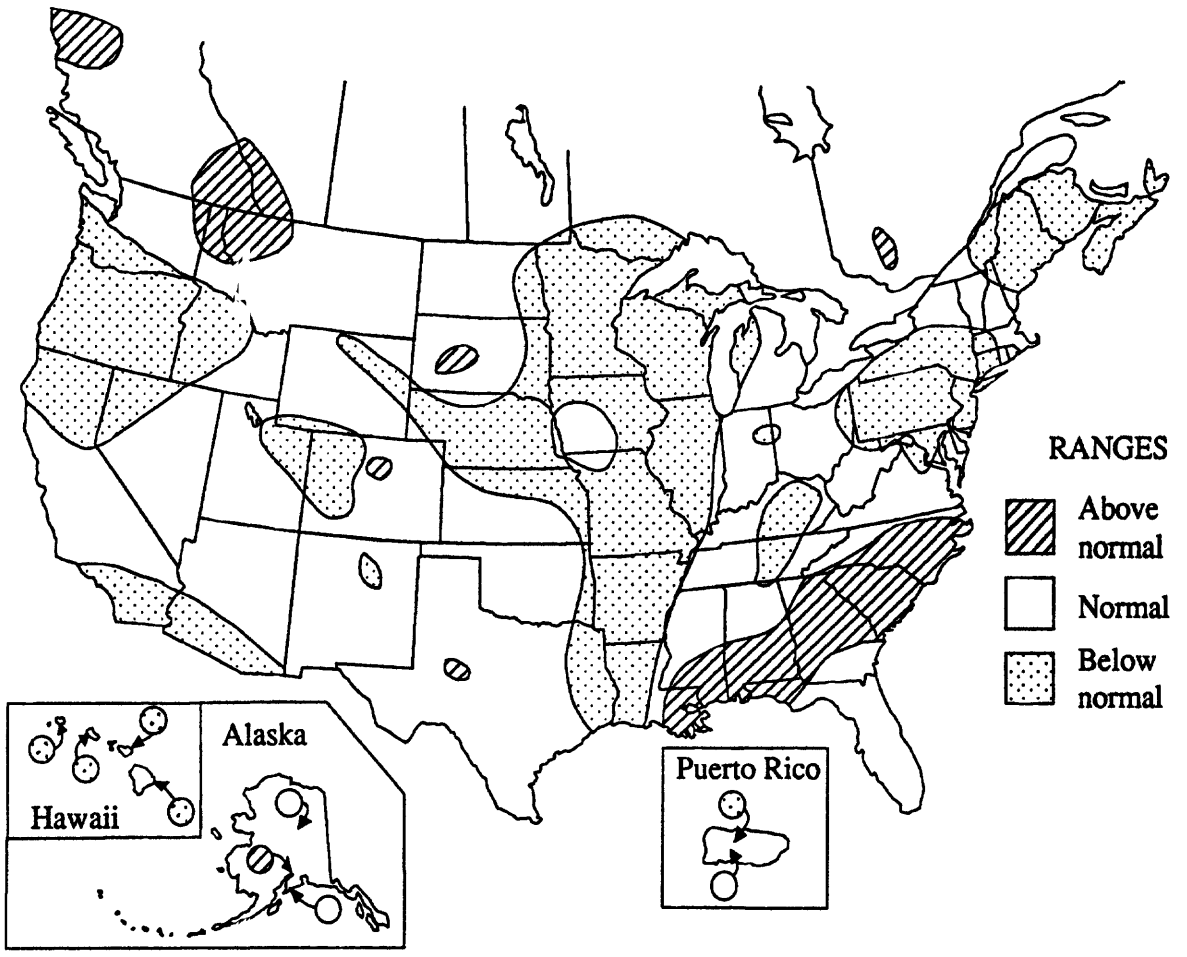


Figure 52. Streamflow during December 1989.

December 1989

Streamflow was in the normal to above-normal range at 53 percent of the 191 index stations in southern Canada, the United States, and Puerto Rico during December. Below-normal streamflow occurred in 29 percent of the area of southern Canada and the conterminous United States during December. New December lows occurred at index stations in Wisconsin, Iowa, and Nebraska. Total December flow for the 181 index stations in the conterminous United States and southern Canada was 21 percent below normal after a 19-percent decrease from November to December.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 19 percent below normal and in the normal range during December but 18 percent less than during November. Flow in all three rivers was in the normal range.

During the 1989 calendar year as a whole, streamflow was in the normal to above-normal range at 66 percent of the index stations in southern Canada, the United States, and Puerto Rico. For the Big Three rivers, the combined flow was in the normal range and about 33 percent more than for calendar year 1988 when combined flow was in the below-normal range. Individually, annual flow in the Mississippi River was 19 percent above normal and in the above-normal range, flow in the St. Lawrence River was 6 percent below normal but still in the normal range, and flow in the Columbia River was 10 percent below normal and in the below-normal range.

Monthend index reservoir contents were in the below-average range at 36 of 100 reporting sites compared with 33 of 100 for November. Lake Tahoe (California-Nevada) had no usable storage at the end of the month. Rye Patch (Nevada) and San Carlos (Arizona) had only 6 percent of maximum contents. Contents were in the above-average range at 33 reservoirs.

December elevations at the four master gages on the Great Lakes were in the average range except on Lake Superior, which persisted in the below-average range. Levels again declined on all of the lakes. Utah's Great Salt Lake remained at the same level as that for November 30.

