INTRODUCTION

Rising temperatures, snowmelt, and rainfall in the upper reaches of the Red River of the North Basin in early April 1989 combined to create hazardous flood conditions along the main stem of the Red River of the North (hereafter referred to as the Red River). On April 5, converging flood waters from the lower reaches of the Otter Tail, the Bois de Sioux, and the Rabbit Rivers caused the Red River to rise to a stage unequaled for almost 100 years in the cities of Wahpeton, N. Dak., and Breckenridge, Minn. By April 9, temperatures had dropped below freezing and flood waters peaked below the expected record stage in the cities of Fargo, N. Dak., and Moorhead, Minn. The purpose of this report is to describe the hydrologic conditions that contributed to the flood, document on topographic maps the areas inundated in both the Wahpeton-Breckenridge and the Fargo-Moorhead areas, and present discharge hydrographs for gaging stations located along the main stem of the Red River from Wahpeton to Fargo. The 1989 flood data for Wahpeton-Breckenridge are compared to data for previous floods, and estimates of the flood-damage costs are included.

The study area is limited to the Red River Basin upstream from and including the Fargo-Moorhead area (fig. 1). Only those areas inundated within the city limits of Wahpeton-Breckenridge (fig. 2), and Fargo-Moorhead (fig. 3), and some surrounding areas, have been delineated.

ACKNOWLEDGMENTS

The aerial photographs used in this report were supplied by KBM, Inc., of Grand Forks, N. Dak. Permission for their use was granted by Wilkin County, Minn., and the U.S. Army Corps of Engineers, St. Paul, Minn.

HYDROLOGIC CONDITIONS PRIOR TO AND DURING THE 1989 FLOOD

Streamflows in the Red River Basin upstream of Fargo were less than normal in November 1988. The less than normal streamflows were the result of widespread drought conditions throughout the study area in the preceding months. Storage levels in Orwell Reservoir on the Otter Tail River were near normal but storage levels in Lake Traverse on the Bois de Sioux River were less than normal.

Soil-moisture content in the upper 6 inches of soil throughout the study area ranged from 8 to 16 percent by weight during November 1988 and was in the dry range of 10 to 15 percent by weight in most of the study area. Normal soil-moisture content in the upper 6 inches of soil in the study area ranges from 15 to 25 percent by weight (M.T. Roletto, National Weather Service, written commun., 1989).

Precipitation in the study area, mainly snow, was near normal for November through February; however, some parts of the study area received greater than normal amounts. Above freezing temperatures in January reduced snow/water equivalent (SWE) to less than 2 inches in areas south of Wahpeton (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, 1989, Red River post flood report, spring 1989: Minneapolis, Minn., 67 p.). Snow depths and SWE increased after the January warming trend ended. March precipitation was greater than normal. On March 19, an airborne snow survey indicated that the SWE in the study area ranged from 2.1 to 4.5 inches and exceeded 2.5 inches in most of the study area. Additional precipitation occurred in many parts of the study area after March 19. More than 0.5 inch of rain fell in many parts of the study area on March 29, and an additional 0.5 inch or more of rain fell during the first 4 days of April.

Except for the January warming trend, daily mean temperatures at Wahpeton, N. Dak., were not above freezing until March 25 (fig. 4). Daily mean temperatures then stayed above freezing through March 29, dropped to below freezing for 2 days, rose to above freezing through April 7, dropped to below freezing for 3 days, and then rose to above freezing again through the middle of April.

EXTENT OF FLOODING

Flooding occurred during April 1989 along the main stem of the Red River all the way from its headwaters to the United States-Canadian border and along nearly all of its tributaries. The most severe flooding occurred at the confluence of the Bois de Sioux and Otter Tail Rivers in the Wahpeton-Breckenridge area. Flooding was also significant in the Fargo-Moorhead area, but flooding downstream from Fargo was less severe. The drop in temperatures to below freezing on April 8-10 helped reduce peak flows through the city of Fargo by slowing the snowmelt and allowing the peak to attenuate rather than increase as it moved downstream; thus, the severity of flooding in the Fargo-Moorhead area and in areas farther downstream was reduced. Aerial photographs taken during the flood peak on April 5, 1989, in the Wahpeton-Breckenridge area and on April 9, 1989, in the Fargo-Moorhead area were used to delineate the extent of the flood on topographic maps (figs. 2 and 3).

