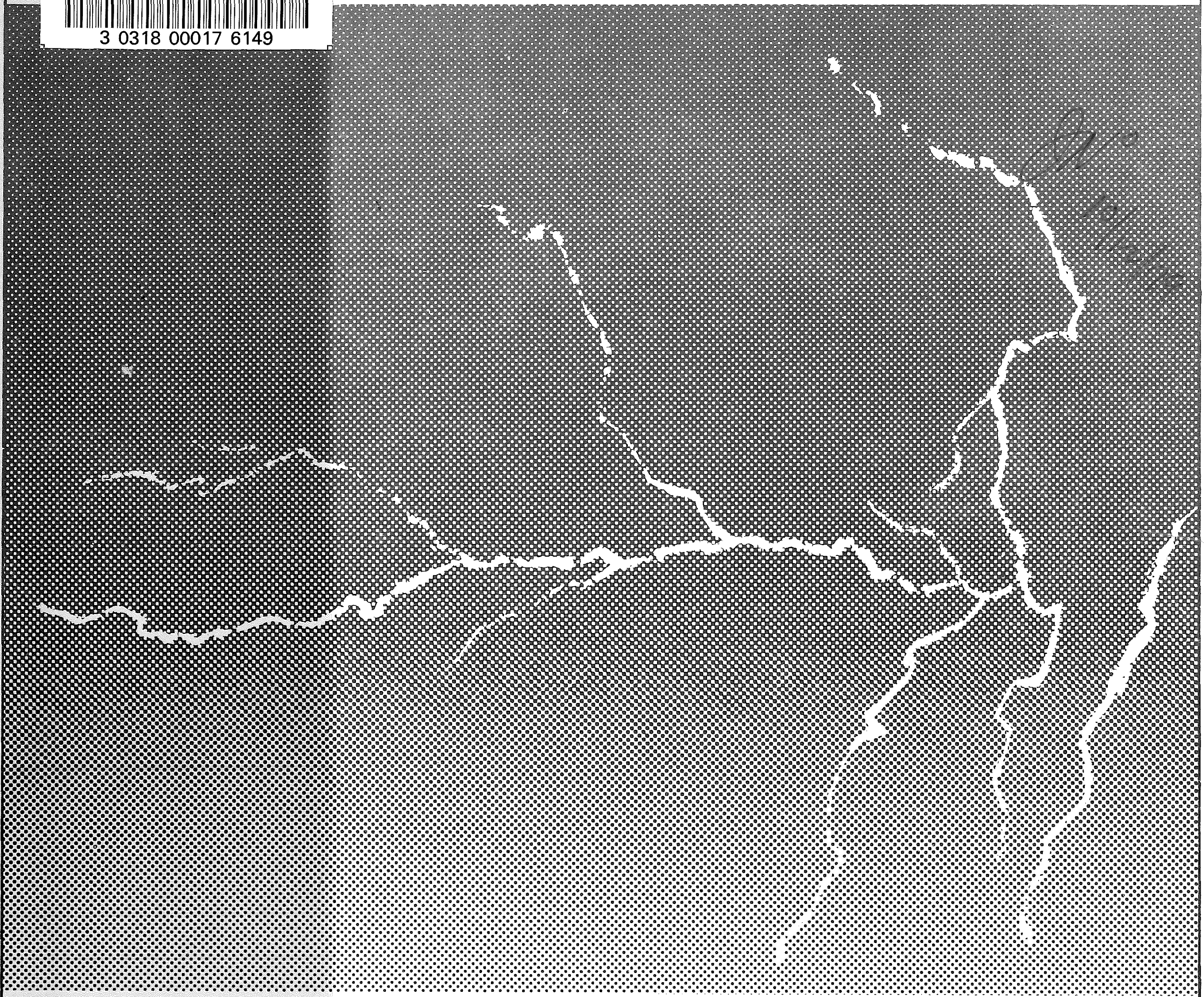
1978 Hydrologic Year Data Publication July 1979

lake hydrology ground water basic data



1978 Division of Waters Hydrologic Year Data 1978

DIVISION of WATERS
HYDROLOGIC YEAR DATA
1978

MINNESOTA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATERS

DIVISION of WATERS
HYDROLOGIC YEAR DATA 1978

1978 Hydrologic Year Data Publication
by the Division of Waters Staff

July 1979
900

MINNESOTA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATERS

DIVISION OF WATERS HYDROLOGIC YEAR DATA 1978

INTRODUCTION

As part of its on-going investigations of the water resources of the State of Minnesota, the Division of Waters of the Department of Natural Resources collects and compiles a variety of hydrologic and climatologic data. Division staff monitor all aspects of the hydrologic cycle, from rain and snow to ground water levels in wells, to stream flow and lake levels. These data are used by the Division in making decisions to approve or not approve a permit application, in making recommendations for modification or realignment of project components to meet environmental and regulatory standards, and in developing a general assessment or inventory of our water supplies.

The Division of Waters has as a long range objective to have information in sufficient detail and with sufficient density to describe the water resources of Minnesota adequately for the many purposes for which this information is needed. These data must be made available in useable form to the permit applicant, project designer, planner and policy-maker to fully achieve our goal. Toward that end this publication, which is intended to appear annually, reports some of data and analyses developed by the Division during Hydrologic Year 1978, October 1, 1977 to September 30, 1978. In future years we hope this publication will expand to contain data from additional programs within the Division of Waters. If the report format or content could be altered to better meet your needs, please let us know; your suggestions are welcomed.

The contents are organized to follow the hydrologic cycle with climatologic data followed by surface water data followed lastly by ground water data. The sequence is intended to suggest the interrelationships of the various elements and to hint at the dynamic nature of water bodies and water supplies. In some instances indices to data rather than the data themselves are published. For example rather than publish logs of observation wells, their locations are shown on a map. The logs and measurements are available at the Division Office in St. Paul at 444 Lafayette Road. (3rd Floor, Space Center Building). Your inquiries are welcomed.

Sarah P. Tufford

Hydrology Section Supervisor

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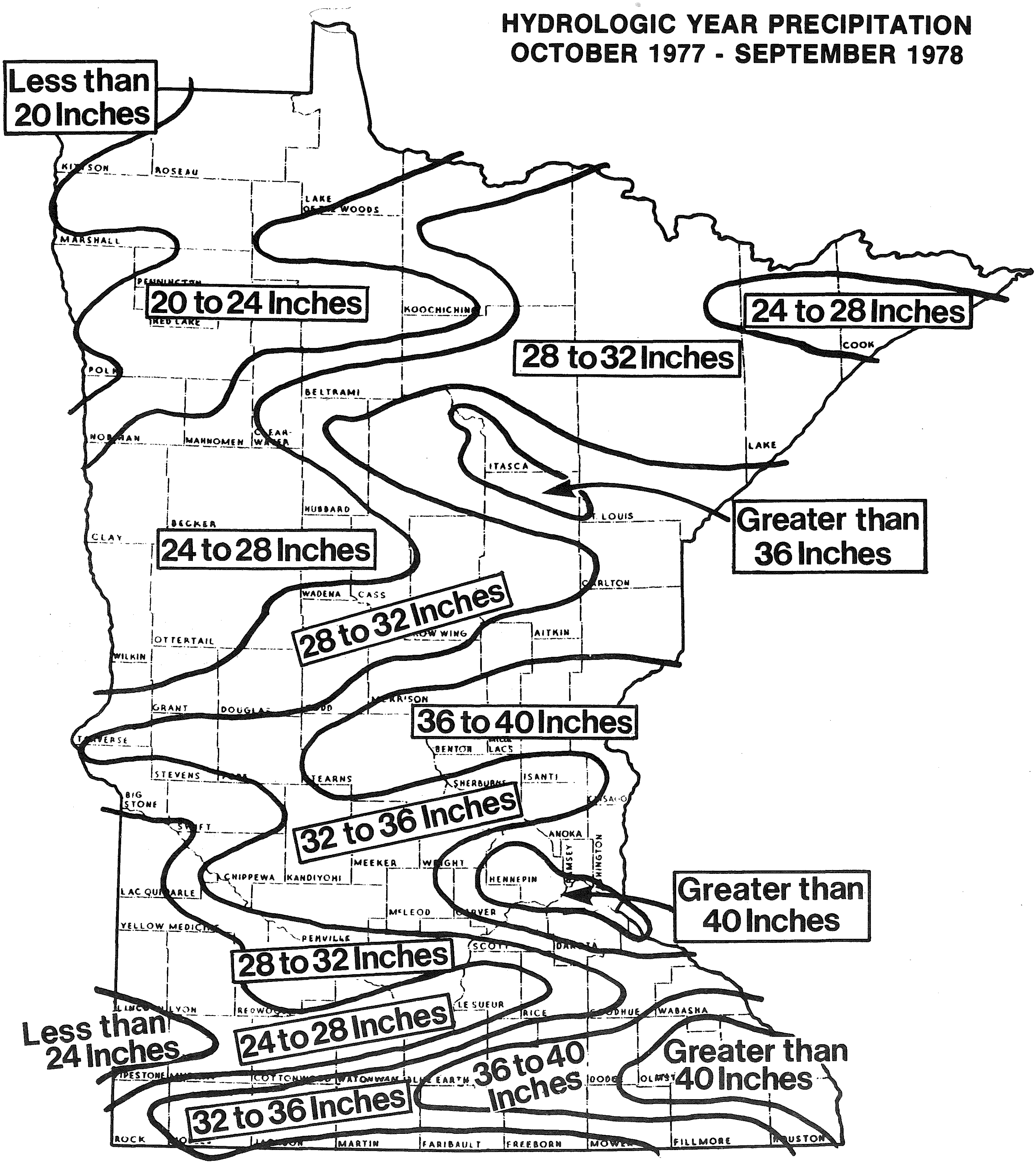
HYDROLOGIC YEAR PRECIPITATION
OCTOBER 1977 - SEPTEMBER 1978