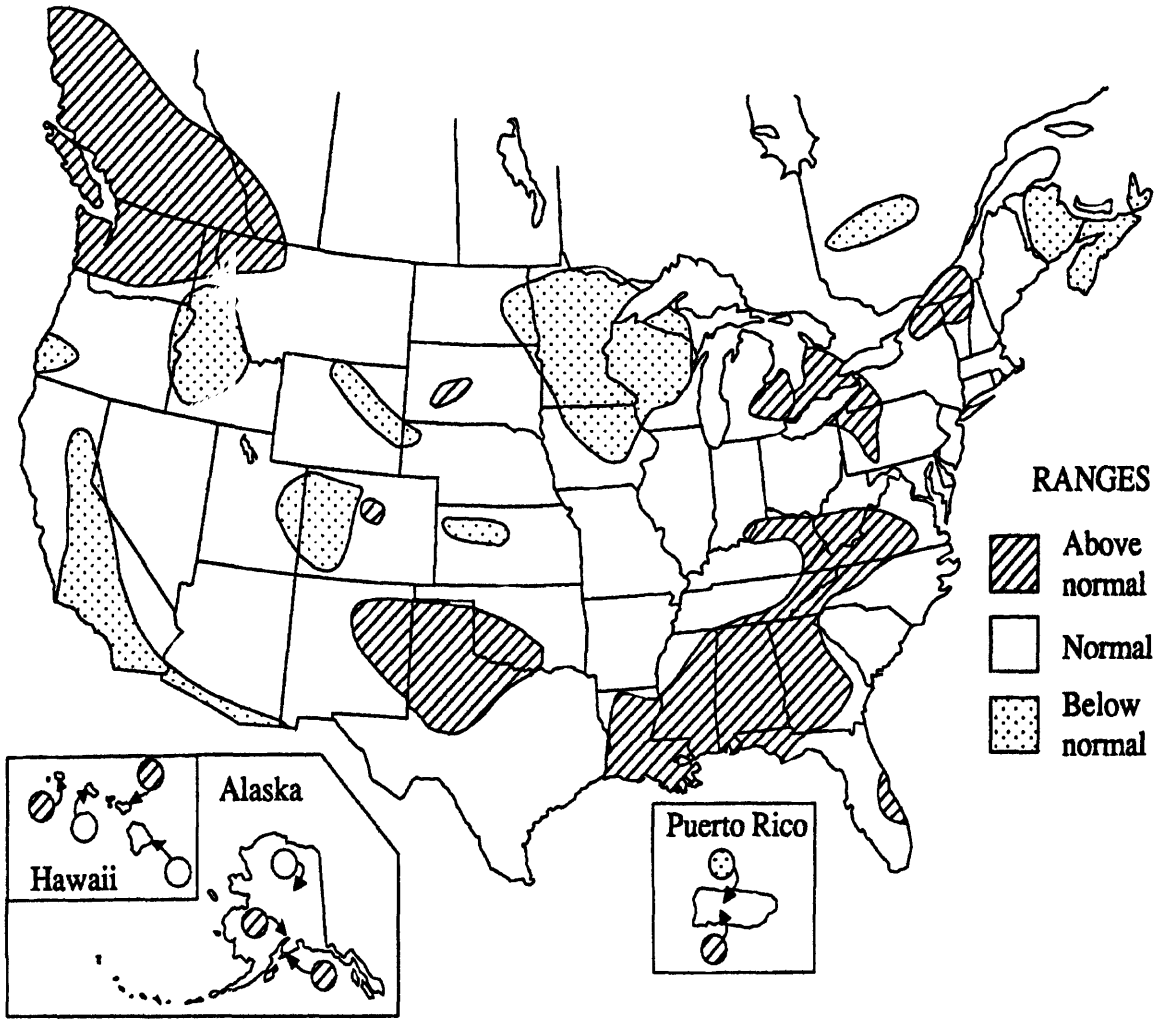


Figure 53. Streamflow during January 1990.

January 1990

Three rainstorms in early January caused flooding in an area that extends from Seattle, Wash., to Tillamook, Oreg. Interstate Highway 5 was closed because of flooding in the Chehalis-Centralia (Washington) area. A state of emergency was declared in Pierce and Lewis Counties, Wash., and in Tillamook and Clatsop Counties, Oreg. Peaks of record were exceeded at six streamflow stations, including two at which the 100-year flood was equaled, one each in Washington (Puyallup River near Electron) and Oregon (Nehalem River near Foss).

Streamflow was in the normal to above-normal range at 80 percent of the index stations in southern Canada, the United States, and Puerto Rico during January. Below-normal streamflow occurred in 11 percent of the area of southern Canada and the conterminous United States during the month. Total January 1990 flow for the index stations in the conterminous United States and southern Canada was 10 percent above normal after a 60-percent increase in flow from December to January.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—was 11 percent below normal and in the normal range during the month but 30 percent less than during December. Flow in all three rivers was in the normal range.

Monthend index reservoir contents were in the below-average range at 32 of 100 reporting sites compared with 36 of 100 during December. Most reservoirs in Canada, Nebraska, North Dakota, Wyoming, Montana, Idaho, California, Nevada, and Colorado were among those with below-average contents. Lake Tahoe had no usable storage at the end of the month, whereas Rye Patch (Nevada) and San Carlos (Arizona) maintained the 6 percent of maximum contents recorded the previous month.

January elevations at the four master gages on the Great Lakes were in the average range except on Lakes Superior and Huron, which were in the below-average range. Levels declined from those for December on all four lakes. Utah's Great Salt Lake rose 0.10 foot during the month to 4,204.50 feet above sea level.

