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Precipitation in the Northern Plains, September 1996 through April 1997

Circular 1185–A

U.S. Department of the Interior
U.S. Geological Survey

Cover photograph: Farmstead and stranded car in rural Bath, South Dakota, January 22, 1997. Photograph by John Davis, Aberdeen American News.

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By Kathleen M. Macek-Rowland, Michael J. Burr, *and* Gregory B. Mitton

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FOREWORD

Floods are a common occurrence on all major streams and rivers of the United States. Many floods are just a minor nuisance when low-lying fields and roads are inundated; however, major floods that result in loss of life and extensive damage occur on a number of the Nation's rivers each year. Knowledge of the flood characteristics of the Nation's streams and rivers is important for preventing the loss of life and mitigating the ever-increasing costs of flood damages.

The U.S. Geological Survey (USGS) plays a critical role in supporting flood mitigation, flood forecasting, and response and recovery efforts during and after floods. The 18,000 streamflow-gaging stations that have been operated by the USGS at some time since 1889 provided much of the base information for assessing flood risk and for designing infrastructure such as dams and levees that minimize flood damages. The streamflow-gaging stations also provide data that are critical to effective management of the Nation's water resources.

The USGS has a current network of 7,000 streamflow-gaging stations. Of these stations, 4,200 are used to provide real-time streamflow data 24 hours a day directly to the public and many organizations, including the National Weather Service, U.S. Army Corps of Engineers, the Bureau of Reclamation, and the Federal Emergency Management Agency. These and other Federal, State, and local agencies use the river-stage data to forecast river conditions, to issue flood warnings and river-conditions statements, to plan flood response and recovery operations, and to plan reservoir releases or water withdrawals. With the advent of the internet, USGS data, real-time and historical, are being disseminated to an even broader range of interested users worldwide.

This report, "Precipitation in the Northern Plains, September 1996 through April 1997," is an example of the type of information produced by the USGS streamflow-gaging network. The report is the first in a two-part series of reports that document the 1997 spring floods in the northern plains. The report describes precipitation and climatic conditions before and during the floods. U.S. Geological Survey Circular 1185–B, "Peak Discharges and Flow Volumes for Streams in the Northern Plains, 1996–97," is the second in the two-part series of reports and presents the magnitude and duration of discharges and volumes, describes the effects of reservoir storage on flood peaks, and summarizes the effects of the 1997 spring floods on the people of the northern plains.

Robert M. Hirsch

Robert M. Hirsch
Chief Hydrologist

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CONVERSION FACTORS

Multiply	By	To obtain
inch	2.54	centimeter
mile	1.609	kilometer

Degree Fahrenheit (°F) may be converted to degree Celsius (°C) by using the following equation:

$$°C = 5/9\ (°F - 32)$$

Precipitation in the Northern Plains, September 1996 through April 1997

By Kathleen M. Macek-Rowland, Michael J. Burr, *and* Gregory B. Mitton

Abstract

Excessive precipitation during the fall and winter of 1996–97 produced record floods that devastated many communities along rivers and streams in parts of the Red River of the North, Missouri River, and upper Mississippi River Basins. Above-normal snowfall throughout the winter of 1996–97, combined with excessive precipitation during the fall of 1996 and additional moisture from a spring blizzard on April 5–6, 1997, caused the worst flooding in several areas in more than 100 years.

During September 1996, monthly precipitation at 6 of 10 weather stations in the northern plains was above normal. During October 1996, monthly precipitation at 7 of the 10 stations was above normal. Precipitation was more than 200 percent of normal at three stations in September and two stations in October.

During November 1996 through March 1997, no less than 3 and as many as 9 of the 10 weather stations received above-normal precipitation in any 1 month. Precipitation was more than 200 percent of normal at many of the stations and 376 percent of normal at one station. This excessive precipitation resulted, in part, from record snowfalls at 4 of the 10 weather stations in the region. At 3 other weather stations, snowfall totals ranked in the top 10 highest snowfalls for the period of record at that station.

The above-normal fall precipitation, frozen moist soils, and record snowfall over most of the northern plains resulted in peak streamflows on many rivers and streams in central and eastern North Dakota, western Minnesota, and central and eastern South Dakota. A storm on April 5–6, 1997, aggravated already serious flooding. Floodwaters and severe weather forced thousands of people to flee their homes, some permanently, and caused more than $2 billion in damages to the region. For the people of the northern plains, the winter of 1996–97, combined with the 1997 spring floods, was one of the worst natural disasters in recent history.

INTRODUCTION

Flooding in the northern plains usually is caused by spring snowmelt. The severity of the flooding is affected by (1) high soil-moisture levels produced by substantial precipitation in the fall; (2) above-normal snowfall in the winter; (3) frozen moist soils that prohibit infiltration of moisture; (4) a late spring thaw; (5) above-normal precipitation during the spring thaw; and (6) ice jams (temporary dams of ice) on rivers and streams. Many of these conditions were present in the northern plains before and during the 1997 spring floods. This report, one of two reports that document the spring floods in the northern plains, describes precipitation during September 1996 through April 1997 in parts of the Red River of the North, upper Mississippi River, and Missouri River Basins[1] (fig. 1). These basins are located in central and eastern North Dakota, western Minnesota, and central and eastern South Dakota.

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[1]U.S. Geological Survey Circular 1185–B, "Peak Discharges and Flow Volumes for Streams in the Northern Plains, 1996–97," by Kathleen M. Macek-Rowland, Michael J. Burr, and Gregory B. Mitton, describes peak discharges and flow volumes for streams in parts of the Red River of the North, upper Mississippi River, and Missouri River Basins.

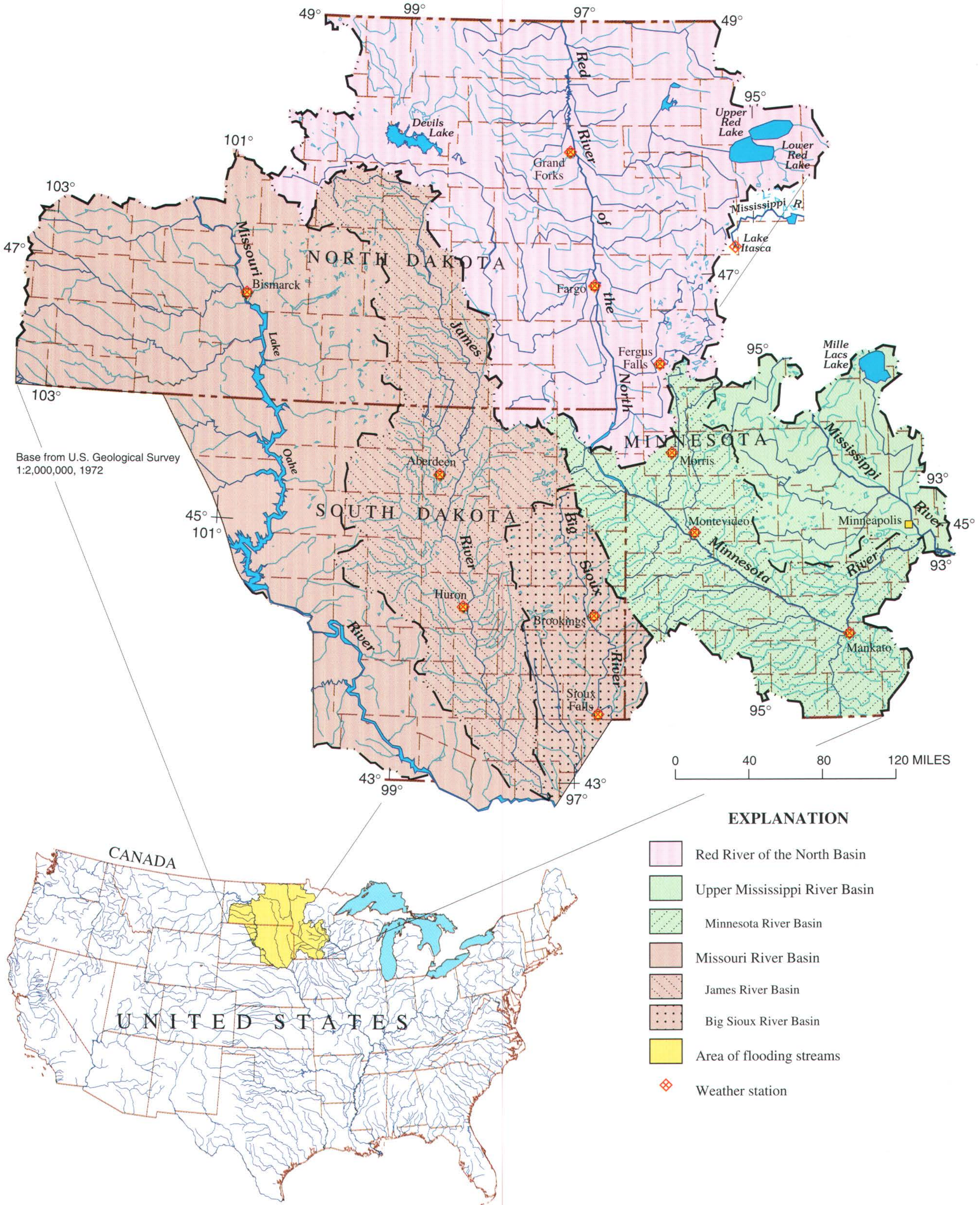
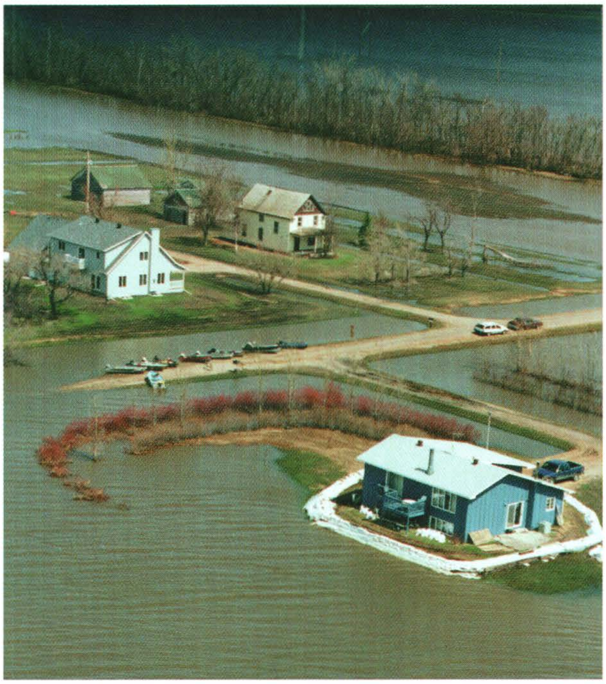


Figure 1. General area of flooding streams, spring 1997, and locations of selected weather stations.