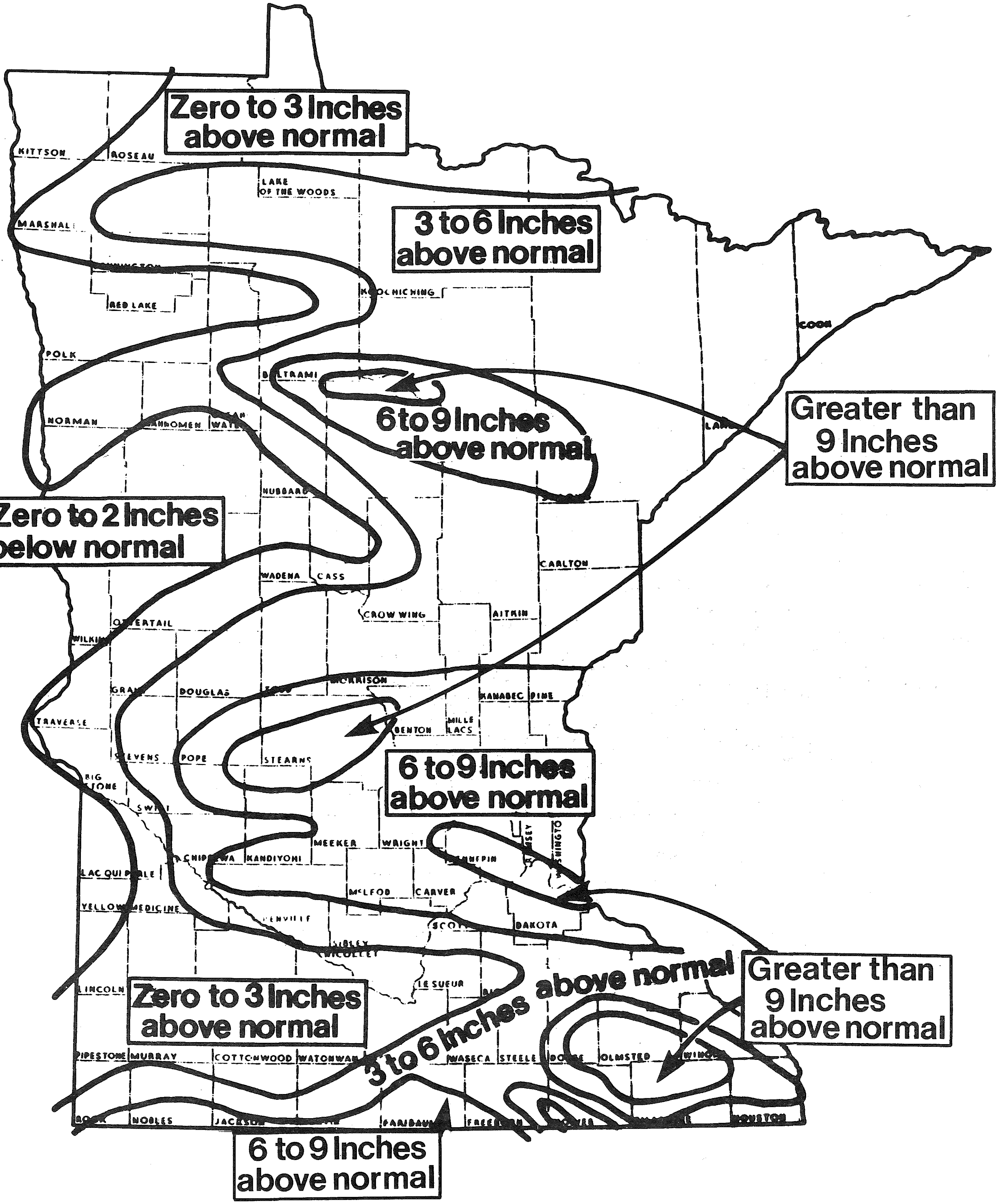
The hydrologic or hydrology year in Minnesota begins October 1st and ends September 30th the following year. The 1978 Minnesota hydrologic year was wet. Other wet hydrologic years were 1941, 1965, and 1972. Precipitation for the state averaged 29.37 inches or 4 inches above the normal. The wettest area was east central Minnesota, averaging nearly 35 inches of precipitation, while the central, south central and the southeast areas of Minnesota averaged more than 30.5 inches of precipitation. Rosemount and Elgin, northeast of Rochester, were the two wettest locations with 45.69 and 45.27 inches respectfully, of precipitation, or about 15 to 16 inches above normal. The only areas that had below normal precipitation were three irregular areas along the North Dakota border and a small area along the South Dakota border and near Austin, Minnesota.