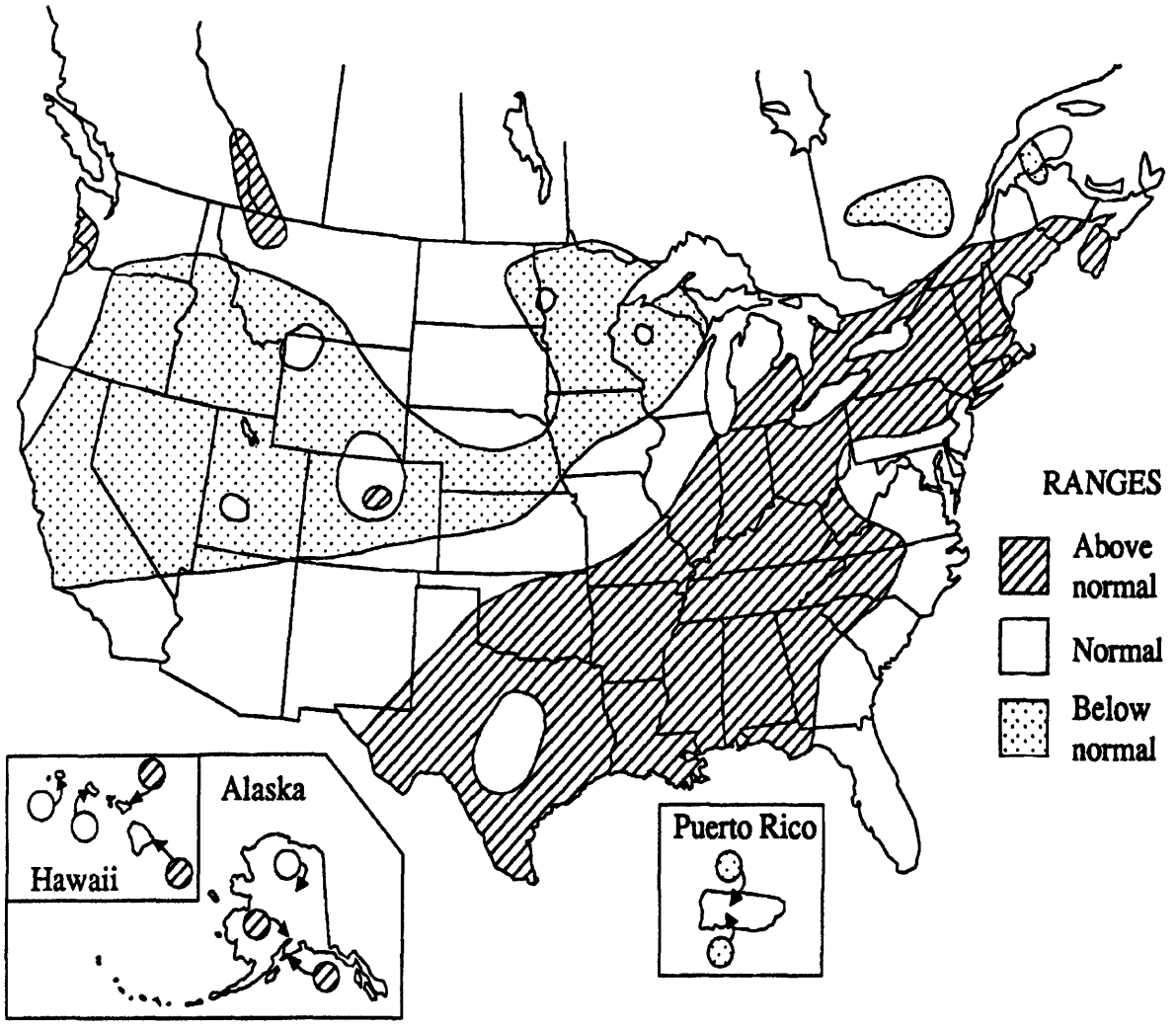


Figure 54. Streamflow during February 1990.

February 1990

Heavy rains that fell on most of the Southeastern United States during February caused flooding in many areas. The most severe floods occurred in northwestern Georgia where peak discharges at some stream-gaging stations exceeded those for both the period of record and the 100-year flood. Less severe floods occurred in Tennessee, Alabama, and Mississippi.

Streamflow was in the normal to above-normal range at 76 percent of the index stations in southern Canada, the United States, and Puerto Rico during February compared with 80 percent of the stations during January. Below-normal streamflow occurred in 23 percent of the area of southern Canada and the conterminous United States during February compared with 11 percent during January. Total February 1990 flow for the index stations in the conterminous United States and southern Canada was 51 percent above normal after a 51-percent increase in streamflow from January to February.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 41 percent above normal and in the above-normal range during February; this was 65 percent more than during January. Flow in the St. Lawrence and Mississippi Rivers was in the above-normal range, whereas flow in the Columbia River was in the below-normal range.

Monthend index reservoir contents were in the below-average range at 33 of 100 reporting sites. Contents were in the above-average range at 46 reservoirs. Lake Tahoe (California-Nevada) had no usable storage for the third consecutive month, and Rye Patch (Nevada) and San Carlos (Arizona) had less than 10 percent of maximum contents, which is a small improvement over the two previous months.

February elevations at the four master gages on the Great Lakes were in the below-average range on Lakes Superior and Huron and in the average range on Lakes Erie and Ontario. Levels declined from those for January only on Lake Superior. Utah's Great Salt Lake rose 0.10 foot to 4,204.60 feet above sea level. The lake, which declined 2.40 feet from the seasonal high of April 1–15, 1989, has now risen 0.20 foot since January 1.

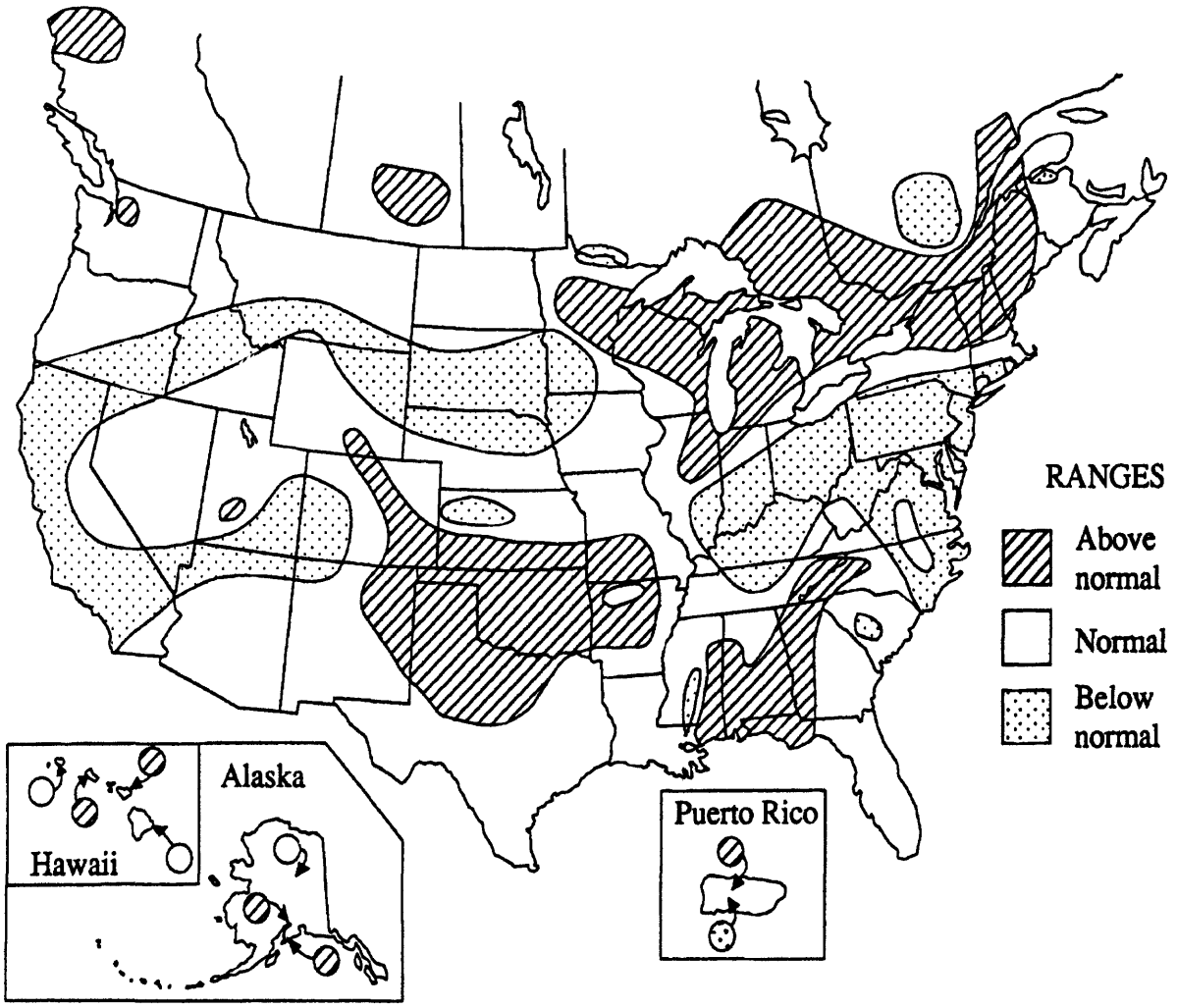


Figure 55. Streamflow during March 1990.

March 1990

Severe flooding, which was caused by 7–10 inches of rainfall, occurred in parts of Georgia, Alabama, and Florida beginning in mid-March. Recurrence intervals were highest on streams with drainage areas of less than 500 square miles. In Alabama, property damage was extensive, and 10 people drowned. About 1,200 people in northwestern Florida were evacuated from low-lying areas. The westbound lanes of the Interstate Highway 10 bridge over the Choctawhatchee River in Florida were closed to traffic because of concern about bridge scouring around the piers on the west bank of the river.