COMPARISON OF FLOODS

The U.S. Geological Survey operates gaging stations at Wahpeton, Hickson, and Fargo on the main stem of the Red River in the study area. Annual peak gage height and annual peak discharge for these three main-stem gaging stations are shown in figures 5-10. A review of annual peak gage heights (fig. 7) and annual peak discharges (fig. 10) for the Fargo gaging station indicates that since 1900 the three most significant floods on the main stem of the Red River in the study area occurred in the last 25 years. These floods occurred in 1969, 1979, and 1989. High flows also occurred in 1952 and 1978. Available records before 1900 indicate major floods also occurred in 1882 and 1897. Discharge hydrographs for the 1969, 1979, and 1989 floods are shown in figures 11-13.

The maximum discharge of the 1989 flood at each of the three main-stem stations on the Red River was greater than that of the 1979 flood, but less than that of the 1969 flood (table 1) at the two main-stem stations in operation during 1969. Although the 1969 peak flood discharge at Wahpeton is the maximum for the period of continuous record, exceeding all recorded peaks except the historic peak of 1897, maximum gage height recorded during the 1989 flood exceeded the 1969 maximum gage height by more than 1 foot. Daily mean gage heights and daily mean discharges for the 1969 and 1989 floods at Wahpeton are plotted in figure 14.

An aerial photograph of the river channel (fig. 15) was taken on April 5, 1989, the day of the flood peak, at a location 1-1/2 miles downstream from the gaging station at Wahpeton. Large sections of the main channel were jammed with ice at the time of the 1989 flood peak. No backwater from ice was reported for the 1969 flood peak.

Flood-crest profiles for the main stem of the Red River from Wahpeton to Fargo for 1969, 1979, and 1989 are shown in figure 16. Available data for the three gaging stations and measurements of maximum water levels at several intervening bridges on the main stem of the Red River were used to compile the profiles. The data for the intervening bridges were provided by the U.S. Army Corps of Engineers (E.G. Eaton, written commun., 1989).

FLOOD FREQUENCY

Recurrence interval (table 1), as applied to flood events, is the average time interval within which a given flood magnitude will be equaled or exceeded once. For example, a flood with a 25-year recurrence interval has a 1 in 25 chance, on the average, of occurring in any given year, or a frequency of 1 in 25 years. The fact that a major flood occurs one year does not decrease the probability of a flood as great or greater occurring the next year.

Peak discharges for April 1989 have been computed for eight gaging stations and one partial-record station in the study area (table 1). Flood frequencies were computed for the nine stations using log-Pearson type III analysis. Results of the flood-frequency analyses were used to compute the recurrence interval for each of the nine stations.

The recurrence interval computed using log-Pearson type III analysis (13 years) for the Red River station at Hickson was significantly less than that for the stations at Wahpeton and Fargo. The smaller recurrence interval at Hickson resulted because the years of concurrent record (1976-89) contained a disproportionate number of larger peaks than occurred during the longer periods of record at Wahpeton and Fargo. Therefore, an estimate of the Hickson recurrence interval was made as follows:

$$R.I._{Hickson} = \frac{(R.I._{Wahpeton})(POR_{Wahpeton}) + (R.I._{Fargo})(POR_{Fargo})}{POR_{Wahpeton} + POR_{Fargo}} = 26 \text{ years}$$

where

$R.I._{Hickson}$ is estimated recurrence interval for the Red River at Hickson;
$R.I._{Wahpeton}$ is recurrence interval for the Red River at Wahpeton;
$POR_{Wahpeton}$ is period of record, in years, for the Red River at Wahpeton;
$R.I._{Fargo}$ is recurrence interval for the Red River at Fargo; and
POR_{Fargo} is period of record, in years, for the Red River at Fargo.