HYDROLOGIC YEAR PRECIPITATION
OCTOBER 1977 - SEPTEMBER 1978

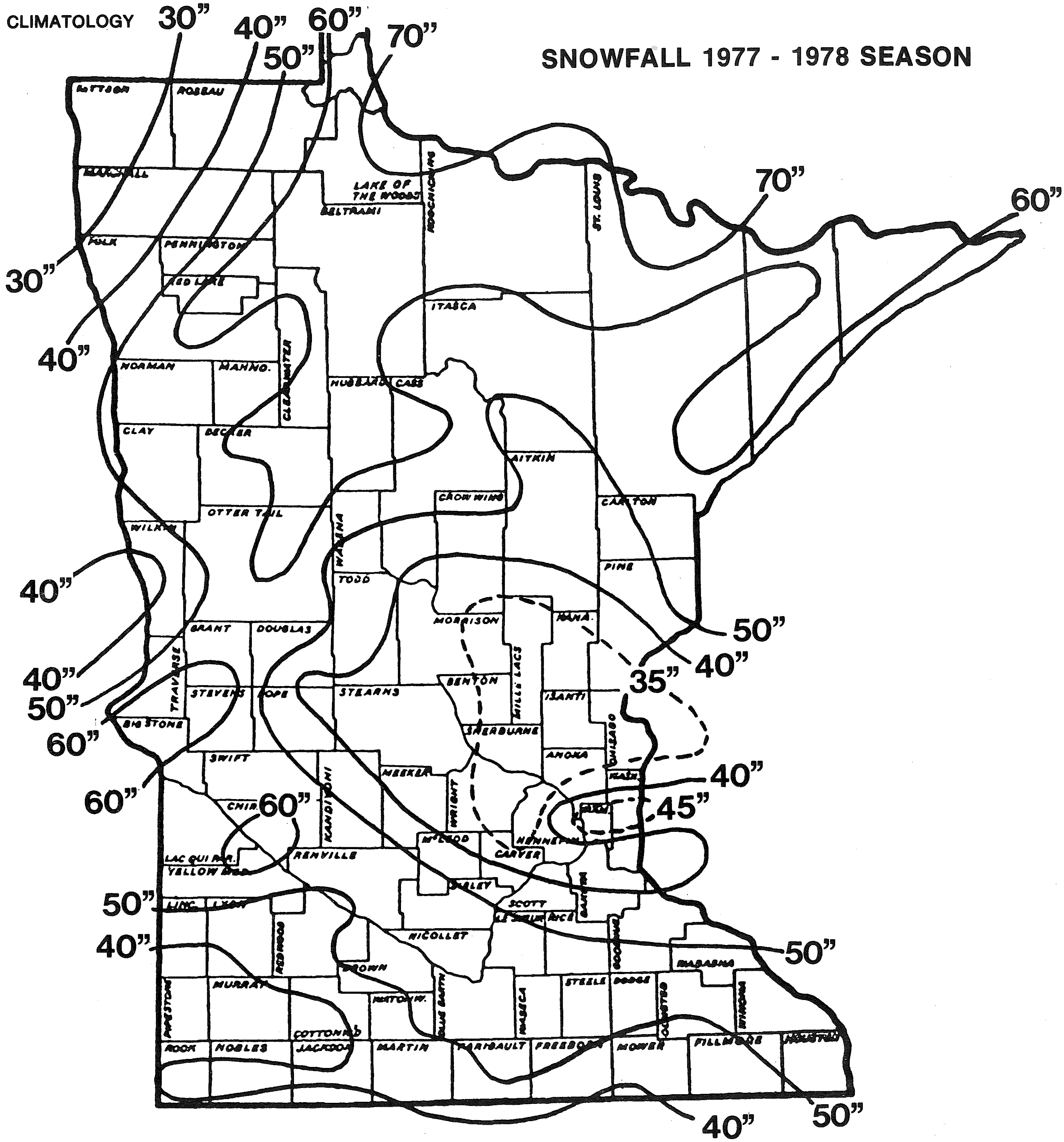


Isolines are drawn through points of approximately equal value. Caution should be used in interpolating on these maps.

PRECIPITATION DEPARTURE FROM NORMAL
HYDROLOGIC YEAR (OCTOBER 1977 - SEPTEMBER 1978)



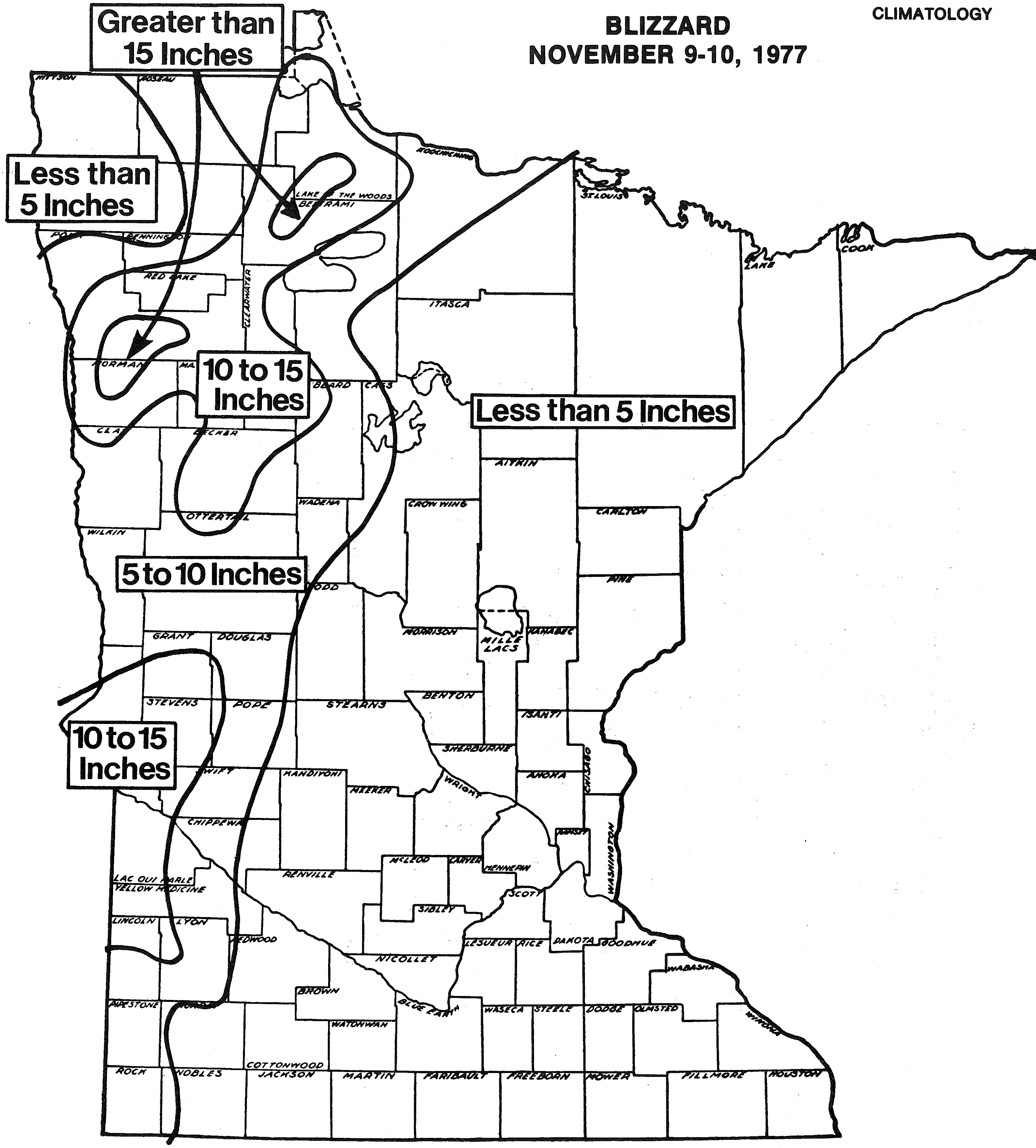
SNOWFALL 1977 - 1978 SEASON



The 1977-78 snowfall season was about 10 inches above the normal in west-central Minnesota, the northern part of the state and a strip 40 to 50 miles wide along the upper Minnesota River to Mankato, and then eastward across the state into Wisconsin.

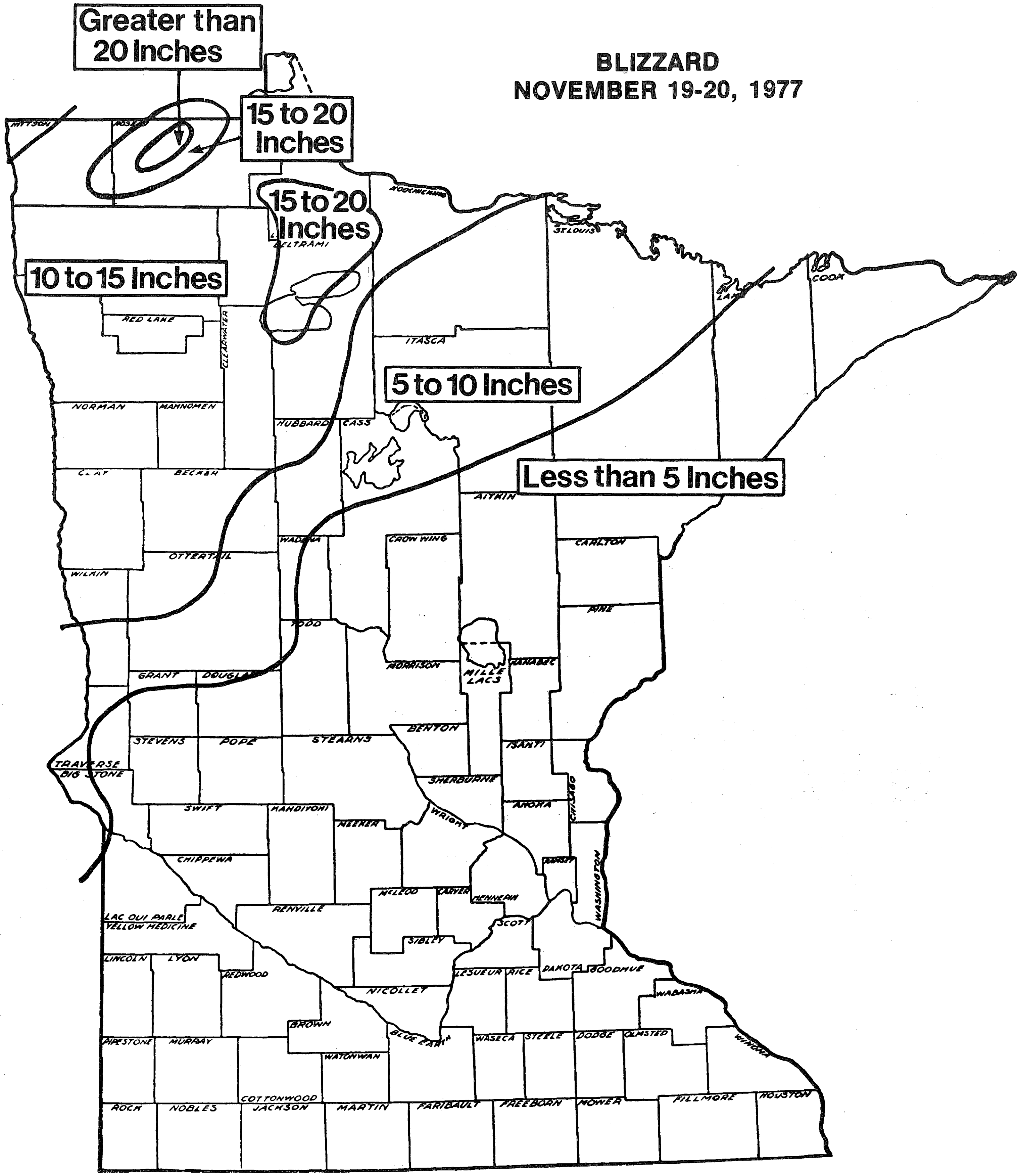
The lightest snowfall area, which was about 10 inches below normal, was generally within the area bounded by the northern suburbs of the Twin Cities, St. Cloud, Lake Mille Lacs and east to the Wisconsin border. The two blizzards of the season occurred on November 9-10 and November 19-20, 1977 and both in the northwest part of the state.