Streamflow was in the normal to above-normal range at 70 percent of the index stations in southern Canada, the United States, and Puerto Rico during March compared with 76 percent during February. Below-normal streamflow occurred in 20 percent of the area of southern Canada and the conterminous United States during February. Total flow for the index stations in the conterminous United States and southern Canada was 9 percent above normal after a 9-percent decrease from February to March.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—was 29 percent above normal and in the above-normal range during March, a 5-percent increase from February. Flow in the St. Lawrence and Columbia Rivers was in the normal range, and flow in the Mississippi River was in the above-normal range.

Monthend index reservoir contents were in the below-average range at 34 of 100 reporting sites. Contents were in the above-average range at 42 reservoirs. Lake Tahoe (California-Nevada) had no usable storage for the fourth consecutive month. Rye Patch (Nevada) had only 17 percent of maximum contents, and San Carlos (Arizona) only 5 percent of maximum contents.

March elevations at the four master gages on the Great Lakes were in the below-average range on Lake Superior, and in the average range on the other three lakes. Levels declined from those for February only on Lake Superior. Utah's Great Salt Lake rose 0.10 foot during the month and was at 4,204.70 feet above sea level on March 31.

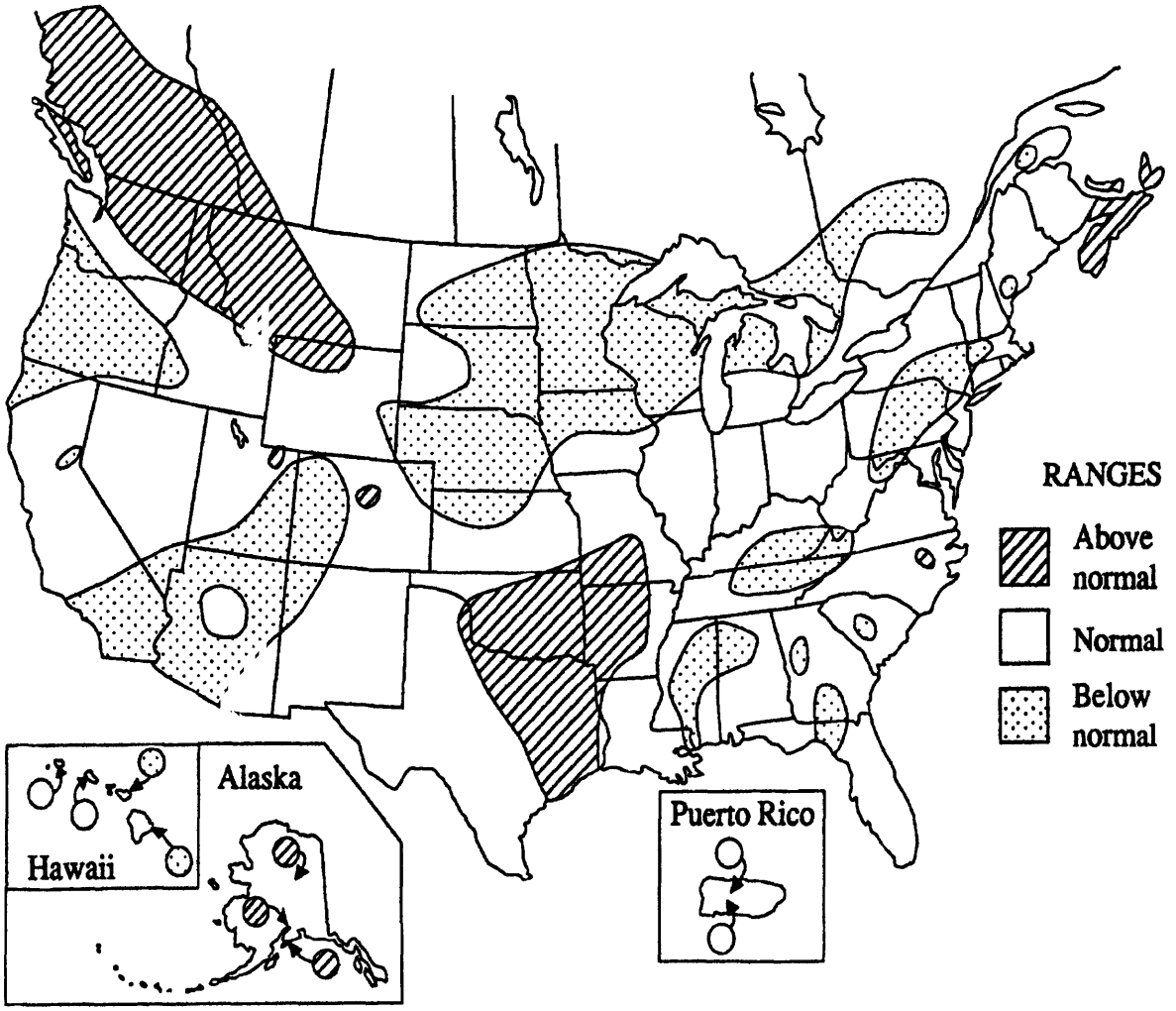


Figure 56. Streamflow during April 1990.

April 1990

Streamflow was in the normal to above-normal range at 65 percent of the index stations in southern Canada, the United States, and Puerto Rico during April compared with 70 percent of stations during March. Below-normal streamflow occurred in 24 percent of the area of southern Canada and the conterminous United States compared with 20 percent during March. Total flow for the index stations in the conterminous United States and southern Canada was 9 percent below normal after a 4-percent decrease in flow from March to April.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—was in the normal range during April, but 6 percent less than during March. Flows in all three rivers were in the normal range.

Monthend index reservoir contents were in the below-average range at 32 of 100 reporting sites compared with 34 of 100 during March. Contents were in the above-average range at 39 reservoirs compared with 42 in March. Lake Tahoe (California-Nevada) had 9 percent of usable storage at the end of the month, which breaks the 4-month trend of no usable storage. San Carlos (Arizona) had only 5 percent of maximum contents for the second consecutive month.

April elevations at the four master gages on the Great Lakes were in the below-average range on Lake Superior, and in the average range on Lakes Huron, Erie, and Ontario. Levels declined from those for March only on Lake Superior. Utah's Great Salt Lake remained at 4,204.70 feet above sea level.