FLOOD-DAMAGE COSTS

Total flood-damage costs in the Red River Basin, from the headwaters of the Red River to the Canadian border, were estimated at more than $8.5 million (Rudy Perpich, Governor, State of Minnesota and George A. Sinner, Governor, State of North Dakota, written commun., 1989). The cities of Wahpeton, N. Dak., and Breckenridge, Minn., had little time to prepare for the flood and consequently suffered major damage. Timely flood forecasts helped mitigate flood damage downstream by allowing time to prepare for predicted flood peaks. Below freezing temperatures on April 8-10 also helped mitigate flood damage downstream by prolonging the snowmelt, which reduced peak discharges and allowed additional time to prepare for predicted flood conditions.

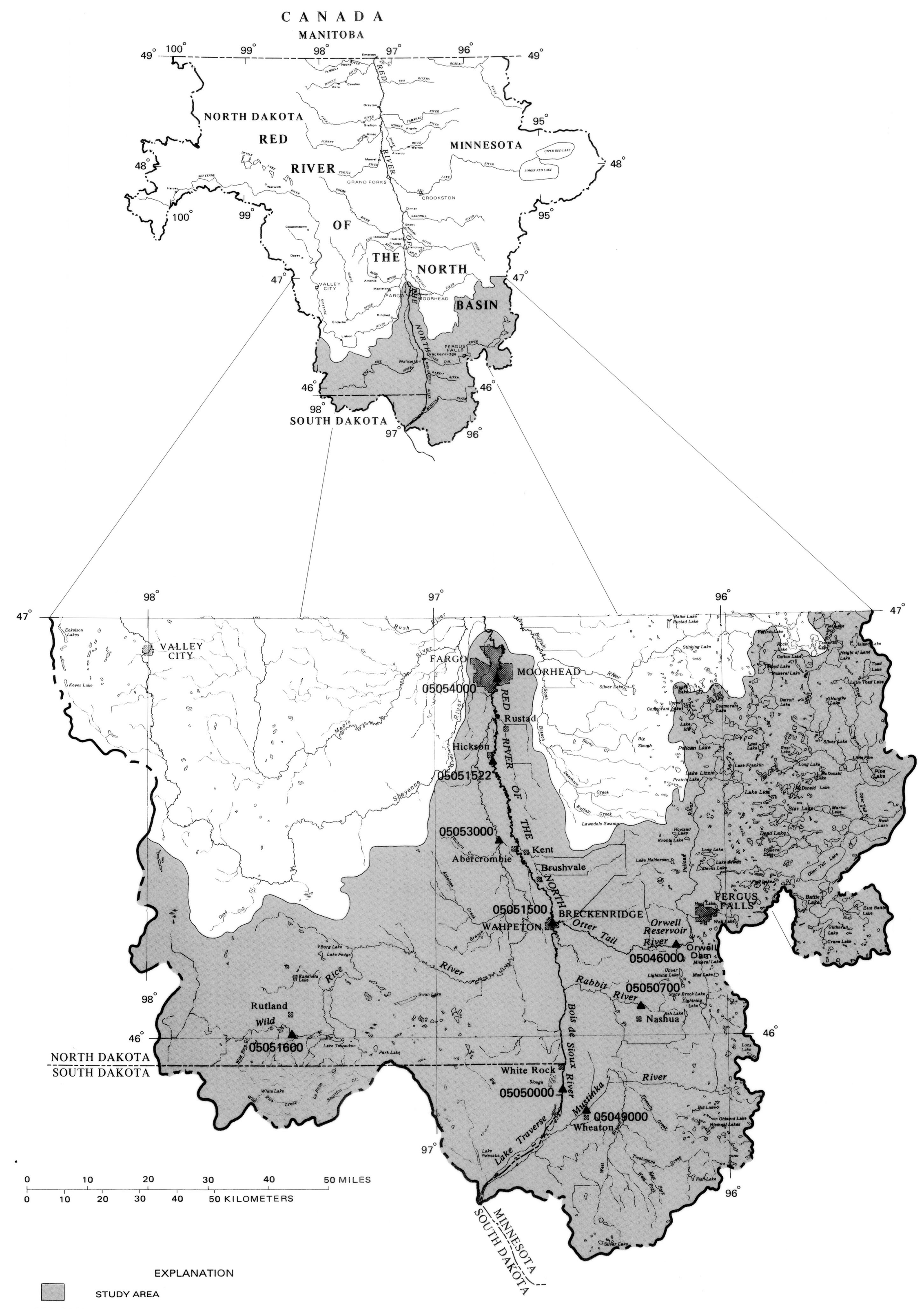

Figure 1. Location of study area in the Red River of the North Basin.