BLIZZARD
NOVEMBER 9-10, 1977



This was an exceptionally dangerous blizzard because it occurred so very early in the season. Wind speeds of 60 to 80 mph and snow falls of near 20 inches occurred in the northwestern part. Two hunters died in the storm.

BLIZZARD NOVEMBER 19-20, 1977



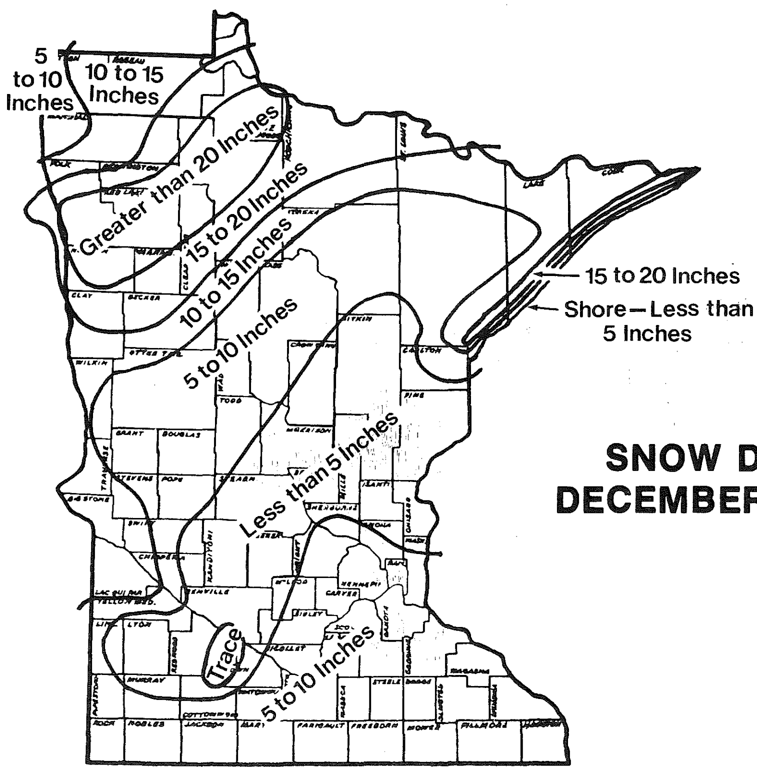
The blizzard occurred over the same area as the November 9-10 blizzard, however, the winds were not as strong (40-60 mph) and the heavy snow of 10-15 inches covered a larger area. Adding to the earlier snows, this heavy snow caused hardships to this area the rest of the winter, including its wildlife.

SNOW DEPTH MAPS OF 1977 - 1978 WINTER SEASON WITH ICE OUT DATA

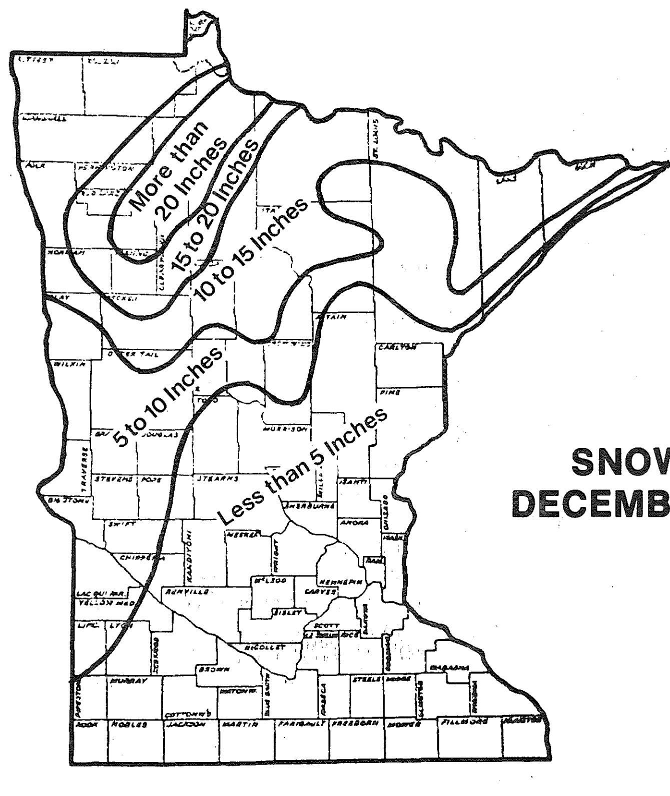
The iso-hyetal maps of snow depths from December 1 to May 10 for spring serve as an annual history of our winter weather. The spring snow melt and lake ice melt data are new tools in assessing and describing the State's climate. These data measure indirect factors relating to spring forest fire danger, the date frost leaves the ground which in turn affects agricultural field work and various phenological events. All of these relationships require further study as we annually add the snow melt and ice melt maps to the past records.

The annual file of snow depth maps in time can be used to approximate spring run-off, agriculture and forest soil moisture recharge, lake level recharge, ground water recharge, spring flood potential, winter recreation potential, wildlife and fish problems.

The snow depth maps are prepared weekly during the winter by the State Climatology Office. Reports are received from about 200 Department of Natural Resources Observers, and 10 National Weather Service Stations. The DNR reports are telephoned to the DNR Information and Education Bureau by State Parks and State Forestry Personnel.