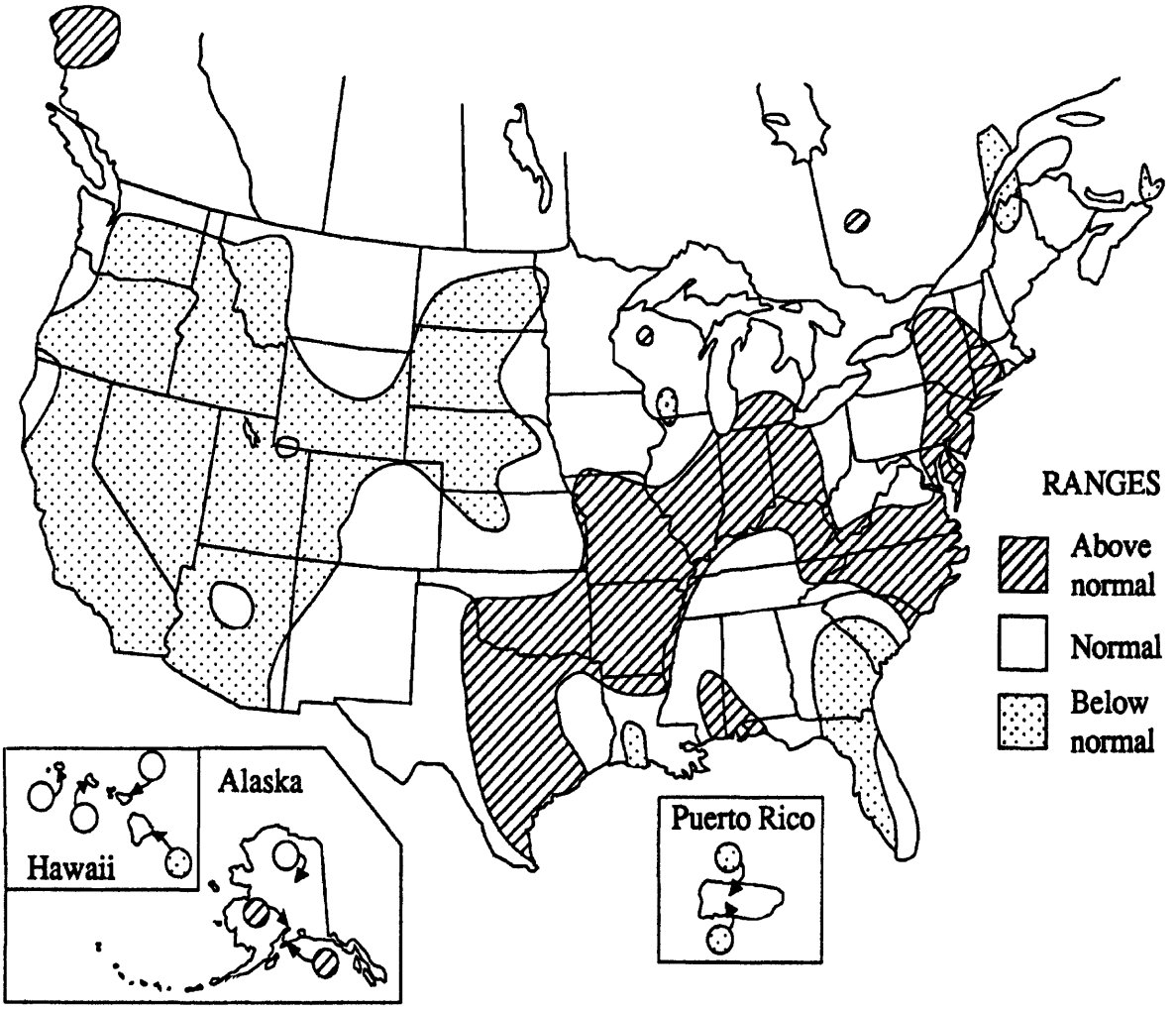


Figure 57. Streamflow during May 1990.

May 1990

Record-breaking floods caused by heavy rains occurred in Oklahoma, Arkansas, Texas, Illinois, and Iowa. The floods in Texas occurred about 1 year after the severe May and June 1989 floods in the Houston area. The heavy rains, however, fell mostly in areas where precipitation had been near average in previous months. As a result, drought conditions continued in most of the West, particularly in California, and in parts of the Southeast.

Streamflow was in the normal to above-normal range at 74 percent of the index stations in southern Canada, the United States, and Puerto Rico during May compared with 65 percent during April. Below-normal streamflow occurred in 28 percent of the area of southern Canada and the conterminous United States compared with 24 percent during April. Total May 1990 flow for the index stations in the conterminous United States and southern Canada was 15 percent above normal after a 32-percent increase in flow from April to May.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 14 percent above normal and in the normal range; this was an increase of 14 percent from April's flow. Flow in the Mississippi River was above normal, normal in the St. Lawrence, and below normal in the Columbia.

Monthend index reservoir contents were in the below-average range at 32 of 100 reporting sites; this was the same as during April. Contents were in the above-average range also at 32 reservoirs. Lake Tahoe had 11 percent of usable storage, but San Carlos in Arizona declined to only 3 percent of maximum contents.

May elevations at the four master gages on the Great Lakes were in the below-average range on Lakes Superior and Huron, and in the average range on Lakes Erie and Ontario. Levels rose from those for April on all four lakes. Utah's Great Salt Lake began its seasonal decline by falling 0.40 foot to 4,204.30 feet above sea level during the month.