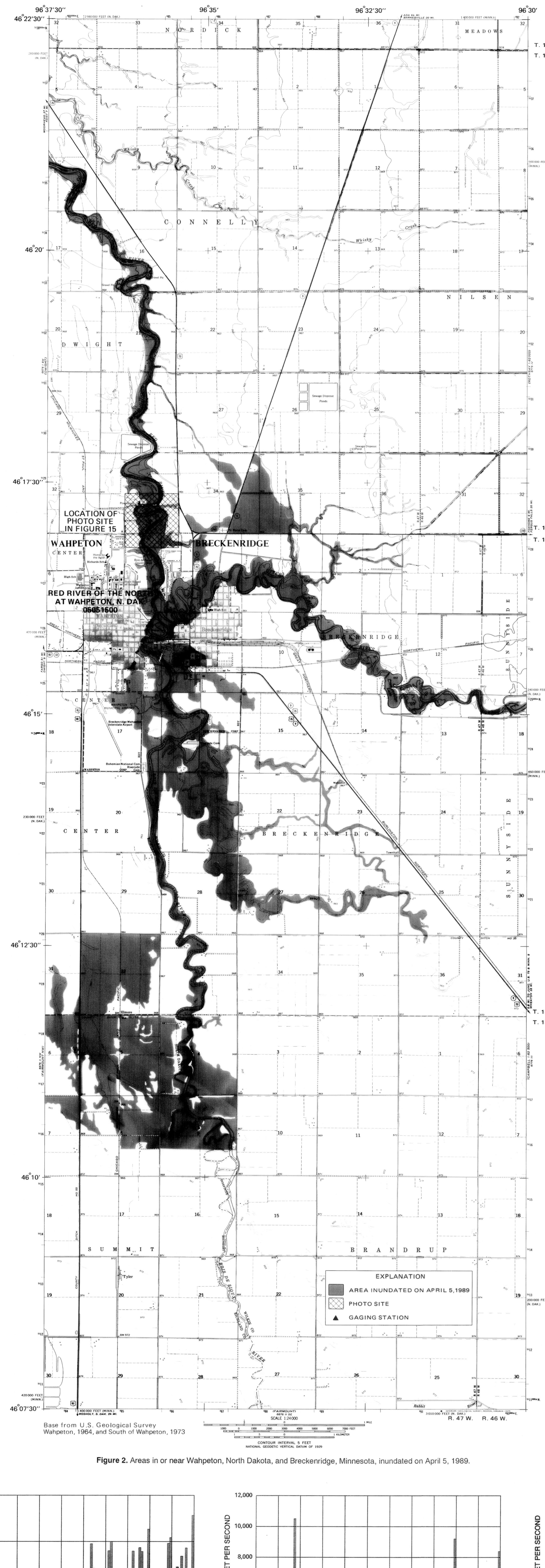

Figure 2. Areas in or near Wahpeton, North Dakota, and Breckenridge, Minnesota, inundated on April 5, 1989.