In the northern plains, precipitation during September and October 1996 occurred as rain, and precipitation during November 1996 through April 1997 occurred as snow during several winter storms or blizzards. Snowfall totals in many areas were 200 to 300 percent above normal for the winter. The above-normal snowfall closed schools and businesses and blocked major roads several times throughout the winter. The accumulated snowfall, combined with excessive precipitation during the fall of 1996 and additional moisture from a spring blizzard on April 5–6, 1997, caused the worst flooding in several areas in more than 100 years. The floodwaters and severe weather forced thousands of people to flee their homes, some permanently, and caused more than $2 billion in damages to the region.

This report provides a general overview of the unusually excessive precipitation that occurred during the fall and winter of 1996–97. A general overview of precipitation during the 8 months from September 1996 through April 1997 is presented along with an analysis of monthly precipitation at 10 weather stations in the flood-affected region. Weather patterns associated with three specific snowstorm systems and the resulting snowfall totals are shown as examples of storms that occurred throughout the region during those 8 months.

The U.S. Geological Survey, one of the principal Federal agencies responsible for the collection and interpretation of water-resources data, works with other Federal, State, and local agencies to ensure the data are made available in an accurate and timely manner. This report represents the combined efforts of U.S. Geological Survey personnel and individuals from other agencies, particularly the National Weather Service and State climatology offices.



Flooding in eastern North Dakota, April 1997. (Photograph from Rural Electric Cooperative and Rural Telephone Cooperative Magazine, North Dakota.)

GENERAL CLIMATOLOGY

North Dakota, Minnesota, and South Dakota have a typical continental climate characterized by warm to hot summers and very cold winters. The climatic conditions across the northern plains are caused by three main types of air masses that can affect the region during every season of the year. These air masses are a continental polar (dry) air mass from the north, a maritime polar (Pacific Ocean) air mass from the northwest, and a tropical air mass that is called continental tropical (dry) if it originates from the southwest or maritime tropical (moist) if it originates from the southeast (Gulf of Mexico). The juxtaposition of these air masses over the region determines the amount and location of precipitation occurring at any given time (U.S. Geological Survey, 1991).

During the summer, precipitation is caused by thunderstorms that develop when warm, moist air that originates in the Pacific Ocean or Gulf of Mexico contacts continental polar air masses moving across the region. The thunderstorms form when warm, moist, unstable air near the ground surface meets colder air aloft. Precipitation in the region can be enhanced when the moisture-laden air masses moving across the continent are modified to include moisture recycled through the land-vegetation-air interface.

During the winter, snowfall occurs when continental polar air masses that usually have low temperatures and little moisture move south from Canada into the northern plains and meet maritime polar or tropical air masses that bear moisture. The results are mid-latitude frontal systems that usually provide precipitation over large areas for an extended period of time. Generally, excessive snowfall occurs when the frontal systems moving eastward stall over the region and continue to receive moisture from maritime tropical air masses moving northward.

PRECIPITATION

Annual precipitation in the northern plains in the area of flooded streams averages about 13 inches in the west and about 26 inches in the east. About 65 to 75 percent of the precipitation falls during the growing season, April through September. If successive periods of normal to much-above-normal precipitation occur, soils become nearly saturated, and numerous potholes, sloughs, and small lakes in the region fill and retain high water levels. Normal to much-above-normal precipitation occurred throughout the northern plains from 1993 to the fall of 1996 (Michael Gillispie, National Weather Service, written commun., 1997; Jim Zandlo, Minnesota State Climatologist, written commun., 1997; Tara Williams-Sether, U.S. Geological Survey, written commun., 1998). Thus, when additional moisture was added to the water-laden systems in the fall and winter of 1996–97, conditions were set for the 1997 spring floods.

Monthly precipitation at 10 weather stations in the northern plains during September 1996 through April 1997 and 30-year precipitation normals for September through April 1961–90 are given in table 1 and shown in figure 2. The precipitation patterns at the stations—Bismarck, Fargo, and Grand Forks, N. Dak.; Fergus Falls, Mankato, and Montevideo, Minn.; and Aberdeen, Brookings, Huron, and Sioux Falls, S. Dak.—are representative of those throughout the flood-affected region.

Fall Precipitation (September through October 1996)

During September through October 1996, precipitation in the flood-affected region generally was between 4 and 8 inches; however, precipitation in east-central South Dakota was more than 10 inches (fig. 3). Most of the region received between 100 and 300 percent of the 30-year precipitation normals for September through October 1961–90 (fig. 4), and single-day totals at many of the weather stations nearly equaled or exceeded the monthly normals for 1961–90.

During September 1996, monthly precipitation ranged from 87 to 286 percent of normal, and precipitation at 6 of the 10 weather stations was above normal (table 1). Many stations had single-day precipitation totals that were more than one-half of the monthly normal for 1961–90 at those stations. The single-day total at Mankato, Minn., was more than 1.5 times the monthly normal.

Station	Date	Single-day precipitation total (inches)	Percent of monthly normal
Bismarck, N. Dak.	09/19/96	1.21	81
Fargo, N. Dak.	09/01/96	1.07	53
Fergus Falls, Minn.	09/07/96	1.62	67
Mankato, Minn.	09/03/96	5.44	177
Aberdeen, S. Dak.	09/19/96	1.41	76
Huron, S. Dak.	09/19/96	1.28	74

During October 1996, monthly precipitation ranged from 92 to 317 percent of normal, and precipitation at 7 of the 10 weather stations was above normal (table 1). Many stations had single-day precipitation totals that were more than one-half of the monthly normal for 1961–90 at those stations.

Station	Date	Single-day precipitation total (inches)	Percent of monthly normal
Bismarck, N. Dak.	10/26/96	1.01	112
Fargo, N. Dak.[1]	10/30/96	1.00	--
Fergus Falls, Minn.	10/30/96	1.00	57
Montevideo, Minn.	10/17/96	1.70	90
Aberdeen, S. Dak.	10/26/96	1.37	122
	10/29/96	1.71	153
Brookings, S. Dak.	10/17/96	1.56	94
Huron, S. Dak.	10/29/96	1.28	87

[1]Fargo probably received more than 1.00 inch of precipitation on October 30, 1996, but, because of missing data, the reported value for that date is substantially lower than the value for weather stations in the surrounding area. Therefore, a corrected daily total for Fargo was derived from an average total based on daily totals at all of the weather stations within Fargo's climatological division.

Table 1. Monthly precipitation at 10 weather stations in the northern plains during September 1996 through April 1997 and 30-year precipitation normals for September through April 1961–90

[Data from Owenby and Ezell, 1992a, 1992b, 1992c, and U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Environmental Satellite, Data and Information Service, 1996–97a, 1996–97b, 1996–97c; bold values indicate normal precipitation was exceeded]

	Bismarck, North Dakota	Fargo, North Dakota	Grand Forks, North Dakota	Fergus Falls, Minnesota	Mankato, Minnesota	Montevideo, Minnesota	Aberdeen, South Dakota	Brookings, South Dakota	Huron, South Dakota	Sioux Falls, South Dakota
September										
Monthly precipitation (inches)	**2.80**	**3.18**	1.94	**3.07**	**6.93**	2.47	**5.32**	2.61	**3.69**	2.82
Normal (inches)	1.49	1.99	2.24	2.42	3.07	2.68	1.86	2.64	1.72	3.02
Percent of normal	**188**	**160**	87	**127**	**226**	92	**286**	99	**215**	93
October										
Monthly precipitation (inches)	**1.73**	[1]**1.86**	1.26	**2.97**	2.24	**3.32**	**3.55**	**2.75**	**3.36**	1.63
Normal (inches)	.90	1.68	1.29	1.74	2.28	1.89	1.12	1.66	1.47	1.78
Percent of normal	**192**	**111**	98	**171**	98	**176**	**317**	**166**	**229**	92
November										
Monthly precipitation (inches)	**1.84**	[1]**1.53**	**1.80**	[1]**2.20**	**4.24**	**2.27**	**1.40**	**1.41**	.25	**2.91**
Normal (inches)	.49	.73	.65	.89	1.55	1.34	.59	.81	.72	1.09
Percent of normal	**376**	**210**	**277**	**247**	**274**	**169**	**237**	**174**	35	**267**
December										
Monthly precipitation (inches)	**.68**	**.69**	**1.32**	**.99**	**1.50**	.66	**.87**	.29	.26	**.78**
Normal (inches)	.51	.65	.64	.66	1.15	.88	.41	.33	.47	.70
Percent of normal	**133**	**106**	**206**	**150**	**130**	75	**212**	88	55	**111**
January										
Monthly precipitation (inches)	**.84**	.53	.60	[1]**2.21**	**1.59**	**1.41**	**1.34**	**.90**	**.93**	.41
Normal (inches)	.45	.67	.72	.73	.90	.98	.37	.32	.41	.51
Percent of normal	**187**	79	83	**302**	**177**	**144**	**362**	**281**	**227**	80
February										
Monthly precipitation (inches)	**.59**	**.59**	.30	**.80**	.24	.20	**.88**	**.56**	.50	**1.39**
Normal (inches)	.43	.45	.49	.54	.79	1.16	.47	.42	.68	.64
Percent of normal	**137**	**131**	61	**148**	30	17	**187**	**133**	74	**217**