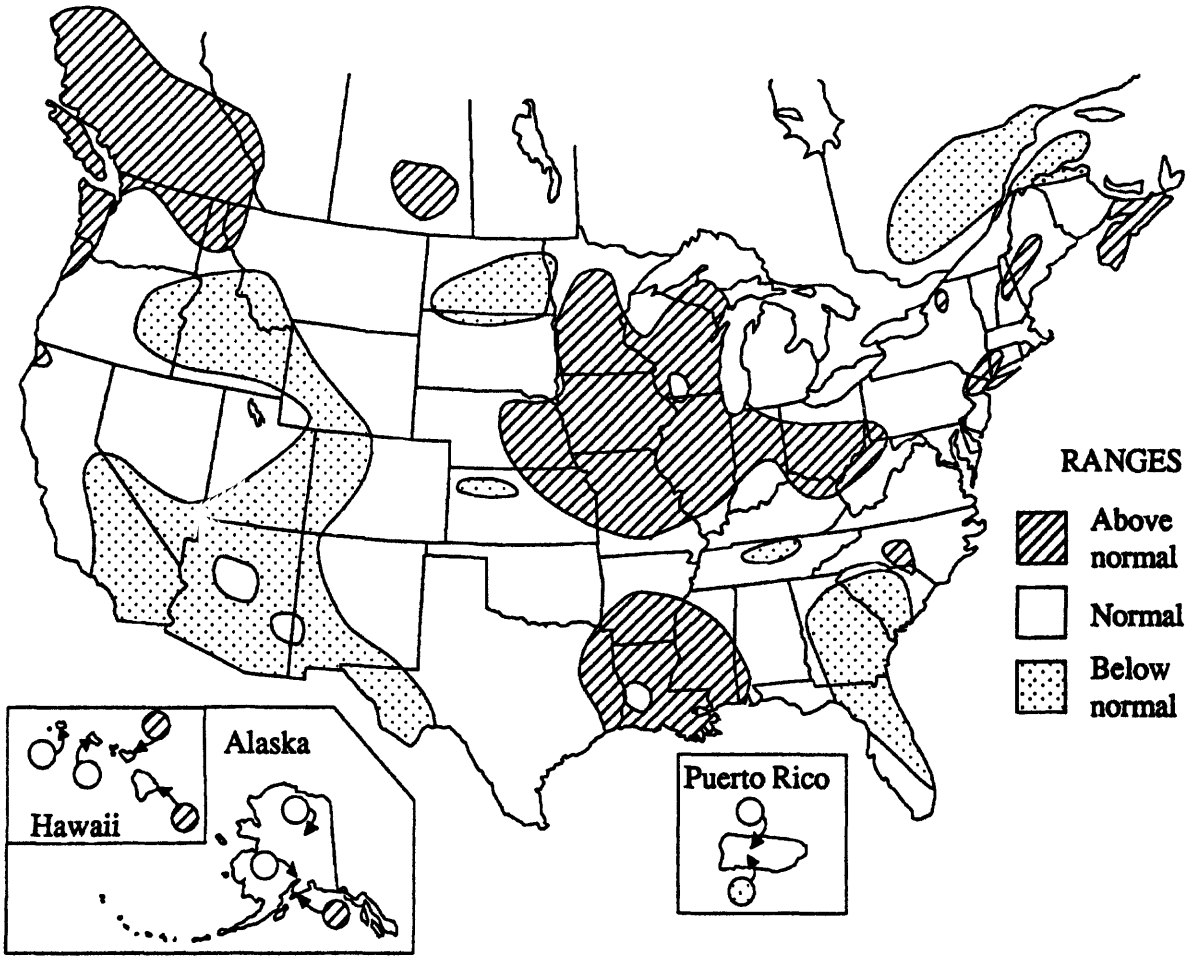


Figure 58. Streamflow during June 1990.

June 1990

Heavy rains caused severe floods in parts of Nebraska, Iowa, and Ohio. The most damaging floods occurred on Wegee and Pipe Creeks in Belmont County, Ohio, where 26 people were killed and 1,200 homes and trailers were destroyed. Peak discharges exceeded either those of record or the 100-year flood at 13 stations in the three States. Floods also occurred in other areas, including Nevada where two people were killed, but no peaks of record were reported. Because most of June's rain fell in areas that were already wet, drought conditions persisted in parts of the West and Southeast.

In Florida, water-use restrictions that were implemented by the St. Johns River Water Management District authorities were in effect in 12 counties as of May 30. Voluntary water-use restrictions have been called for in seven other counties.

Streamflow was in the normal to above-normal range at 81 percent of the index stations in southern Canada, the United States, and Puerto Rico during June compared with 74 percent of stations during May. Below-normal streamflow occurred in 19 percent of the area of southern Canada and the conterminous United States during June compared with 28 percent during May. Total flow for the index stations in the conterminous United States and southern Canada was 40 percent above normal after a 3-percent increase from May to June.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 29 percent above normal and was in the above-normal range during June, 11 percent more than during May. Flows were in the normal range in the St. Lawrence and Columbia Rivers and above normal in the Mississippi River.

Monthend index reservoir contents were in the below-average range at 39 of 100 reporting sites, including most reservoirs in Nebraska, the Dakotas, Wyoming, Idaho, Utah, Nevada, and California. In California, contents of eight of nine index reservoirs were well below monthend averages, as were Lake Sakakawea in North Dakota and Lake Oahe in South Dakota.

June elevations at the four master gages on the Great Lakes were in the below-average range on Lake Superior and in the average range on Lakes Huron, Erie, and Ontario. Levels rose from those for May on all four lakes. Utah's Great Salt Lake declined 0.30 foot to 4,204.00 feet above sea level as the lake level continued to decline seasonally.

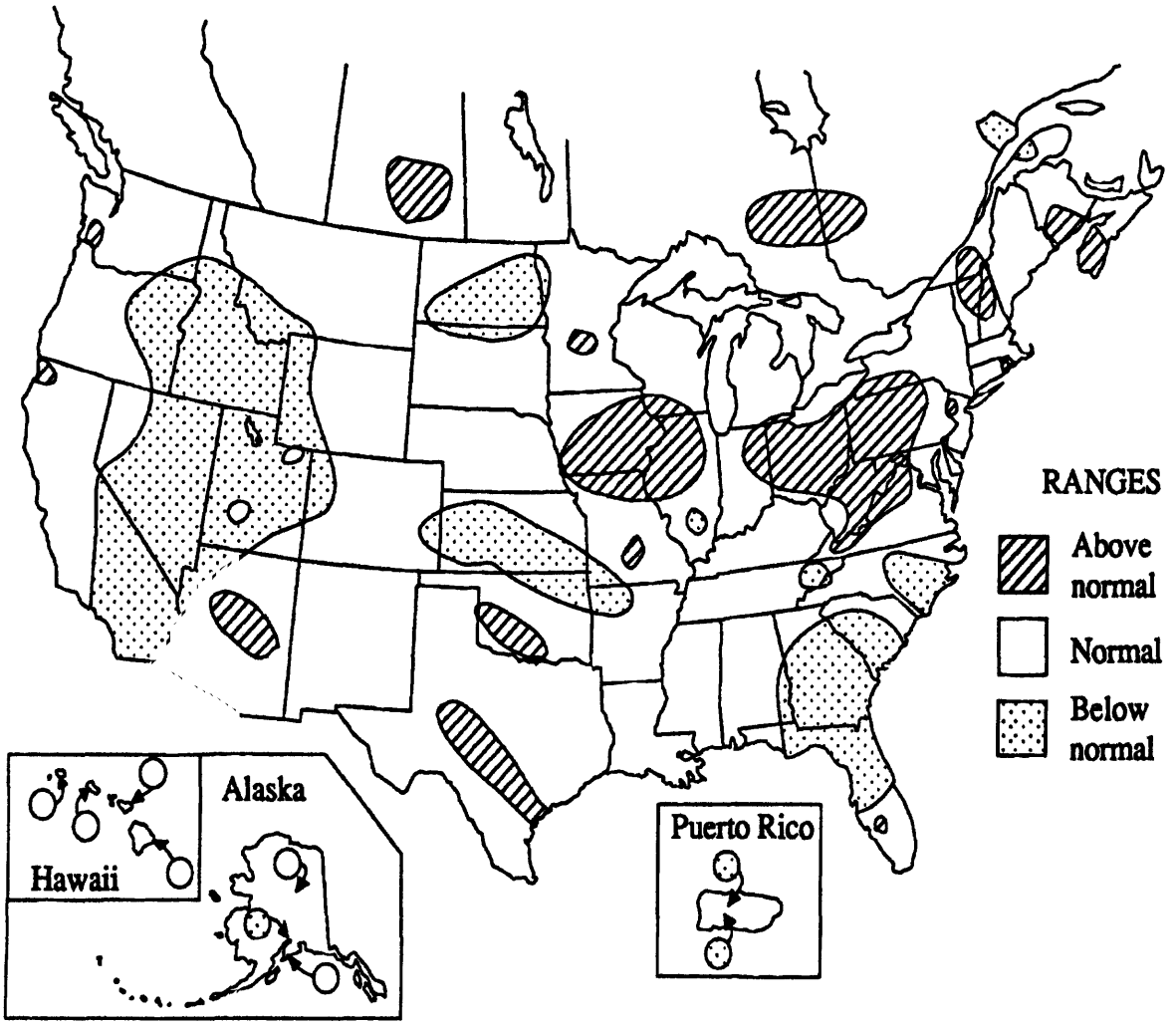


Figure 59. Streamflow during July 1990.