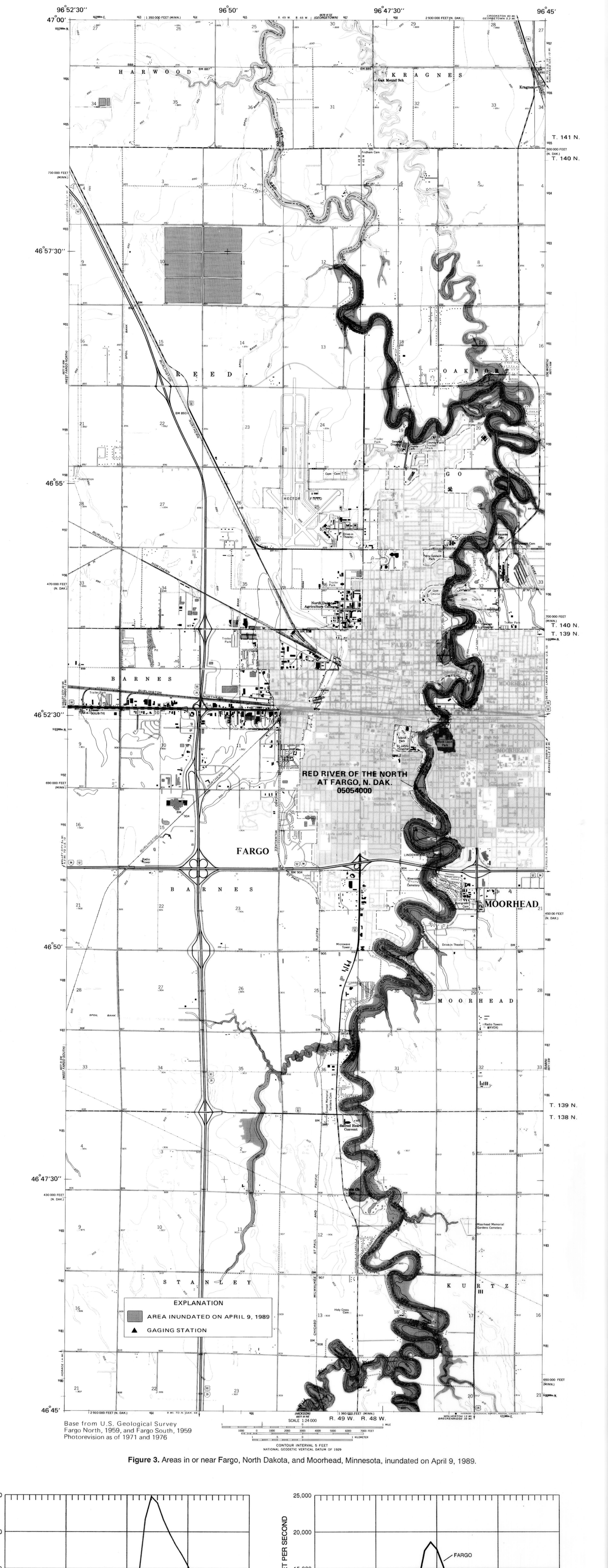

Figure 3. Areas in or near Fargo, North Dakota, and Moorhead, Minnesota, inundated on April 9, 1989.

Figure 15. River channel downstream from the Red River of the North at Wahpeton, North Dakota, gaging station, April 5, 1989. (Location of photo site shown in figure 2. Photograph from KBM, Inc., Grand Forks, North Dakota.)

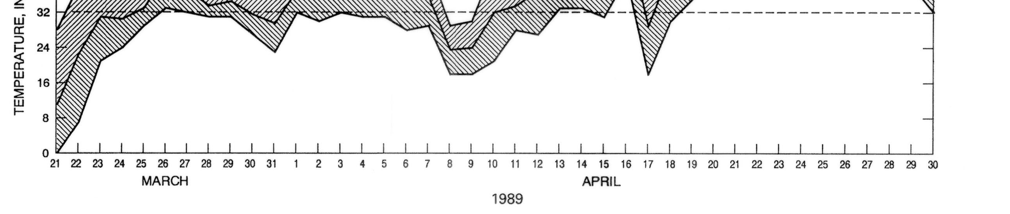

Figure 4. Maximum, mean, and minimum temperatures at Wahpeton, North Dakota, March 21 through April 30, 1989.

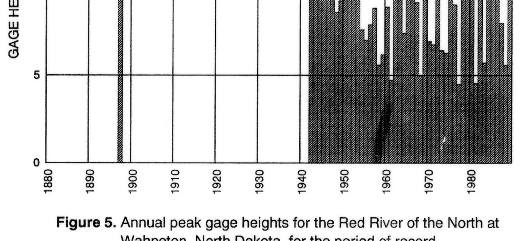

Figure 5. Annual peak gage heights for the Red River of the North at Wahpeton, North Dakota, for the period of record.