Table 1. Monthly precipitation at 10 weather stations in the northern plains during September 1996 through April 1997 and 30-year precipitation normals for September through April 1961–90—Continued

[Data from Owenby and Ezell, 1992a, 1992b, 1992c, and U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Environmental Satellite, Data and Information Service, 1996–97a, 1996–97b, 1996–97c; bold values indicate normal precipitation was exceeded]

	Bismarck, North Dakota	Fargo, North Dakota	Grand Forks, North Dakota	Fergus Falls, Minnesota	Mankato, Minnesota	Montevideo, Minnesota	Aberdeen, South Dakota	Brookings, South Dakota	Huron, South Dakota	Sioux Falls, South Dakota
March										
Monthly precipitation (inches)	**.97**	**1.89**	[2].87	[1]**1.42**	.97	1.21	.79	.67	.16	.23
Normal (inches)	.77	1.06	.94	1.13	1.95	1.64	1.34	1.24	1.66	1.64
Percent of normal	**126**	**178**	93	**126**	50	74	59	54	10	14
November through March										
Monthly precipitation (inches)	**4.92**	**5.23**	**4.89**	**7.62**	**8.54**	5.75	**5.28**	**3.83**	2.11	**5.72**
Normal (inches)	2.65	3.56	3.44	3.95	6.34	6.00	3.18	3.12	3.94	4.58
Percent of normal	**185**	**147**	**142**	**193**	**135**	96	**166**	**123**	53	**125**
April										
Monthly precipitation (inches)	**3.26**	**2.14**	**1.64**	**2.90**	1.58	**2.52**	**2.01**	**2.14**	**2.70**	2.43
Normal (inches)	1.67	1.82	1.35	2.12	2.79	2.39	1.95	2.07	2.09	2.52
Percent of normal	**195**	**118**	**121**	**137**	57	**105**	**103**	**103**	**129**	96
September through April										
Monthly precipitation (inches)	**12.71**	**12.41**	**9.73**	**16.56**	**19.29**	**14.06**	**16.16**	**11.33**	**11.85**	**12.60**
Normal (inches)	6.71	9.05	8.32	10.23	14.48	12.96	8.11	9.49	9.22	11.90
Percent of normal	189	137	117	162	133	108	199	119	129	106

[1]Average for all stations within climatological division (excluding those stations with missing data).

[2]Value from University of North Dakota weather station.

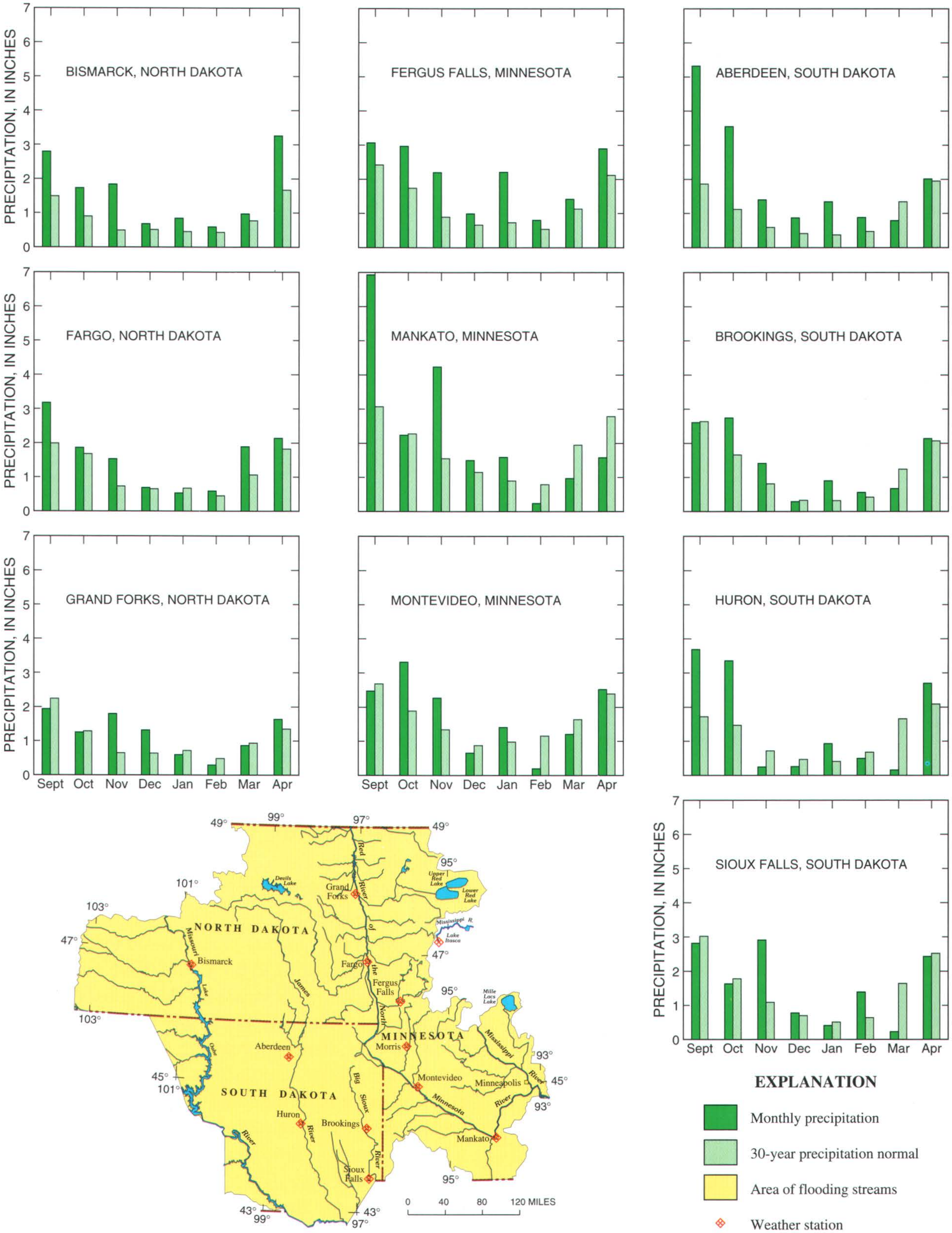


Figure 2. Monthly precipitation at 10 weather stations in the northern plains during September 1996 through April 1997 and 30-year precipitation normals for September through April 1961–90. (Data from Owenby and Ezell, 1992a, 1992b, 1992c, and U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Environmental Satellite, Data and Information Service, 1996–97a, 1996–97b, 1996–97c.)

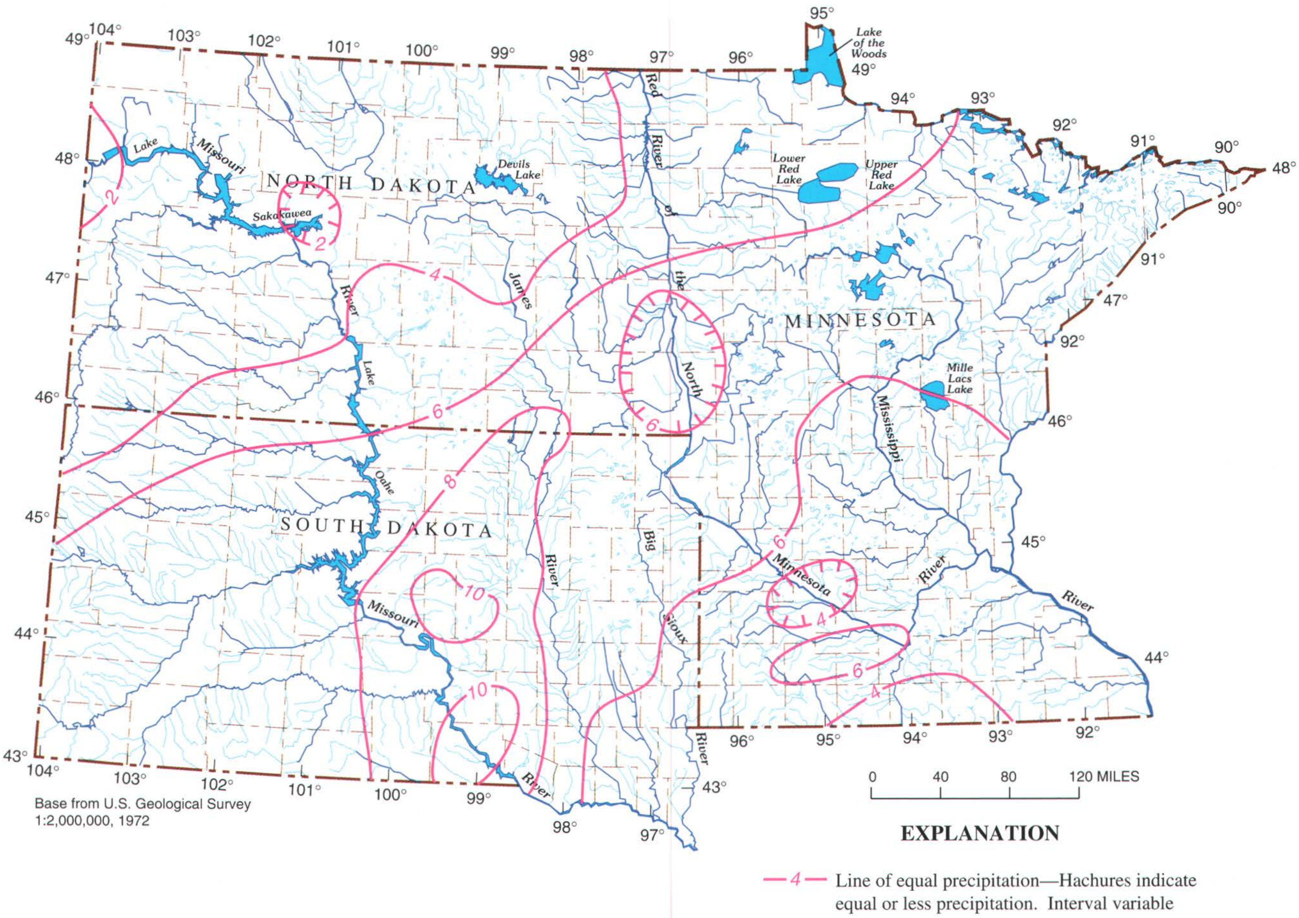


Figure 3. Areal distribution of precipitation, in inches, for the northern plains, September through October 1996. (Data from U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Environmental Satellite, Data and Information Service, 1996–97a, 1996–97b, 1996–97c.)