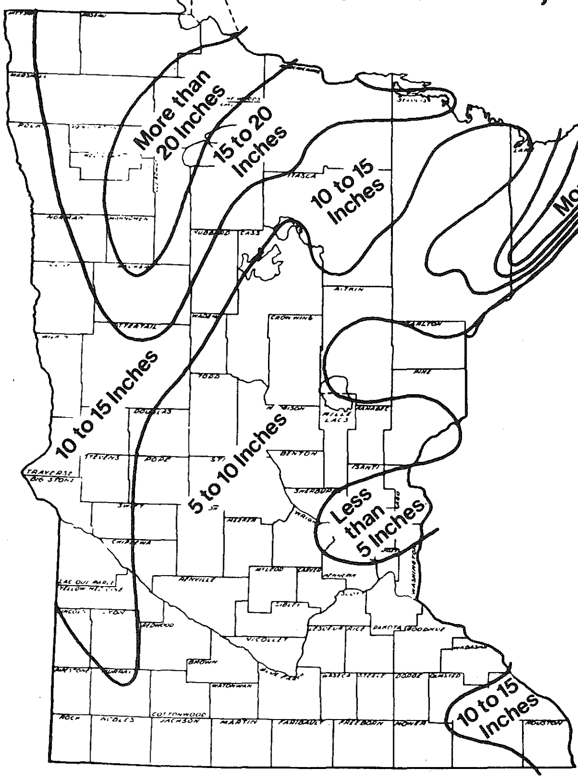


SNOW DEPTH
DECEMBER 1, 1977



SNOW DEPTH
DECEMBER 20, 1977

SNOW DEPTH JANUARY 4, 1978



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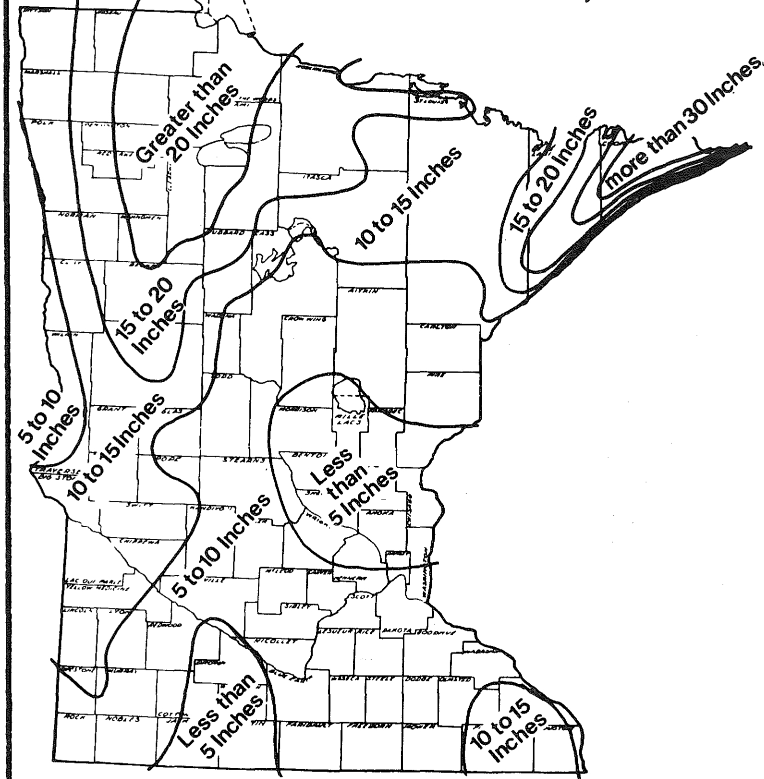

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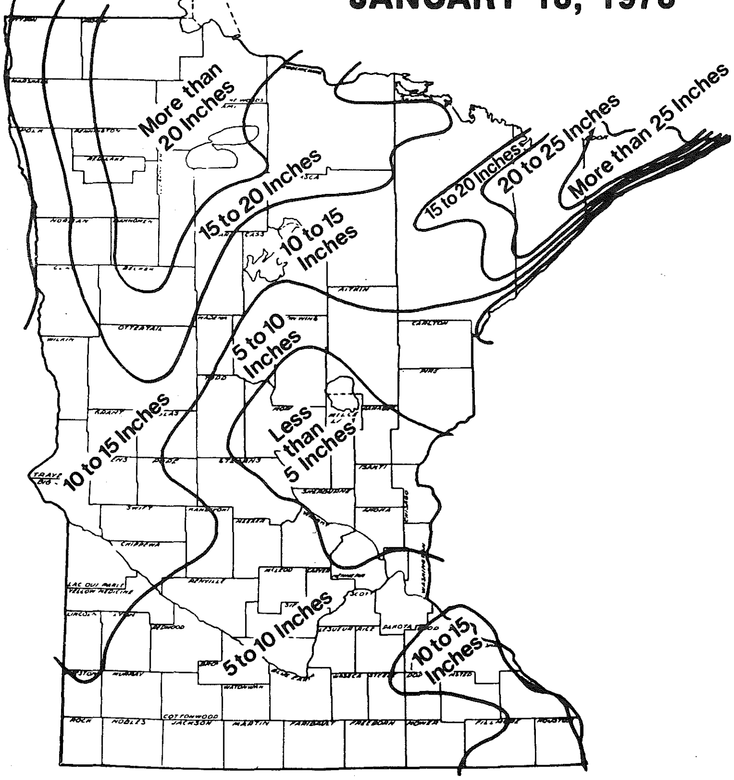
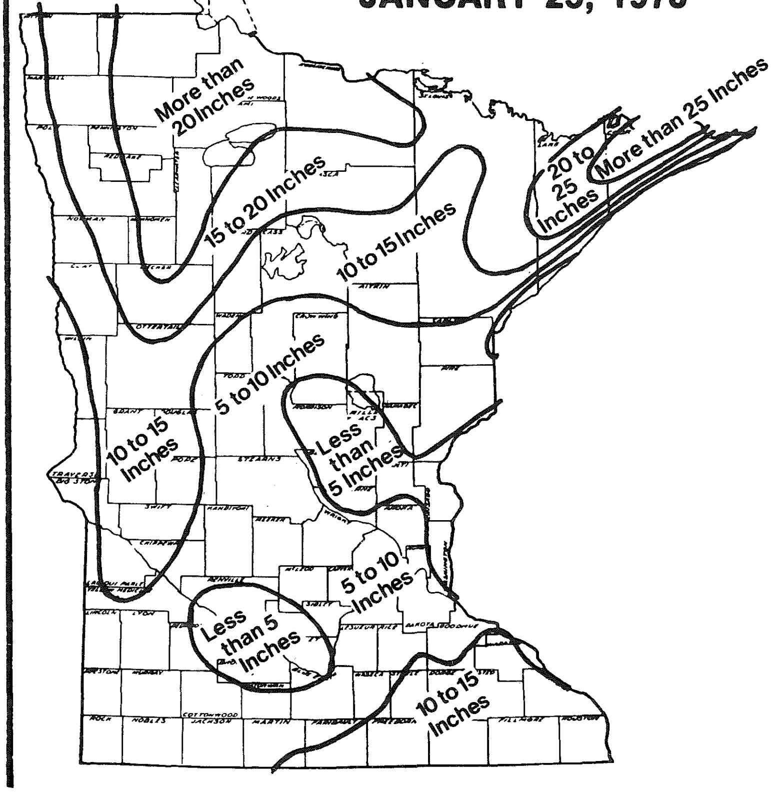
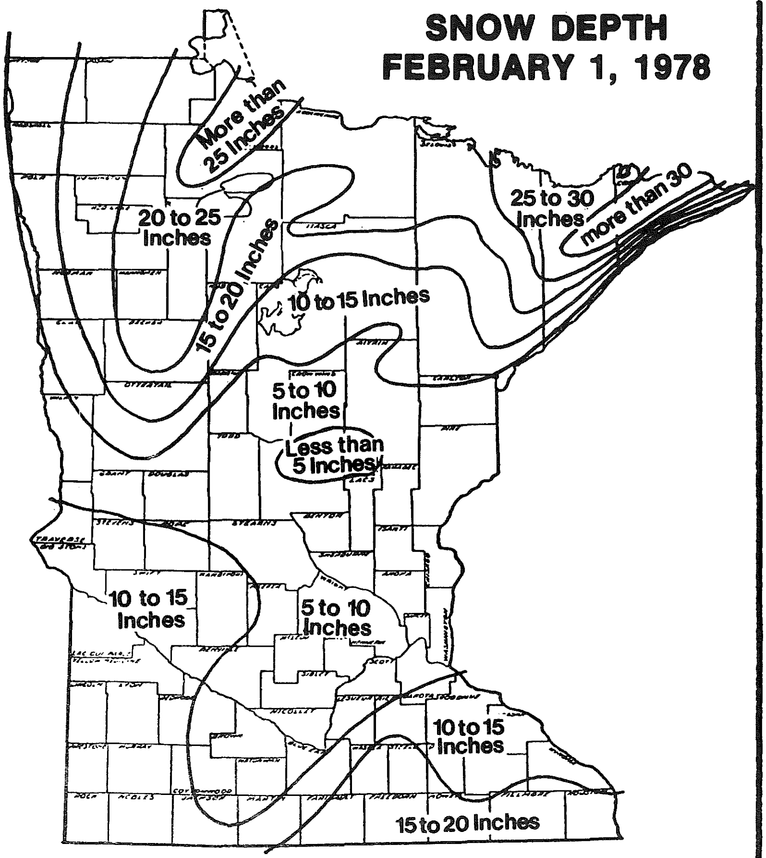