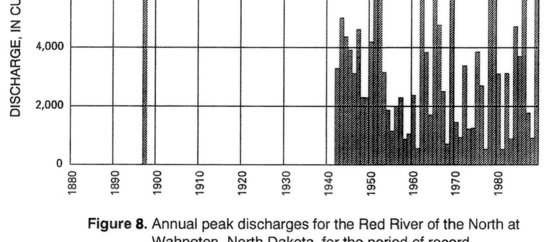

Figure 8. Annual peak discharges for the Red River of the North at Wahpeton, North Dakota, for the period of record.

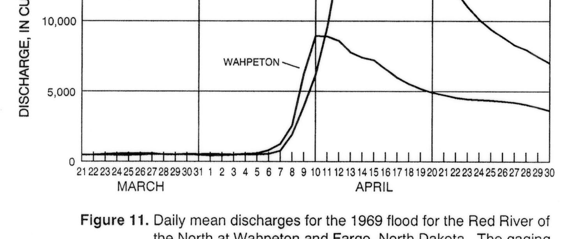

Figure 11. Daily mean discharges for the 1969 flood for the Red River of the North at Wahpeton and Fargo, North Dakota. The gaging station at Hickson was not installed until October 1975.

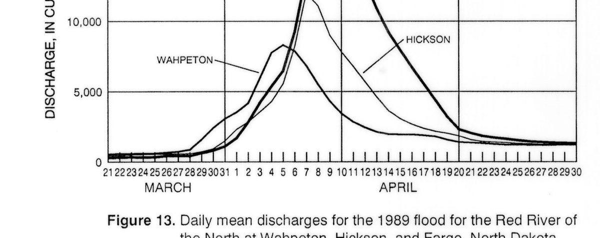

Figure 13. Daily mean discharges for the 1989 flood for the Red River of the North at Wahpeton, Hickson, and Fargo, North Dakota.

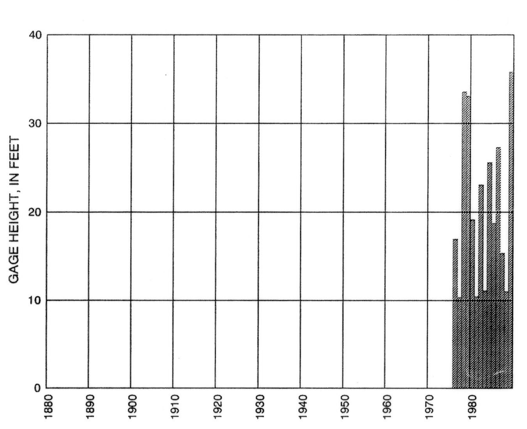

Figure 6. Annual peak gage heights for the Red River of the North at Hickson, North Dakota, for the period of record.

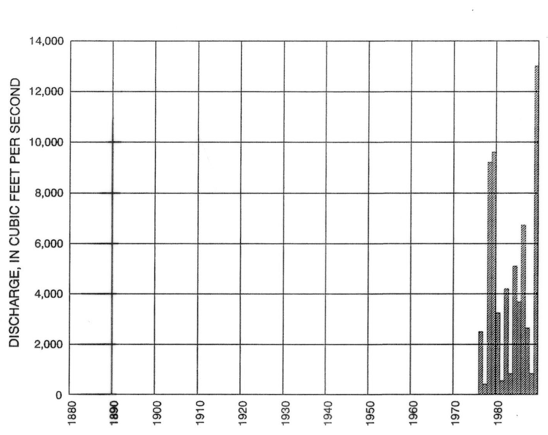

Figure 9. Annual peak discharges for the Red River of the North at Hickson, North Dakota, for the period of record.

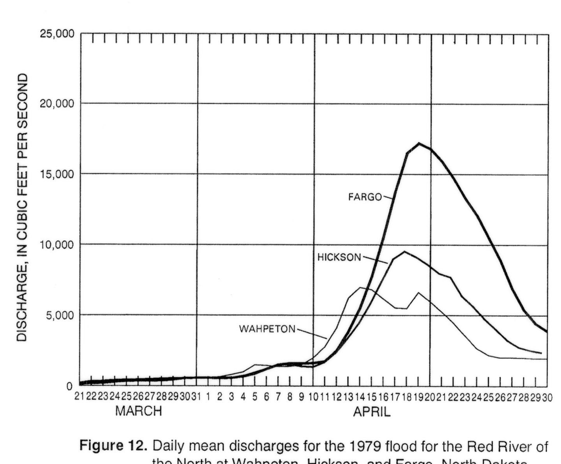

Figure 12. Daily mean discharges for the 1979 flood for the Red River of the North at Wahpeton, Hickson, and Fargo, North Dakota.