The five greatest September through October precipitation totals for six weather stations—Bismarck and Grand Forks, N. Dak.; Lake Itasca and Morris, Minn.; and Aberdeen and Brookings, S. Dak.—are given in table 2 along with the September through October 1996 precipitation total at each station and the mean for the period of record. The Lake Itasca and Morris weather stations (fig. 1) were substituted for the Fergus Falls, Mankato, and Montevideo weather stations, which had limited or missing data in their long-term records (Mathew Werner, High Plains Climate Center, written commun., 1998). September through October 1996 was the 12th wettest period in 122 years of record at Bismarck, the 33d wettest period in 65 years of record at Grand Forks, the 6th wettest period in 85 years of record at Lake Itasca, the 4th wettest period in 111 years of record at Morris, the wettest period in 65 years of record at Aberdeen, and the 19th wettest period in 103 years of record at Brookings. The precipitation total at Aberdeen was about 35 percent greater than the second greatest total of 6.55 inches in 1946. The precipitation totals at all of the weather stations except Grand Forks were at least 44 percent greater than the mean for the period of record at each station.

The above-normal precipitation that occurred in the northern plains in the fall of 1996 resulted in above-normal soil-moisture levels in most of the region before freezeup. These soil-moisture conditions added to the potential for severe flooding because, if the ground is near saturation at freezeup, an impermeable soil layer is formed during freezeup. This impermeable soil layer can retard or prevent any additional moisture from infiltrating the ground.

Soil-moisture data for the northern plains for the fall of 1996 were limited. However, a drought severity index (long-term Palmer) by climatological division for September 28, 1996, indicated near-normal soil-moisture conditions in central and eastern North Dakota, incipient drought conditions in southeastern

Minnesota, and extremely moist conditions in central and eastern South Dakota (U.S. Department of Commerce, National Oceanic and Atmospheric Administration/United States Department of Agriculture Weather Facility, 1996). In North Dakota, soil-moisture levels for the fall of 1996 ranged from 4.0 inches in the west to 10.0 inches in the southeast (Charlene Prindiville, National Weather Service, written commun., 1998). [Soil-moisture level is the amount of moisture (water) in the soil zone.] In Minnesota, soil-moisture levels at the Morris West-Central Experimental Station increased from about 5.5 inches on October 1, 1996, to more than 7.5 inches on November 1, 1996 (Mark Seeley, University of Minnesota, Department of Soil, Water, and Climate, written commun., 1997). Much of this increase resulted from the 1.98 inches of precipitation that occurred at Morris on October 30, 1996. The 7.5-inch soil-moisture level compared closely with an 8.0-inch soil-moisture level for west-central Minnesota in March 1997, suggesting that soil-moisture conditions were enhanced by the additional precipitation in the fall of 1996 before freezeup and did not change appreciably through the winter.

Winter Precipitation (November 1996 through March 1997)

During November 1996 through March 1997, precipitation at all 10 weather stations was between 3.83 and 8.54 inches. Much of the region received about 125 to 200 percent of the 30-year precipitation normals for November 1996 through March 1997. The above-normal precipitation resulted in record or near-record snowfalls in much of central and eastern North Dakota, western Minnesota, and central and eastern South Dakota. The largest snowfall totals exceeded

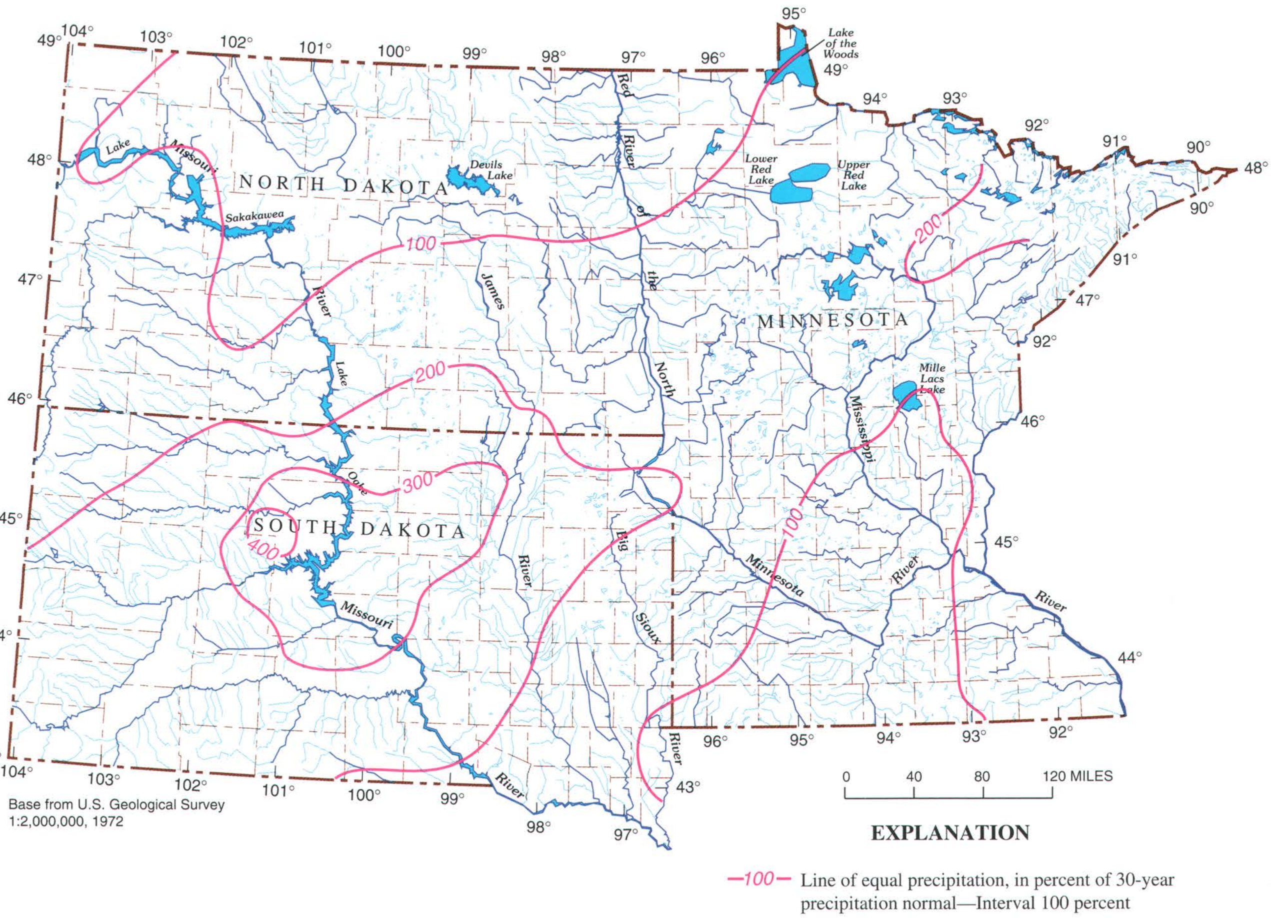


Figure 4. Areal distribution of precipitation, in percent of 30-year precipitation normal, for the northern plains, September through October 1961–90. (Data from Owenby and Ezell, 1992a, 1992b, 1992c, and U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Environmental Satellite, Data and Information Service, 1996–97a, 1996–97b, 1996–97c.)

Table 2. The five greatest September through October precipitation totals, September through October 1996 precipitation totals, and means for the period of record at six weather stations in the northern plains

[Data from Sandra Wiche (National Weather Service, written commun., 1998) and Mathew Werner (High Plains Climate Center, written commun., 1998); record length given in parentheses; precipitation total given in inches; 1996 precipitation total given in bold; 1996 rank given in brackets]

Bismarck, North Dakota (122 years)		Grand Forks, North Dakota (65 years)		Lake Itasca, Minnesota (85 years)		Morris, Minnesota (111 years)		Aberdeen, South Dakota (65 years)		Brookings, South Dakota (103 years)	
Year	Total	Year	Total	Year	Total	Year	Total	Year	Total	Year	Total
Five greatest September through October precipitation totals											
1994	8.42	1957	9.48	1984	11.46	1984	11.03	**1996**	**8.87**	1946	10.23
1977	7.93	1973	7.46	1971	11.34	1971	9.16	1946	6.55	1900	8.30
1876	5.91	1981	6.94	1973	9.47	1982	8.32	1941	6.18	1984	8.26
1900	5.70	1950	6.61	1970	8.21	**1996**	**7.85**	1982	6.09	1911	8.15
1971	5.37	1961	6.56	1946	8.04	1921	7.76	1977	5.60	1906	8.14
September through October 1996 precipitation total											
1996	**4.53**	**1996**	**2.99**	**1996**	**7.89**	**1996**	**7.85**	**1996**	**8.87**	**1996**	**5.36**
[Rank 12]		[Rank 33]		[Rank 6]		[Rank 4]		[Rank 1]		[Rank 19]	
Mean for period of record											
Mean	2.86	Mean	3.33	Mean	4.49	Mean	4.01	Mean	2.92	Mean	3.72

100 inches and occurred in the southern part of the Red River of the North Basin, the middle part of the Big Sioux River Basin, and near the Missouri River in southern North Dakota (fig. 5).