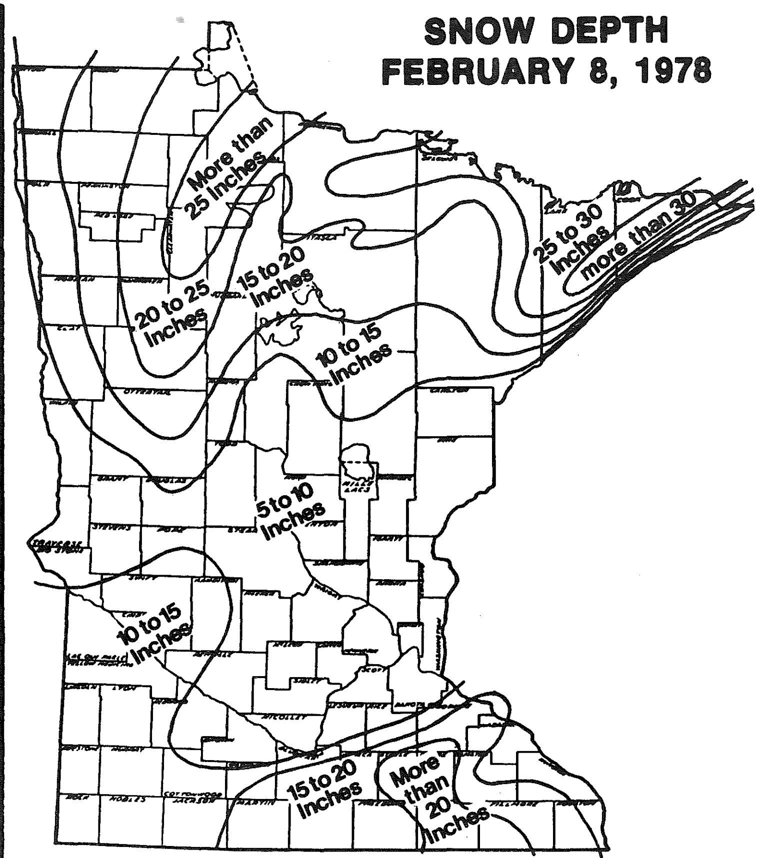
SNOW DEPTH JANUARY 25, 1978



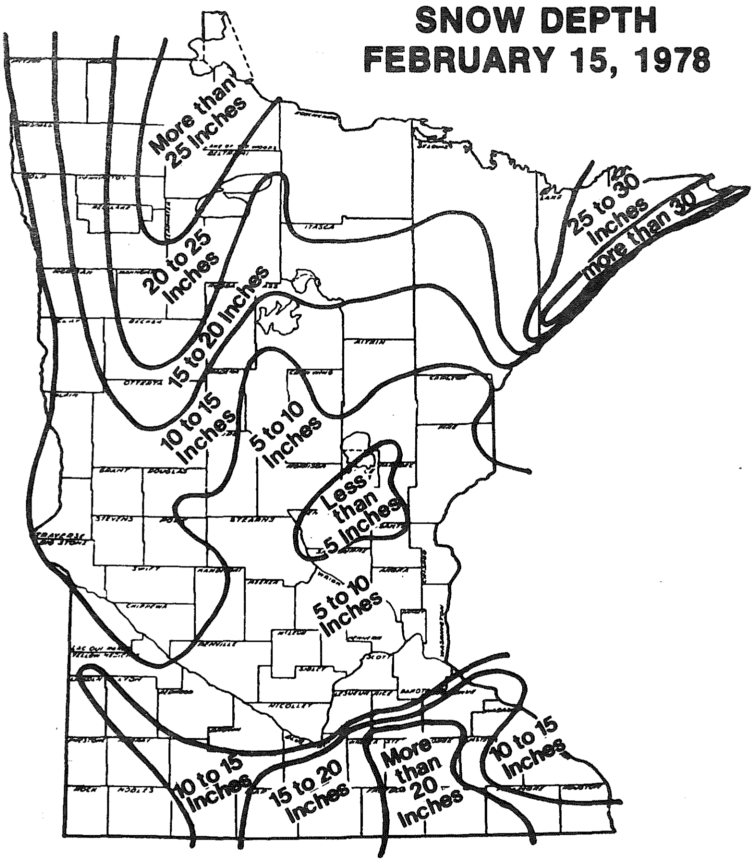
SNOW DEPTH FEBRUARY 1, 1978



SNOW DEPTH FEBRUARY 8, 1978



SNOW DEPTH FEBRUARY 15, 1978



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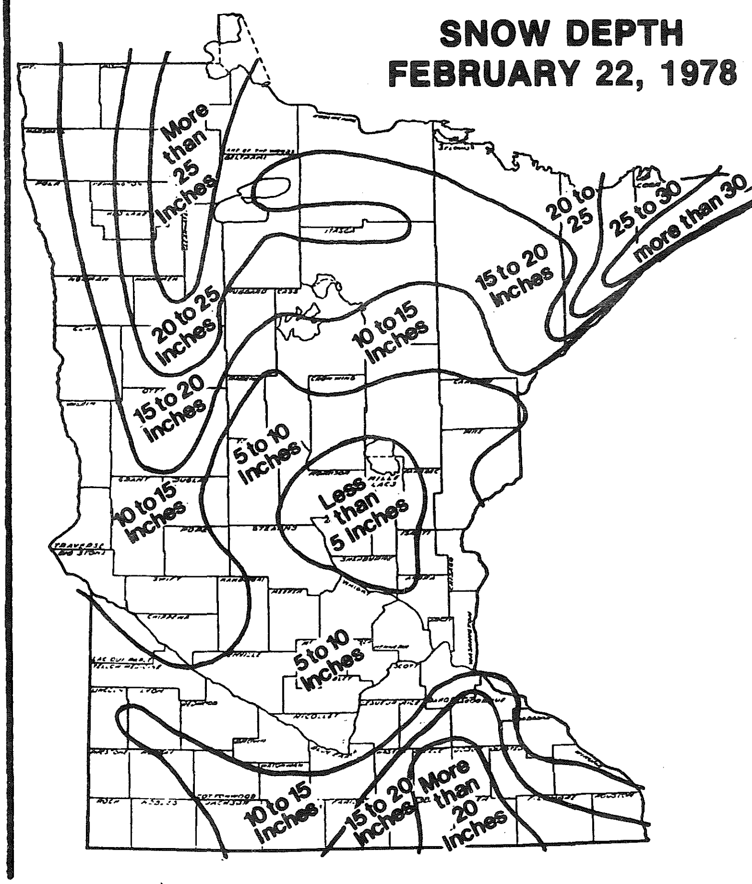

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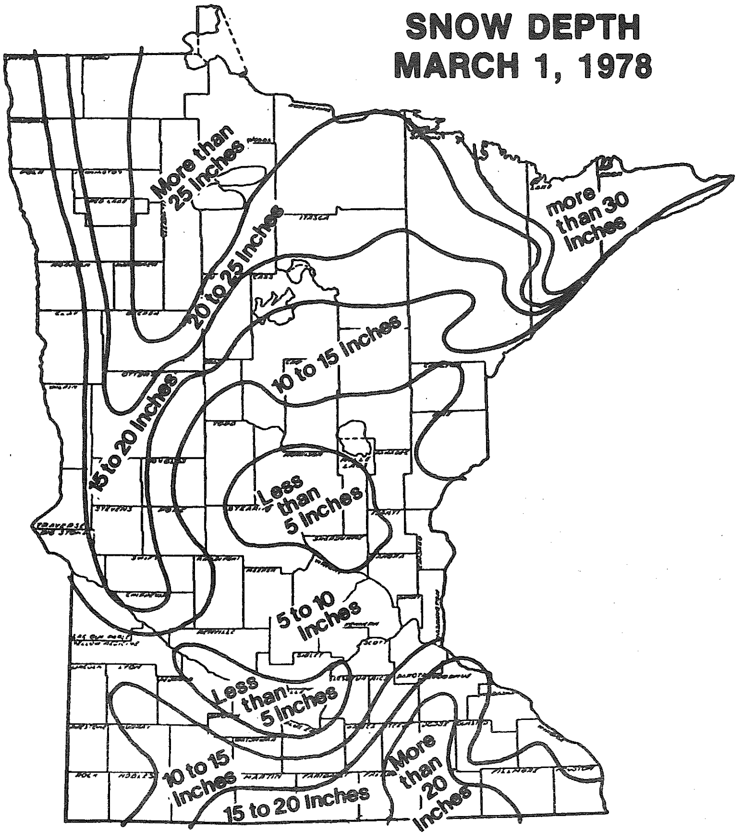