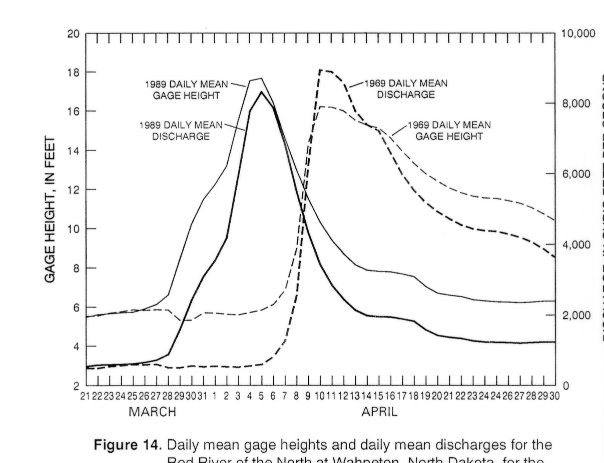

Figure 14. Daily mean gage heights and daily mean discharges for the Red River of the North at Wahpeton, North Dakota, for the March 21 through April 30, 1969 and 1989 floods.

Table 1. Summary of gage heights and discharges in the study area

[-- indicates no data are available]

Station number	Gaging or partial-record station	Drainage area (square miles)	Period of record	Maximums previously known: Date	Maximums previously known: Gage height (feet)	Maximums previously known: Discharge (cubic feet per second)	Maximums during 1989 flood: Date	Maximums during 1989 flood: Gage height (feet)	Maximums during 1989 flood: Discharge (cubic feet per second)	Recurrence interval (years)
05046000	Otter Tail River below Orwell Dam, near Fergus Falls, Minn.	1,830	1931-89	06-17-53 06-01-66 05-27-86	5.60 4.59 4.75	1,710 1,490 1,600	04-10-89	4.17	[1]1,180	5
05049000	Mustinka River above Wheaton, Minn.[2]	834	1916-24, 1931-58, 1985-89	04-08-51 04-10-52 03-29-86	-- -- 18.91	3,180 7,320 5,500	03-29-89	20.01	5,400	26
05050000	Bois de Sioux River near White Rock, S. Dak.	1,160	1942-89	08-06-62 [3]04-20-69 05-07-86	11.41 15.07 12.12	1,620 3,770 1,820	04-14-89	10.72	[1]693	3
05050700	Rabbit River near Nashua, Minn.	56	1979-89	06-08-84 05-09-85 09-21-86	14.06 13.34 14.27	910 960 1,280	03-27-89	[4]15.08	760	4
05051500	Red River of the North at Wahpeton, N. Dak.	4,010	1897, 1942-89	Spring, 1897 04-10-69 04-14-79	17.00 16.34 [4]15.44	10,500 9,200 7,050	04-05-89	[4]17.95	8,370	21
05051522	Red River of the North at Hickson, N. Dak.	4,300	1976-89	04-02-78 04-18-79	33.54 33.03	9,200 9,600	04-07-89	35.81	12,900	[5]26
05051600	Wild Rice River near Rutland, N. Dak.	546	1960-89	03-15-66 04-08-69 03-29-78	[4]7.12 [4]8.77 [4]7.64	660 1,270 600	03-31-89	[4]8.47	700	12
05053000	Wild Rice River near Abercrombie, N. Dak.	2,080	1897, 1933-89	Spring, 1897 04-11-69 04-15-79	27.50 24.58 [4]22.39	-- 9,540 6,000	04-07-89	23.27	7,150	31
05054000	Red River of the North at Fargo, N. Dak.	6,800	1882, 1897, 1902-89	[6]04-11-1882 [6]04-07-1897 04-15-69 04-19-79	37.80 39.10 37.34 34.93	20,000 25,000 25,300 17,300	04-09-89	35.39	18,900	29

[1]Results of regulation.
[2]Partial-record station.
[3]Occurred on about the date given.
[4]Backwater from ice.
[5]The recurrence interval was estimated based on recurrence intervals and length of record at the adjacent stations on the Red River of the North at Wahpeton and at Fargo.
[6]Site was 1.5 miles downstream from present gaging station.