Snowfall often is difficult to measure because of the variability in weather conditions, and periods of missing data often occur. Therefore, total precipitation is the focus of this discussion, but snowfall is discussed when continuous data records exist. Cumulative snowfall at six selected weather stations during November 1996 through April 1997 is shown in figure 6. The influences of some of the snowstorms occurring in the region are evident by the vertical rises on the graphs. The presence of a major snowstorm over the region is indicated when the rises, such as those in mid-December and early April, on the individual graphs coincide.

During November 1996, monthly precipitation at 9 of the 10 weather stations ranged from 169 to 376 percent of normal (table 1). Precipitation at six of the nine stations ranged from 210 to 277 percent of normal, and precipitation at one station (Bismarck) was 376 percent of normal. Monthly precipitation ranged from 0.25 inch at Huron to 4.24 inches at Mankato. In terms of snowfall (fig. 6), Bismarck received 25.2 inches, Grand Forks received 14.4 inches, Mankato received 11.5 inches, Montevideo received 15.0 inches, Aberdeen received 20.3 inches, and Sioux Falls received 11.3 inches.

During December 1996, monthly precipitation at 7 of the 10 weather stations ranged from 106 to 212 percent of normal (table 1). Monthly precipitation ranged from 0.26 inch at Huron to 1.50 inches at Mankato. In terms of snowfall (fig. 6), Bismarck received 13.5 inches, Grand Forks received 30.2 inches, Mankato received 15.5 inches, Montevideo received 20.6 inches, Aberdeen received 13.9 inches, and Sioux Falls received 19.8 inches. The snowfall at Sioux Falls was the 4th highest on record for that month and the 20th highest on record for all months (Richard Ryrholm, National Weather Service, written commun., 1998).

During January 1997, monthly precipitation at 7 of the 10 weather stations ranged from 144 to 362 percent of normal (table 1). Monthly precipitation ranged from 0.41 inch at Sioux Falls to an estimated 2.21 inches at Fergus Falls. In terms of snowfall (fig. 6), Bismarck received 15.1 inches, Grand Forks received 19.9 inches, Mankato received 11.1 inches, Montevideo received 16.5 inches, Aberdeen received 19.2 inches, and Sioux Falls received 8.8 inches.

During February 1997, monthly precipitation at 6 of the 10 weather stations ranged from 131 to 217 percent of normal (table 1). Monthly precipitation ranged from 0.20 inch at Montevideo to 1.39 inches at Sioux Falls. In terms of snowfall (fig. 6), Bismarck received 9.2 inches, Grand Forks received 7.6 inches, Mankato received 5.6 inches, Montevideo received 5.0 inches, Aberdeen received 9.2 inches, and Sioux Falls received 16.5 inches.

During March 1997, precipitation generally was less than normal. Monthly precipitation was above normal at only 3 of the 10 weather stations and ranged from 126 to 178 percent of normal (table 1). The remaining seven stations received between 10 and 93 percent of the normal amount of precipitation at those stations. Monthly precipitation ranged from 0.16 inch at Huron to 1.89 inches at Fargo. In terms of snowfall (fig. 6), Bismarck received 16.1 inches, Grand Forks received 17.5 inches, Mankato received 9.5 inches, Montevideo received 12.5 inches, Aberdeen received 8.5 inches, and Sioux Falls received 1.3 inches.

Spring Precipitation (April 1997)

During April 1997, precipitation was again greater than normal. Monthly precipitation at 8 of the 10 weather stations ranged from 103 to 195 percent of normal (table 1). Monthly precipitation ranged from 1.58 inches at Mankato to 3.26 inches at Bismarck. The precipitation occurring in April was not always in the form of snow. However, in the first part of April, Bismarck received 17.5 inches of snowfall, Grand Forks received 8.0 inches, Mankato received 4.0 inches, Montevideo received 4.3 inches, Aberdeen received 4.6 inches, and Sioux Falls received 6.0 inches. Most of the snowfall occurred during a blizzard on April 5–6, 1997.

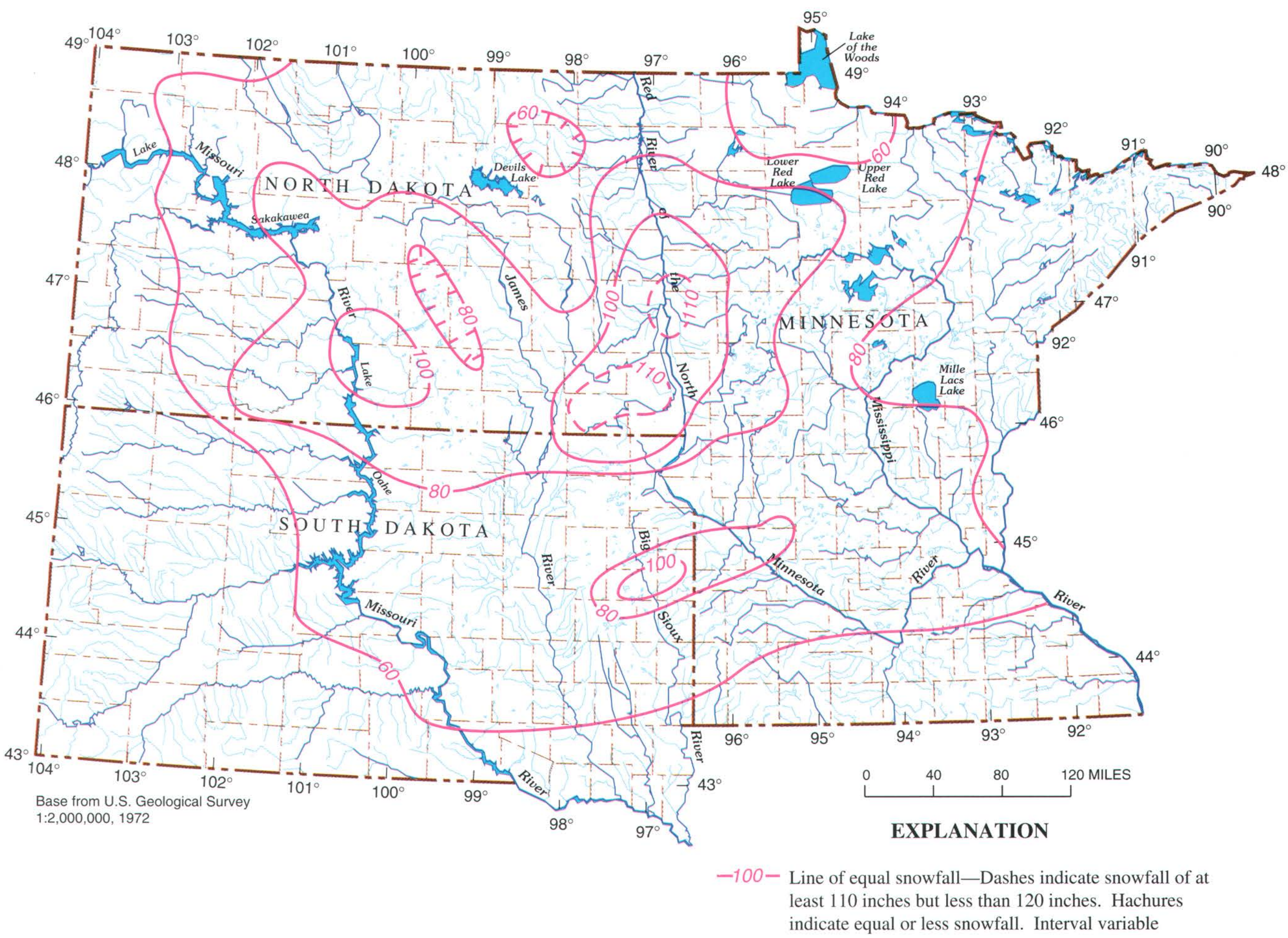


Figure 5. Areal distribution of snowfall, in inches, for the northern plains, November 1996 through April 1997. (Data from U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Environmental Satellite, Data and Information Service, 1996–97a, 1996–97b, 1996–97c.)