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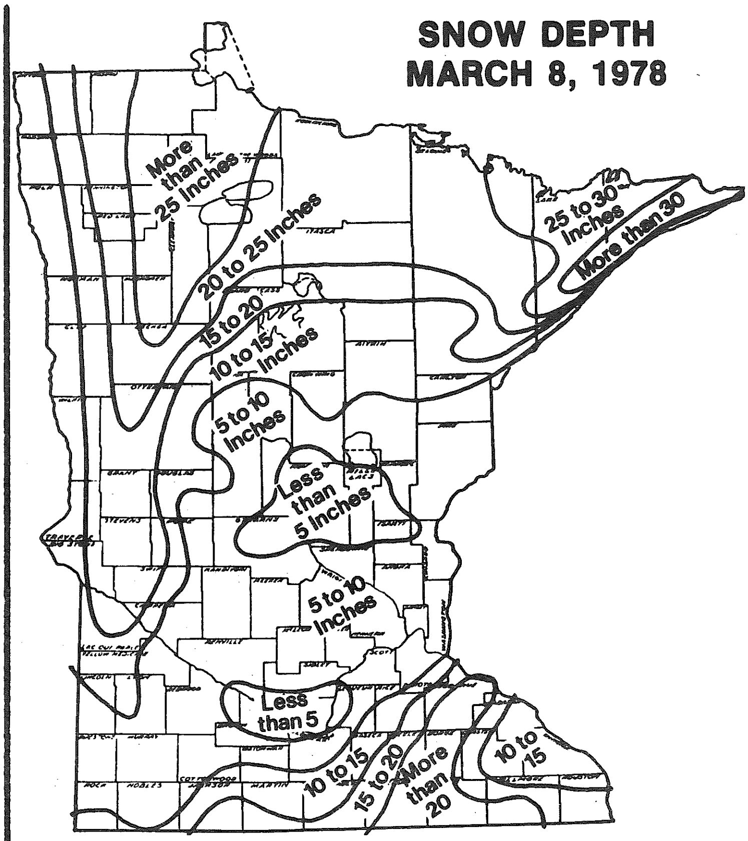

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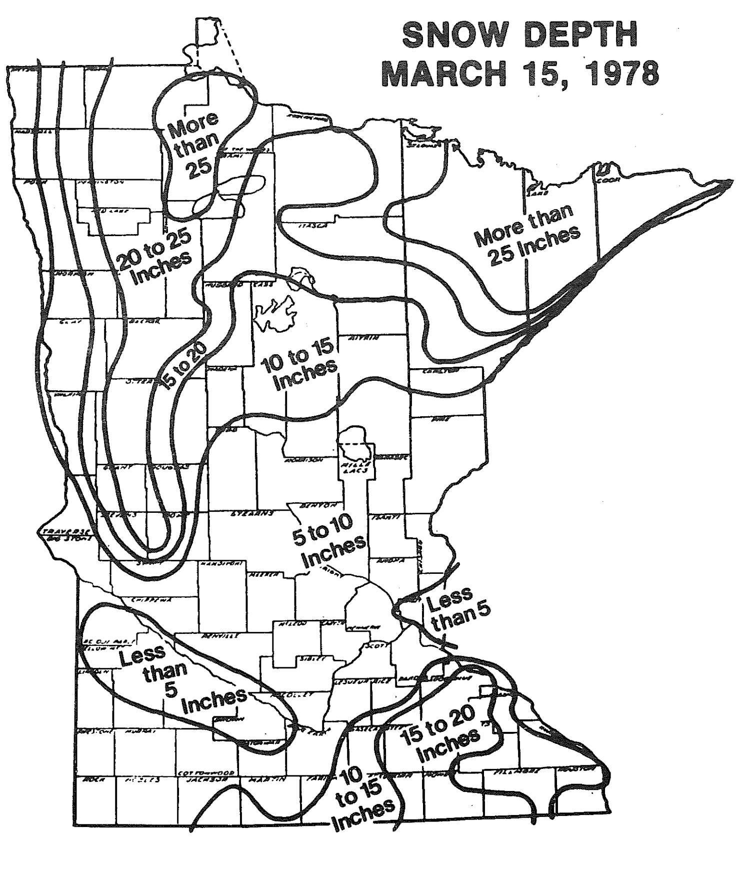

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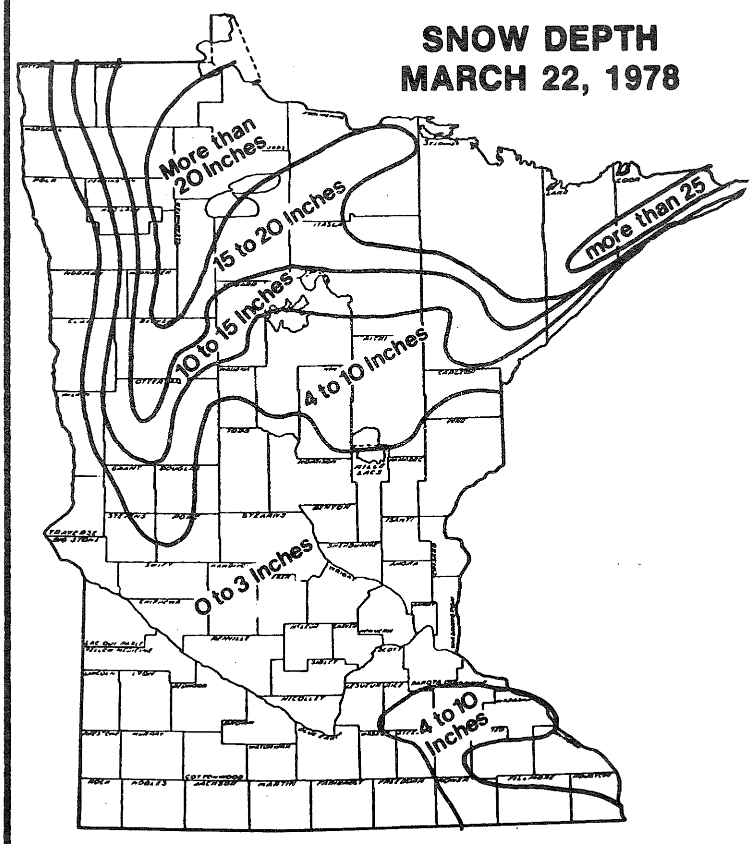
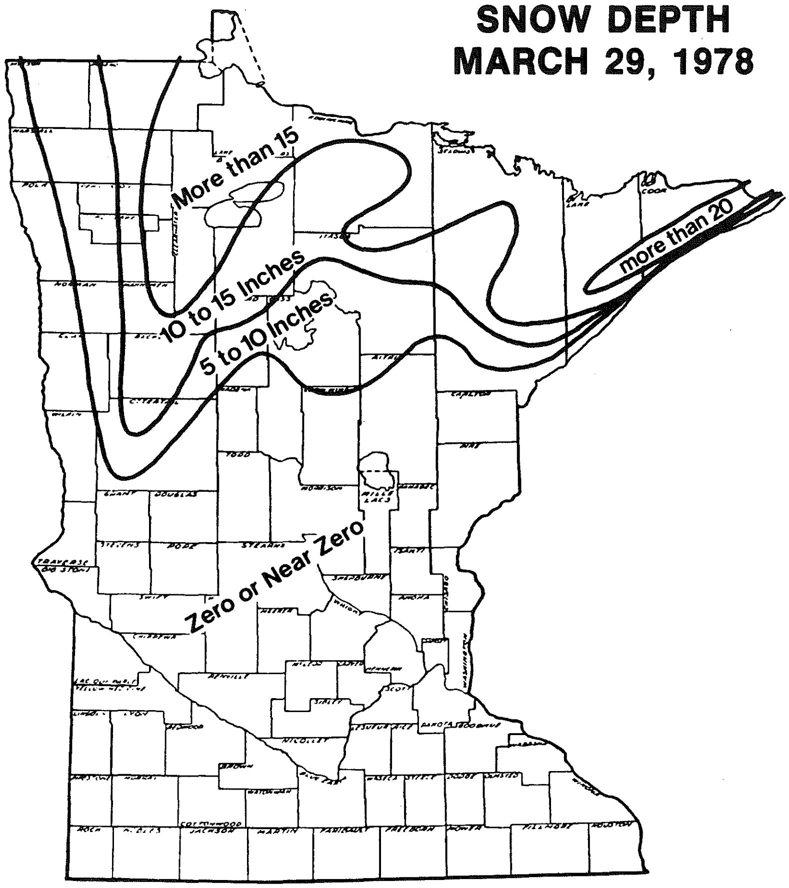
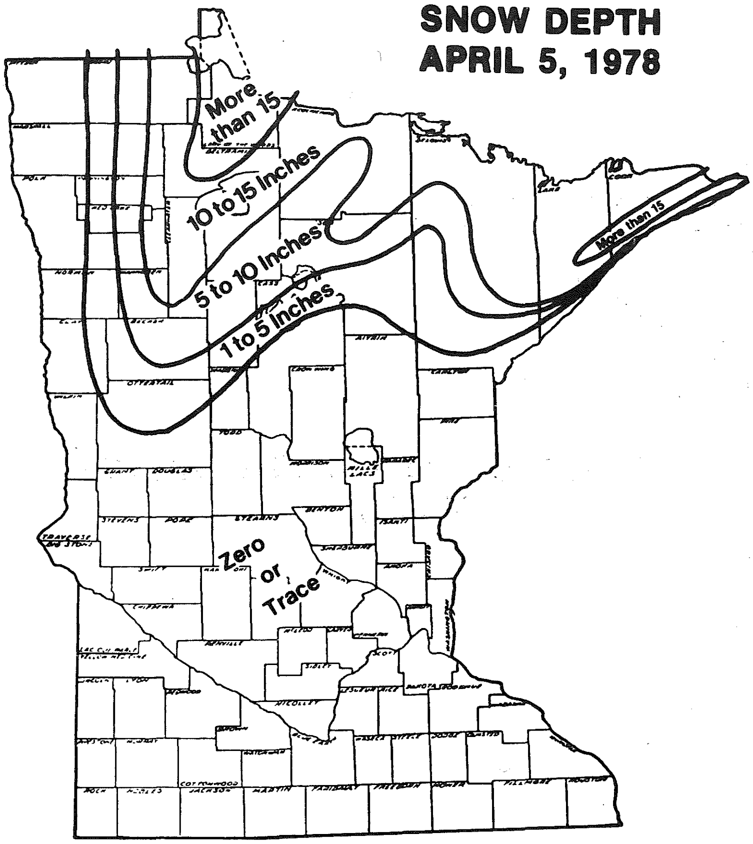