July 1990

On July 16, heavy rains west of Las Vegas, Nev., caused what appeared to be the highest floods in the Flamingo Wash in the last 20 years. One person was killed and two people were missing as a result of the flood. Damages are estimated to have exceeded the $2.6 million figure from the June 10, 1990, flood.

Flooding caused by heavy rains near the end of July in the Cedar River basin in the northeastern part of Iowa caused the evacuation of most of the residents of Finchford on the West Fork Cedar River. Less severe flooding occurred on the Cedar River above Waterloo.

Streamflow was in the normal to above-normal range at 80 percent of the index stations in southern Canada, the United States, and Puerto Rico during July compared with 81 percent of stations during June. Below-normal streamflow occurred in 18 percent of the area of southern Canada and the conterminous United States, compared with 19 percent during June. Total flow for the index stations in the conterminous United States and southern Canada was 23 percent above normal after a 39-percent decrease in streamflow from June to July.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 1,177,800 cubic feet per second, which was 22 percent above normal and in the above-normal range but 39 percent less than during June. Flows in the St. Lawrence and Columbia Rivers were in the normal range and in the above-normal range in the Mississippi River.

Monthend index reservoir contents were in the below-average range at 36 of 100 reporting sites (all west of the Mississippi River) compared with 39 of 100 during June. Contents were in the above-average range at 26 reservoirs.

Elevations at the four master gages on the Great Lakes were in the below-average range on Lake Superior and in the average range on Lakes Huron, Erie, and Ontario. Levels rose from those for June on Lakes Superior and Huron and declined from those for June on Lakes Erie and Ontario. Utah's Great Salt Lake declined 0.20 foot to 4,203.80 feet above sea level as the lake level continued to decline seasonally.

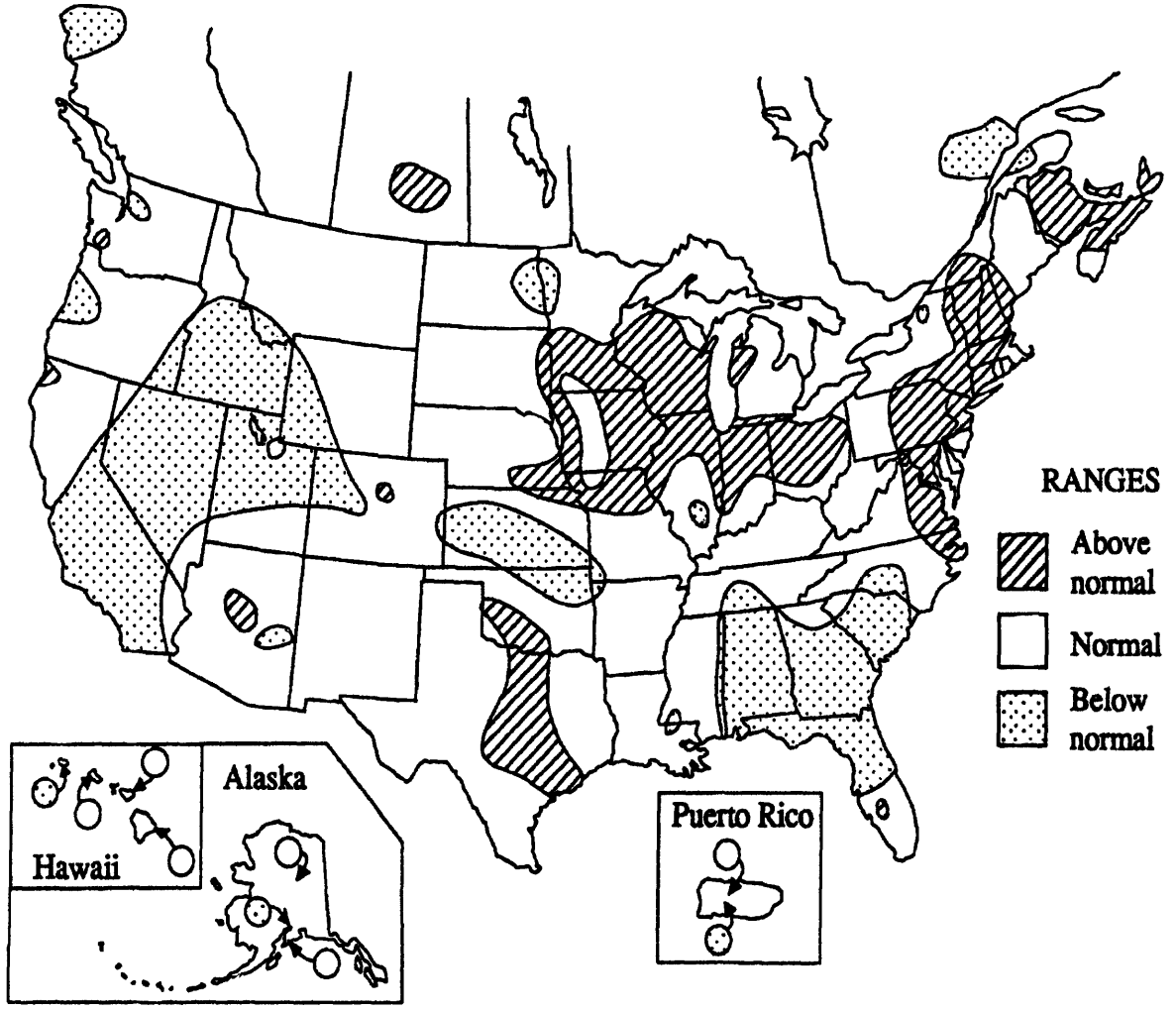


Figure 60. Streamflow during August 1990.

August 1990

Heavy rains on August 24–25 caused flooding in the Wapsipinicon and Turkey River basins in northeastern Iowa. As a result, 10 counties were declared Federal disaster areas.

Streamflow was in the normal to above-normal range at 77 percent of the index stations in southern Canada, the United States, and Puerto Rico during August compared with 80 percent of stations during July. Below-normal streamflow occurred in 18 percent of the area of southern Canada and the conterminous United States, which was the same as during July. Total August flow of 1,552,800 cubic feet per second for the index stations in the conterminous United States and southern Canada was 18 percent above normal in spite of a 30-percent decrease in streamflow from July to August.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 842,200 cubic feet per second, which was 14 percent above normal and in the above-normal range but 28 percent less than during July. Flows in the St. Lawrence and Columbia Rivers were in the normal range. Flow in the Mississippi River was above normal.