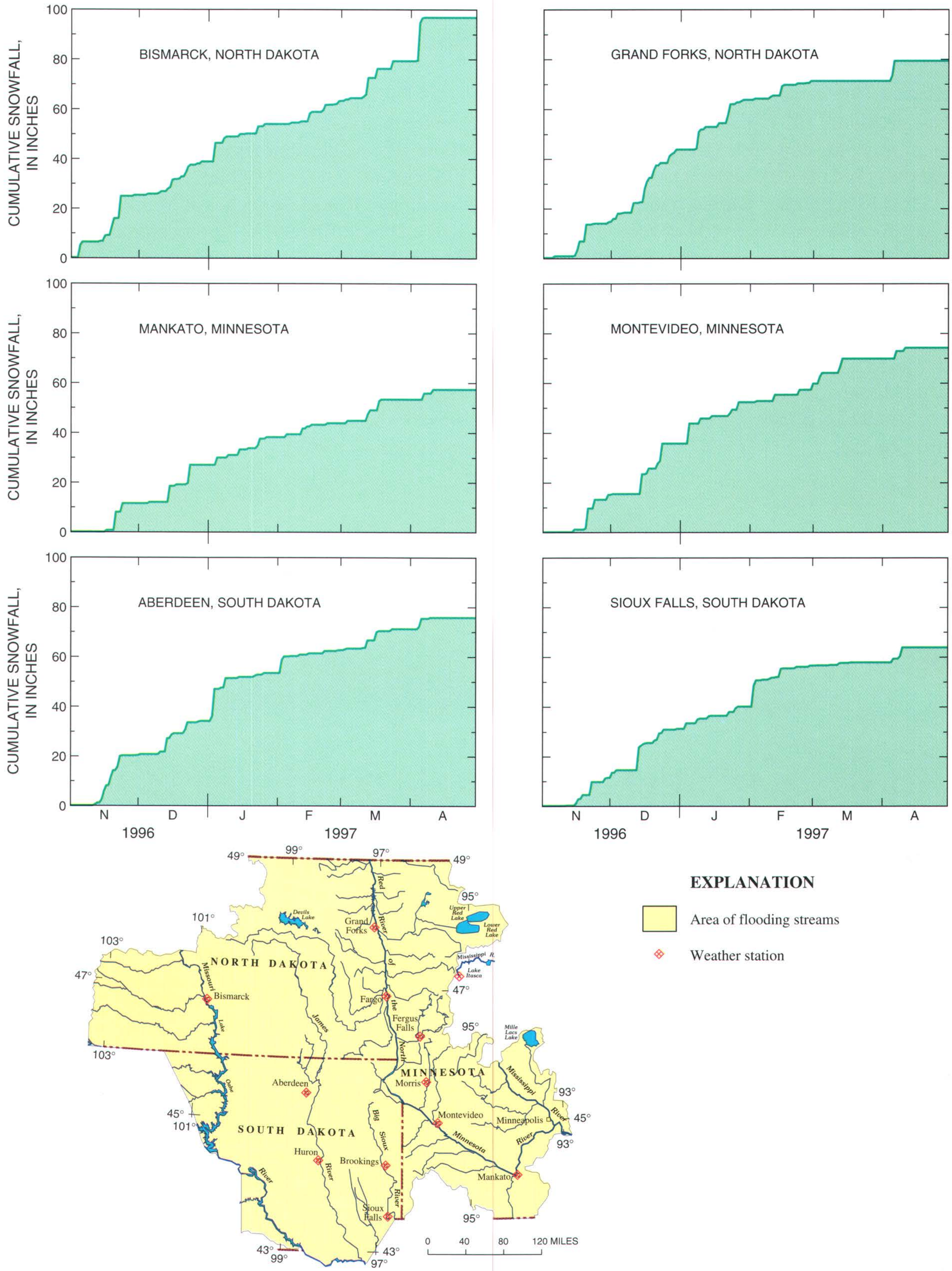
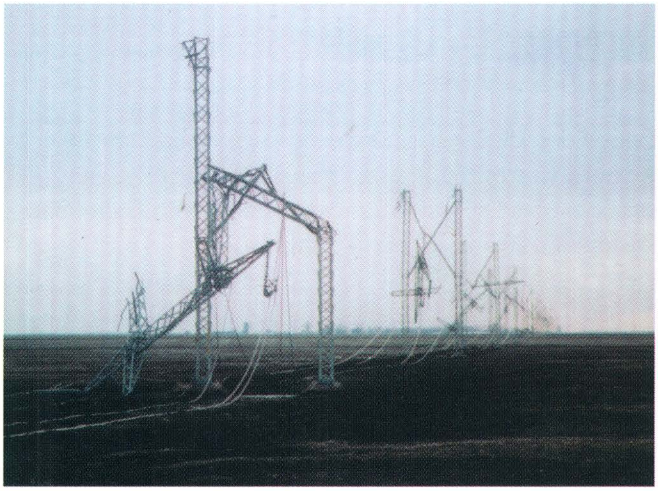


Figure 6. Cumulative snowfall at six weather stations in the northern plains, November 1996 through April 1997. (Data from U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Environmental Satellite, Data and Information Service, 1996–97a, 1996–97b, 1996–97c.)

The precipitation in April aggravated already serious flooding by adding to the streamflows. The storm that occurred on April 5–6, 1997, was preceded in many places by wind-driven rain and sleet. The weather conditions hampered flood and rescue operations by closing many roads. Windspeeds were as much as 70 miles per hour in many places, and wind and ice toppled trees and powerlines in many areas of the region. In central and eastern North Dakota, 5,729 power poles were lost to ice damage, causing about 36,150 consumers to be without power for many days (North Dakota Association of Rural Electric Cooperatives, 1997). The loss of power inhibited the ability of the U.S. Geological Survey to collect and transmit data from several streamflow-gaging stations in the region.

Livestock losses across the region also were high. In North Dakota, unofficial reports indicate 90,000 to 120,000 head of cattle, including many calves, were lost as a result of the blizzard. In South Dakota, total livestock losses for the winter, including during the blizzard, were estimated to be more than 296,000 (Teller and Burr, 1998). The floodwaters and severe weather forced thousands of people to flee their homes and caused more than $2 billion in damages to the region.

With the additional snowfall in April, many areas in the northern plains set new records for total snowfall. Official and unofficial snowfall totals for October 1996 through April 1997 at 9 of the 10 weather stations and the record October through April snowfall before 1996–97 are listed in the following table.



Downed power lines and towers in eastern North Dakota were the result of a blizzard on April 5–6, 1997. (Photograph from North Dakota National Guard and North Dakota Water Education Foundation.)

ANALYSIS OF SELECTED STORMS

After the wet fall of 1996, precipitation continued to accumulate across the northern plains. Weather patterns that kept temperatures below normal produced several storms during the winter and early spring. Many of the storms were quick-moving "clipper"-type storms that produced snowfall totals of a few inches, but a few of the storms, typically maritime tropical types, persisted over the region and produced snowfall totals exceeding 12 inches in many places.

Station	Snowfall total for October 1996 through April 1997 (inches)	Record October through April snowfall before 1996–97		Remarks about 1996–97
		Total (inches)	Date	
Bismarck, N. Dak.	101.3	91.8	1993–94	New record.
Fargo, N. Dak.	117.0	89.1	1993–94	New record.
Grand Forks, N. Dak.	97.9	91.0	1896–97	New record.
Fergus Falls, Minn.	105.3	84.8	1891–92	New record.
Mankato, Minn.	57.2	70.8	1961–62	No new record.
Montevideo, Minn.	73.9	76.3	1950–51	No new record.
Aberdeen, S. Dak.	75.7	76.8	1993–94	Second highest on record.
Brookings, S. Dak	48.3	72.5	1892–93	Sixth highest on record.
Huron, S. Dak.[1]	--	--	--	--
Sioux Falls, S. Dak.	63.7	94.7	1947–48	No new record.

[1]Not reported because of missing record.

December 16–18, 1996

A storm formed in southern Canada on December 15, 1996, and spread snow across the western part of the region. The storm moved slowly across North Dakota, Minnesota, and South Dakota on December 16–17, 1996, and into Wisconsin on December 18, 1996 (fig. 7). Temperatures in the region were below freezing both before and after the storm, indicating no snowmelt occurred. Snowfall was widespread, and unofficial totals of about 24 inches were reported. Official reports indicate Bismarck received 4.9 inches of snowfall, Grand Forks received 9.8 inches, Mankato received 2.3 inches, Montevideo received 0.60 inch, Aberdeen received 7.5 inches, and Sioux Falls received 11.0 inches. Windspeeds during the storm ranged from 20 to 60 miles per hour and caused considerable blowing and redistribution of snow, particularly in sheltered areas. Temperatures plunged to between –20°F (degrees Fahrenheit) and –40°F across the region after the storm, and new low-temperature records were set in many places. Another storm moving through the region a few days later produced additional snowfall totals of 4.0 to 10 inches.