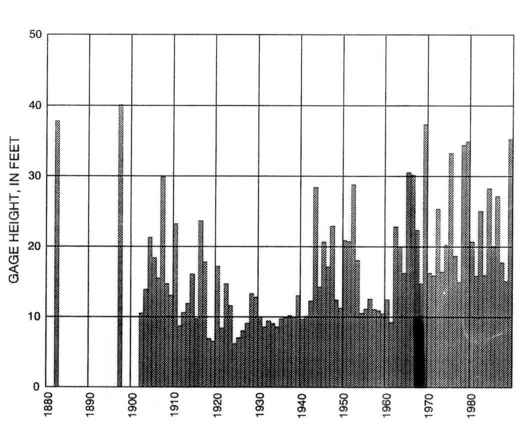

Figure 7. Annual peak gage heights for the Red River of the North at Fargo, North Dakota, for the period of record.

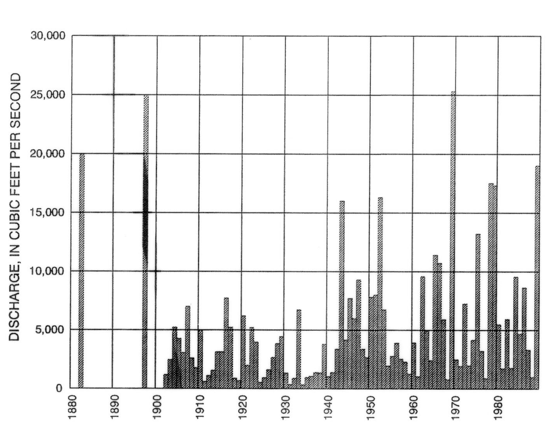

Figure 10. Annual peak discharges for the Red River of the North at Fargo, North Dakota, for the period of record.

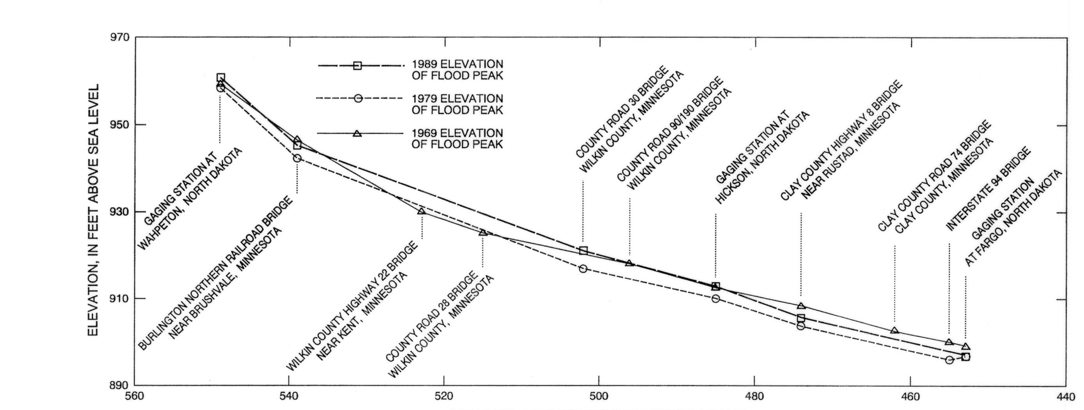

Figure 16. Flood-crest profile for the Red River of the North from Wahpeton to Fargo, North Dakota.

FLOOD OF APRIL 1989 IN THE WAHPETON-BRECKENRIDGE AND FARGO-MOORHEAD AREAS, RED RIVER OF THE NORTH BASIN, NORTH DAKOTA AND MINNESOTA

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1993

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