Monthend index reservoir contents were in the below-average range at 32 of 100 reporting sites (all west of the Mississippi River) compared with 36 of 100 during July. Contents were in the above-average range at 35 reservoirs compared with 26 last month.

Elevations at the four master gages on the Great Lakes were in the below-average range on Lake Superior and in the average range on Lakes Huron, Erie, and Ontario. Only the level on Lake Superior rose this month; those for the other three lakes declined. Utah's Great Salt Lake declined 0.50 foot to 4,203.00 feet above sea level as the lake level continued to decline seasonally.

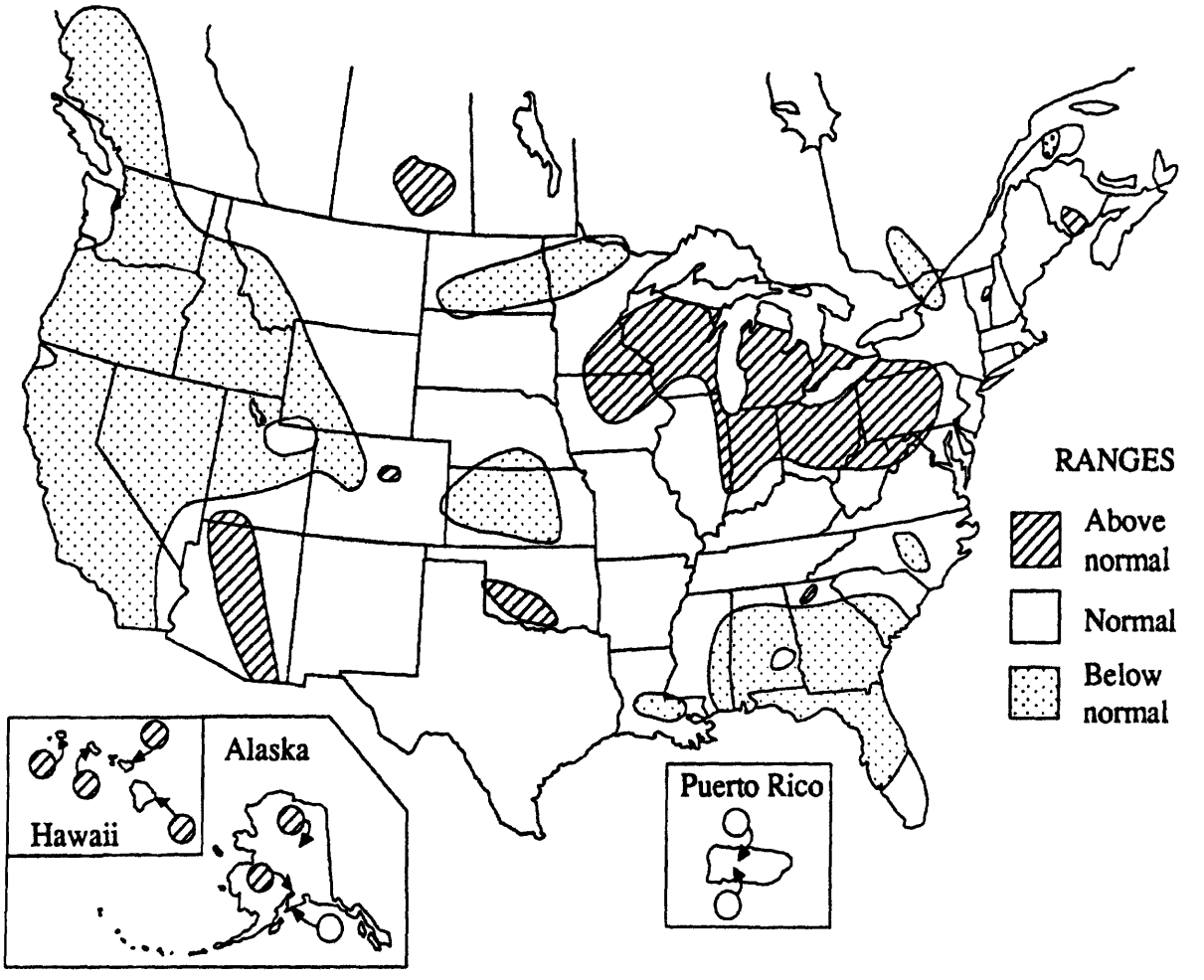


Figure 61. Streamflow during September 1990.

September 1990

Streamflow was in the normal to above-normal range at 74 percent of the index stations in southern Canada, the United States, and Puerto Rico during September compared with 77 percent of stations during August. Below-normal streamflow occurred in 18 percent of the area of the conterminous United States and southern Canada during September compared with 18 percent during August. Total September flow of 1,279,600 cubic feet per second for the index stations in the conterminous United States and southern Canada was 13 percent above normal in spite of an 18-percent decrease in streamflow from August to September.

The combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 723,100 cubic feet per second, which was 13 percent above normal and in the normal range during September but 14 percent less than during August. The combined flow of the three rivers had been in the above-normal range from June through August. Individually, flow in the Mississippi River was above normal for the fifth consecutive month, flow in the St. Lawrence River was normal for the seventh consecutive month, and flow in the Columbia River was below normal after three consecutive months in the normal range.

Monthend index reservoir contents were in the below-average range at 40 of 100 reporting sites (all west of the Mississippi River) compared with 32 during August. Contents were in the above-average range at 34 reservoirs compared with 35 last month.

September elevations at the four master gages on the Great Lakes were in the below-average range on Lake Superior and in the average range on Lakes Huron, Erie, and Ontario. The level of Lake Ontario, however, was only 0.01 foot higher than the below-average range. Levels on all four lakes have been in the same ranges for 4 months. Only the level on Lake Superior rose; levels on the other Great Lakes declined. Utah's Great Salt Lake declined 0.40 foot to 4,202.60 feet above sea level as the lake level continued to decline seasonally.

For the 1990 water year as a whole, the combined flow of the three largest rivers in the United States—the Mississippi, St. Lawrence, and Columbia—averaged 1,162,000 cubic feet per second, which was 29 percent above normal and in the normal range. The 1990 combined flow was also about 33 percent more than for water year 1989, for which the average flow was in the below-normal range. Annual flow in the Mississippi River was 25 percent above normal and in the above-normal range. Flow in the St. Lawrence River was 1 percent below normal and in the normal range. Flow in the Columbia River was 7 percent below normal and in the below-normal range.

Streamflow was in the normal to above-normal range at 76 percent of the index stations in southern Canada, the United States, and Puerto Rico. In the five areas affected by drought during 1988–89, streamflow was below normal in California, the Pacific Northwest, and the Southeast and above normal in the Northern Great Plains and the Western Great Lakes.