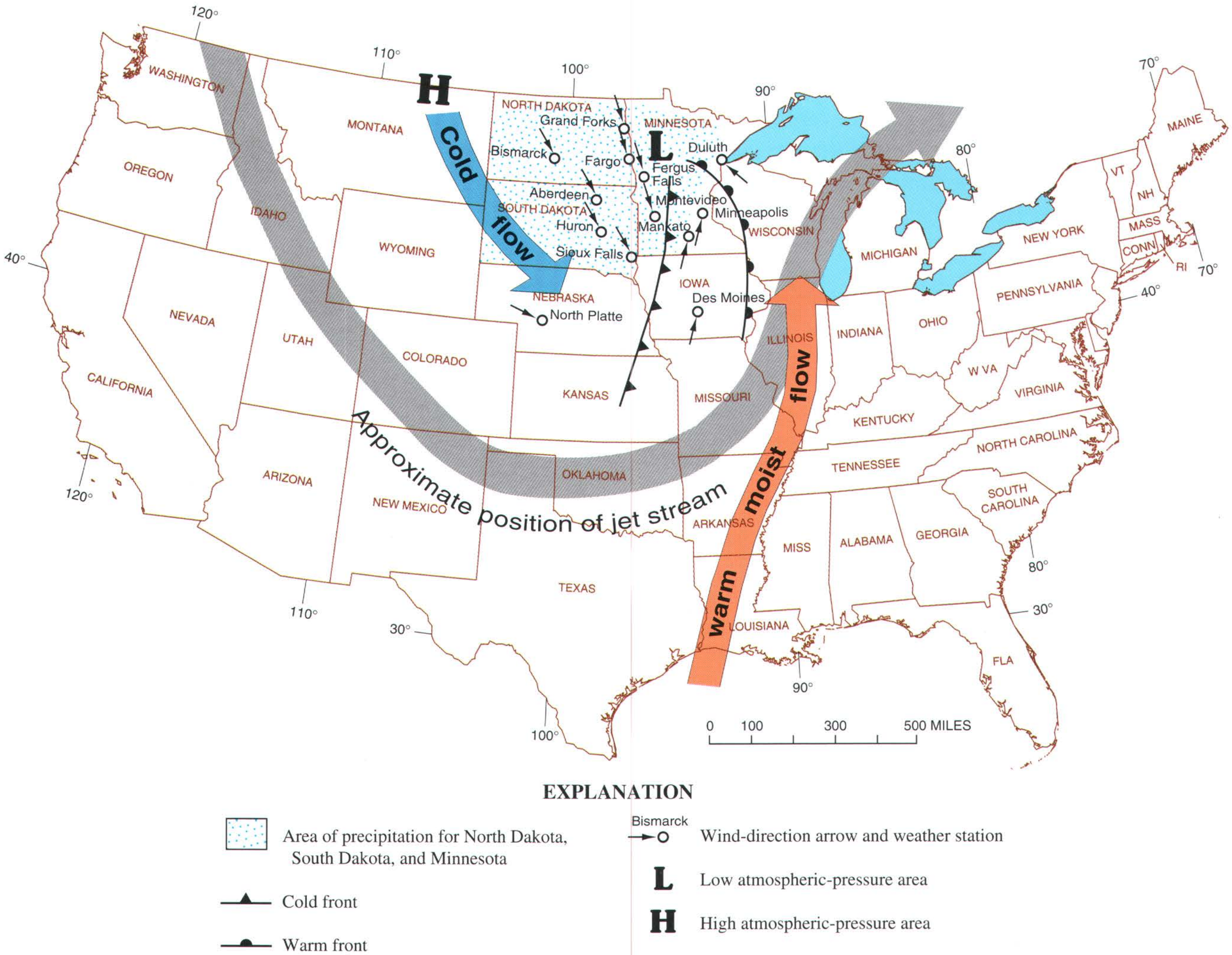


Figure 7. Average weather patterns over the northern plains, December 16–18, 1996. (Data from U.S. Department of Commerce, National Oceanic and Atmospheric Administration, n.d.)

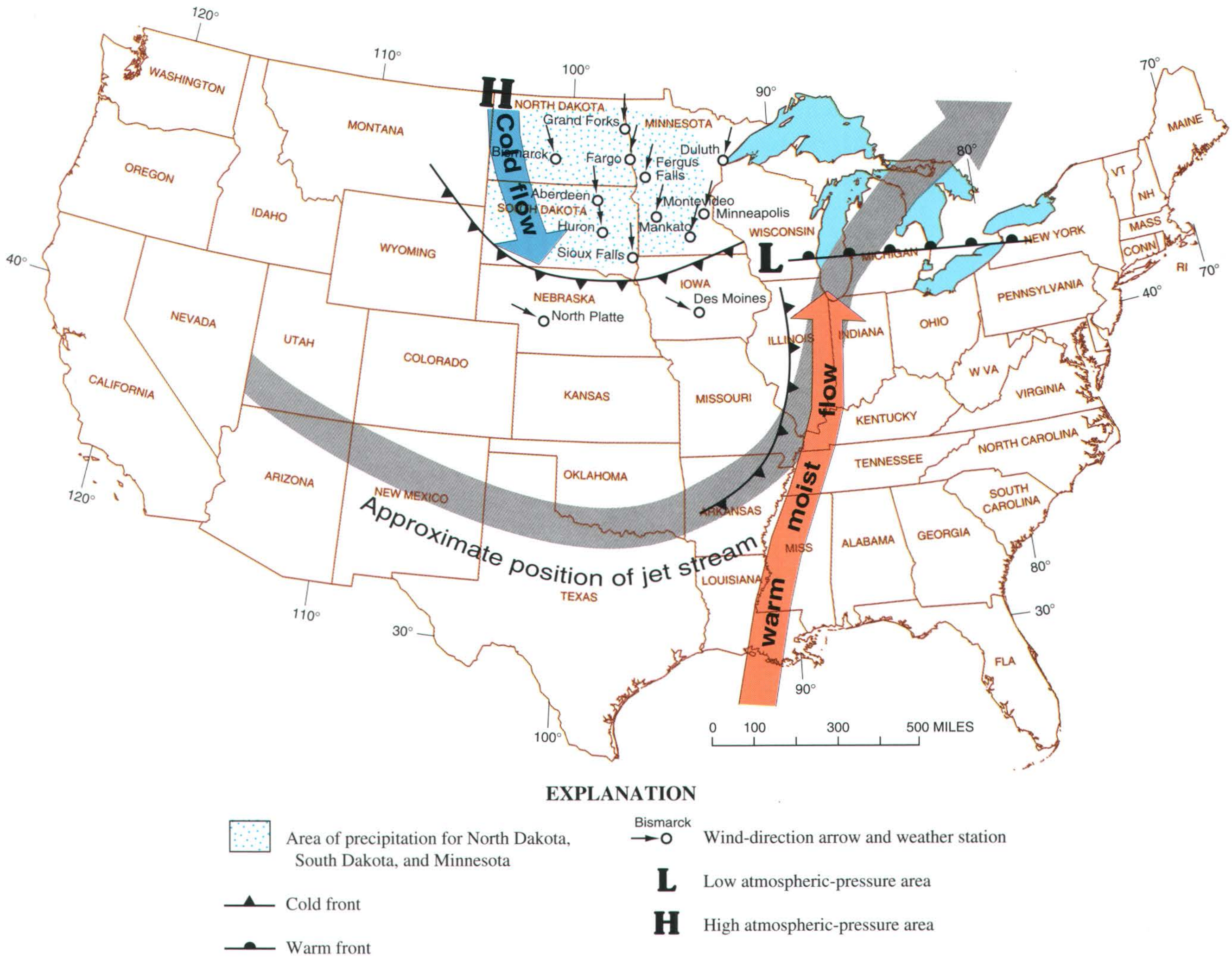


Figure 8. Average weather patterns over the northern plains, January 4–5, 1997. (Data from U.S. Department of Commerce, National Oceanic and Atmospheric Administration, n.d.)

January 4–5, 1997

The storm that occurred on January 4–5, 1997, formed in eastern Colorado and western Kansas on January 3, 1997 (fig. 8). Weather conditions in the northern plains were relatively warm, and some temperatures were in the 40°F range. A wind flow from the south at ground surface brought moisture into the central part of the region on January 3, 1997, and aided in the development of the storm. On January 4, 1997, the storm moved quickly into southern Iowa, spreading rain and snow over the southern part of the region, and on January 5, 1997, the storm moved slowly into Wisconsin. Temperatures throughout the region were around zero, and snowfall totals varied. Bismarck received 7.5 inches of snowfall, Grand Forks received a trace, Mankato received 2.9 inches, Montevideo received 8.0 inches, Aberdeen received 12.8 inches, and Sioux Falls received 2.2 inches. Fergus Falls received 12 inches of snow on January 5, 1997, and had a combined 3-day total of 24 inches, which was 12.6 inches above the monthly normal for January (Jim Zandlo, Minnesota State Climatologist, written commun., 1997). A few days later, these cities received additional snowfall totals of 1.0 to 8.0 inches.

April 5–6, 1997

Late spring snowstorms are common in parts of the northern plains, but the intensity and timing of the April 5–6, 1997, snowstorm made it one of the worst on record (fig. 9). Besides snow, this "Colorado low" storm produced rain, sleet, and ice in many areas. The storm was caused by a warm, moist flow of air from the Gulf of Mexico entering the central and northern plains on April 3, 1997. Some temperatures in the region reached 50°F to 60°F before colder air began moving south across Montana. The interaction of the existing warm air mass with the colder air mass from Montana aided in the development of the storm. On April 5, 1997, the storm center strengthened and moved from Colorado into Nebraska and South Dakota, spreading rain, sleet, and snow into the northern plains. On April 6, 1997, the storm intensified and moved northward into western Minnesota. Several inches of rain and sleet preceded the snow in southeastern North Dakota, western Minnesota, and eastern South Dakota while snow fell in the rest of the region. Precipitation spread across the entire region on April 6, 1997. Windspeeds of 30 to 50 miles per hour were common, and, combined with temperatures of zero to 20°F, brought windchills of –60°F. Bismarck received 17.5 inches of snowfall, Grand Forks received 8.0 inches, Mankato received 2.5 inches, Montevideo received 3.0 inches, Aberdeen received 4.2 inches, and Sioux Falls received 1.5 inches. Some of these cities also received rain and sleet before the snowfall. Temperatures, which were 10 degrees above normal before the storm, plunged to about 20 degrees below normal as the storm moved into Canada. The additional moisture from the storm added to the increasing streamflows in rivers and streams in the region.

Snow from an April 5–6, 1997, blizzard covers cars in a Bismarck, North Dakota, mall parking lot. (Photograph from Bismarck Tribune.)

Melting ice and snow cause the Red River of the North to flood a Clay County, Minnesota, road on April 9, 1997. (Photograph from U.S. Geological Survey.)

CHRONOLOGICAL OVERVIEW

Flooding in the northern plains usually is caused by spring snowmelt, and the severity of the flooding is affected by antecedent climatic conditions such as above-normal precipitation in the fall, high soil-moisture levels at freezeup, above-normal snowfall in the winter, a late spring thaw, above-normal precipitation during the spring thaw, and ice jams on rivers and streams. Many of these conditions were present in the northern plains before and during the 1997 spring floods.

Many areas in the northern plains received normal to much-above-normal precipitation from 1993 to the fall of 1996. Thus, soils in lowland areas became saturated and numerous potholes, sloughs, and small lakes in the region were filled and retained high water levels before the winter of 1996–97. Soil moisture in upland areas was below normal to normal before the winter of 1996–97 but was above normal after above-normal precipitation during September and October 1996. During September, 6 of 10 weather stations in the northern plains received above-normal precipitation, and during October, 7 of 10 stations received above-normal precipitation. During September, precipitation was more than 200 percent of normal at Mankato, Minn., and at Aberdeen and Huron, S. Dak.; and, during October, precipitation was more than 200 percent of normal at Aberdeen and Huron.

At Aberdeen, September through October 1996 was the wettest in 65 years of record. At many of the weather stations, single-day precipitation totals during September and October nearly equaled or exceeded the monthly normals for 1961–90. On September 3, 1996, Mankato received 5.44 inches of precipitation, the second largest single-day total ever recorded at that station. In October 1996, Aberdeen had two single-day totals that exceeded the monthly normal of 1.12 inches.

A series of winter storms moving through the northern plains between November 1996 and early March 1997 caused above-normal precipitation, mostly in the form of snow. In any one

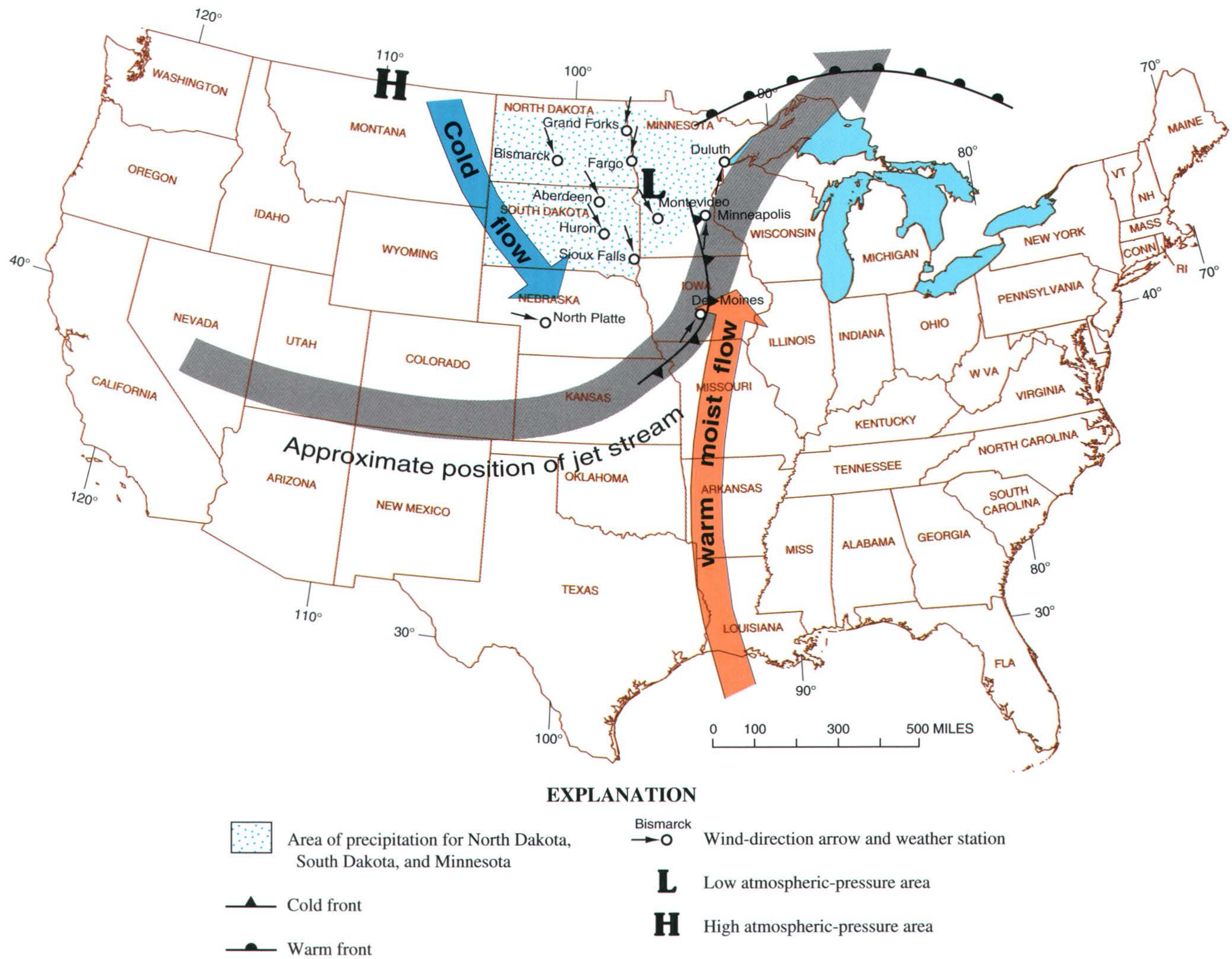


Figure 9. Average weather patterns over the northern plains, April 5–6, 1997. (Data from U.S. Department of Commerce, National Oceanic and Atmospheric Administration, n.d.)

month, no less than 3 and as many as 9 of the 10 weather stations received above-normal precipitation. Precipitation was more than 200 percent of normal at many of the stations. This excessive precipitation resulted, in part, from record snowfalls at 4 of the 10 weather stations in the region. Because temperatures in the northern plains were below normal longer than usual, fewer mild days (days with temperatures at or above 32°F) occurred during the winter. The absence of these mild winter days along with frozen moist soils slowed the gradual dissipation of accumulated snowfall through sublimation, evaporation, or infiltration in much of the region.

During March, snowmelt and warm temperatures generally began to occur in the southwestern part of the northern plains. By the second and third weeks of March, temperatures rose to above freezing and peak streamflows began occurring on many rivers and streams in western North Dakota and central and western South Dakota.

In the northern part of the region, snowpacks at the beginning of freezeup covered frozen moist soils, minimizing the infiltration of any additional fall and winter moisture. For the most part, additional fall and winter moisture was retained by the snowpacks. Moisture in the snowpacks, along with above-normal precipitation during March, increased runoff during snowmelt in many areas in the northern part of the region.

During April 1997, temperatures across many parts of the northern plains dropped to below freezing, and a final winter storm moved into the region on April 5–6, 1997. Official and unofficial snowfall totals for October 1996 through April 1997 include 101.3 inches at Bismarck, 117 inches at Fargo, 97.9 inches at Grand Forks, and 105.3 inches at Fergus Falls. At 3 other weather stations, snowfall totals ranked in the top 10 highest snowfalls for the period of record at that station. Montevideo received 73.9 inches of snowfall, Aberdeen received 75.7 inches, and Brookings received 48.3 inches.

The storm on April 5–6, 1997, caused already cold temperatures to drop severely and brought high winds and as much as 2 feet of snow to many places. The storm was preceded by wind-driven rain and sleet in many areas, and wind and ice toppled trees and many power lines, leaving thousands of people without power for days. The snowfall closed schools and businesses and blocked many roads throughout the region, hampering flood and rescue operations. The intensity and timing of the storm caused high livestock losses because many farmers and ranchers were unable to react in time to save their animals. The additional moisture from the storm added to increasing streamflows in rivers and streams in the region. Ice jams that began to form on many of the rivers and streams affected the high streamflows. As the floodwaters rushed to record highs, towns such as Ada, Minn., and cities such as Grand Forks, N. Dak., and East Grand Forks, Minn., were evacuated. The floodwaters and severe weather forced thousands of people to flee their homes, some permanently, and caused more than $2 billion in damages to the region. For the people of the northern plains, the winter of 1996–97, combined with the 1997 spring floods, was one of the worst natural disasters in recent history.

Bridge structure denotes channel location of the flooding Red River of the North. View is looking west to Grand Forks, North Dakota, April 1997. (Photograph from North Dakota Water Education Foundation and North Dakota National Guard.)

REFERENCES

North Dakota Association of Rural Electric Cooperatives, 1997, The fury: North Dakota REC/RTC, v. 43, no. 11, p. 4–10.

Owenby, J.R., and Ezell, D.S., 1992a, Monthly station normals of temperature, precipitation, and heating and cooling degree days, 1961–90, Minnesota: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina, Climatography of the United States No. 81, unpaginated.

Owenby, J.R., and Ezell, D.S., 1992b, Monthly station normals of temperature, precipitation, and heating and cooling degree days, 1961–90, North Dakota: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina, Climatography of the United States No. 81, unpaginated.

Owenby, J.R., and Ezell, D.S., 1992c, Monthly station normals of temperature, precipitation, and heating and cooling degree days, 1961–90, South Dakota: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina, Climatography of the United States No. 81, unpaginated.

Teller, R.W., and Burr, M.J., 1998, Floods in north-central and eastern South Dakota, spring 1997: U.S. Geological Survey Fact Sheet FS–021–98, 4 p.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, [n.d.], Daily weather maps, Weekly series, December 16–22, 1996; December 30, 1996–January 5, 1997; and March 31–April 6, 1997: unpaginated.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Environmental Satellite, Data and Information Service, 1996–97a, Climatological data, Minnesota, September 1996 through April 1997: Asheville, North Carolina, v. 102, no. 9, through v. 103, no. 4, unpaginated.

———1996–97b, Climatological data, North Dakota, September 1996 through April 1997: Asheville, North Carolina, v. 105, no. 9, through v. 106, no. 4, unpaginated.

———1996–97c, Climatological data, South Dakota, September 1996 through April 1997: Asheville, North Carolina, v. 101, no. 9, through v. 102, no. 4, unpaginated.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration/United States Department of Agriculture Weather Facility, 1996, Weekly weather and crop bulletin: October 1, 1996, p. 3.

U.S. Geological Survey, 1991, National water summary 1988–89—Hydrologic events and floods and droughts: U.S. Geological Survey Water-Supply Paper 2400, 591 p.

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