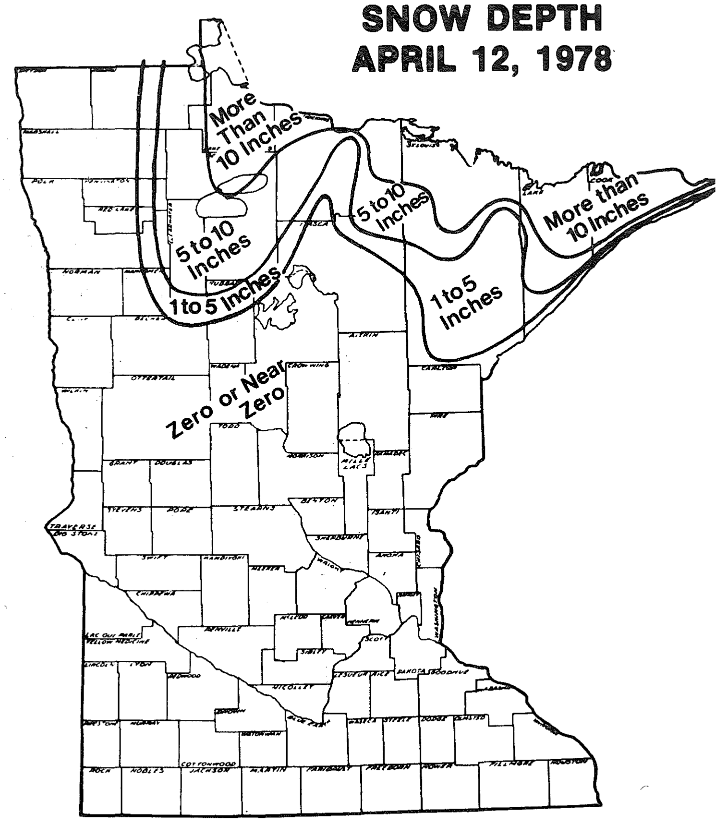
SNOW DEPTH
MARCH 29, 1978



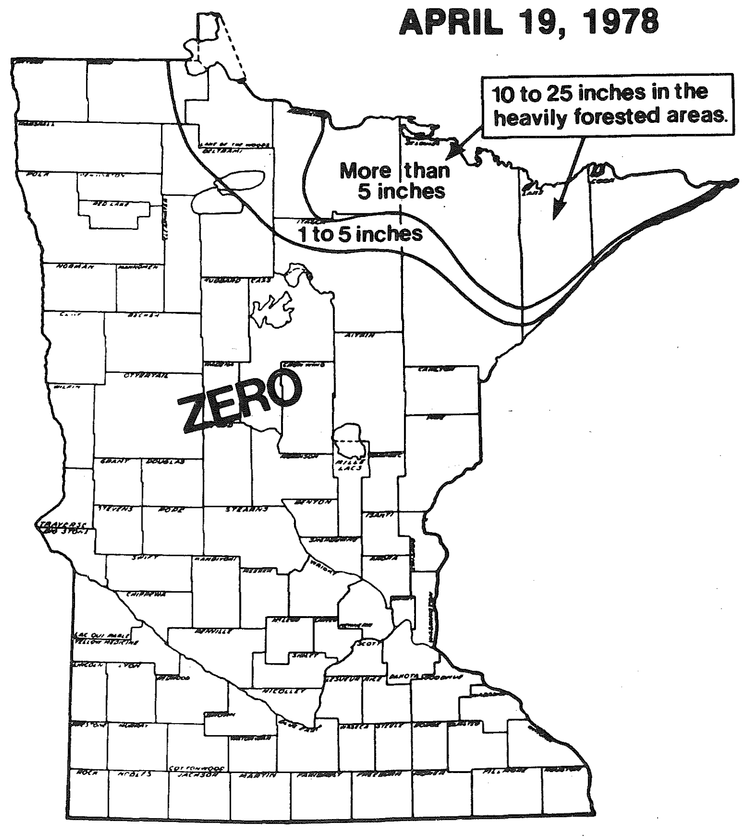
SNOW DEPTH APRIL 5, 1978



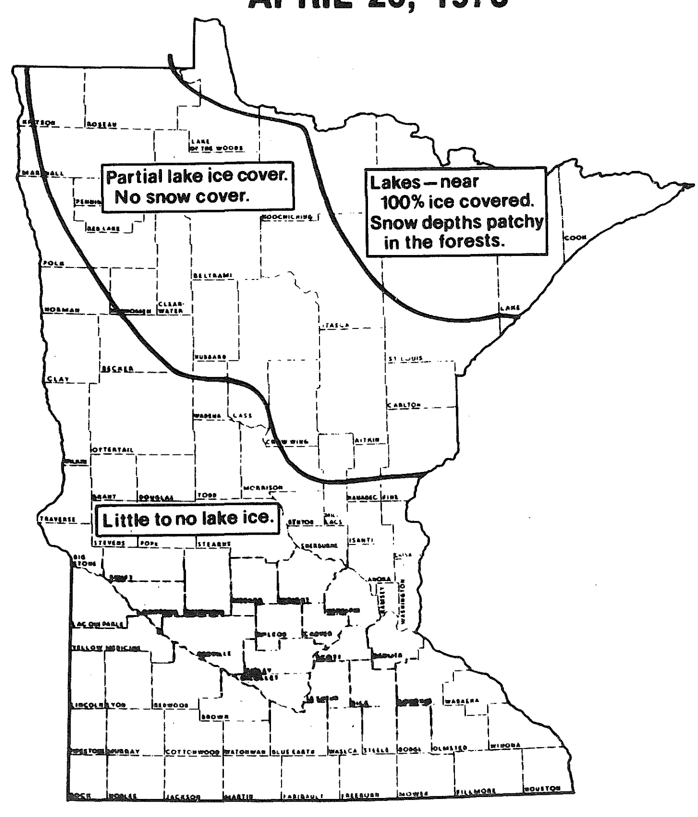
SNOW DEPTH APRIL 12, 1978

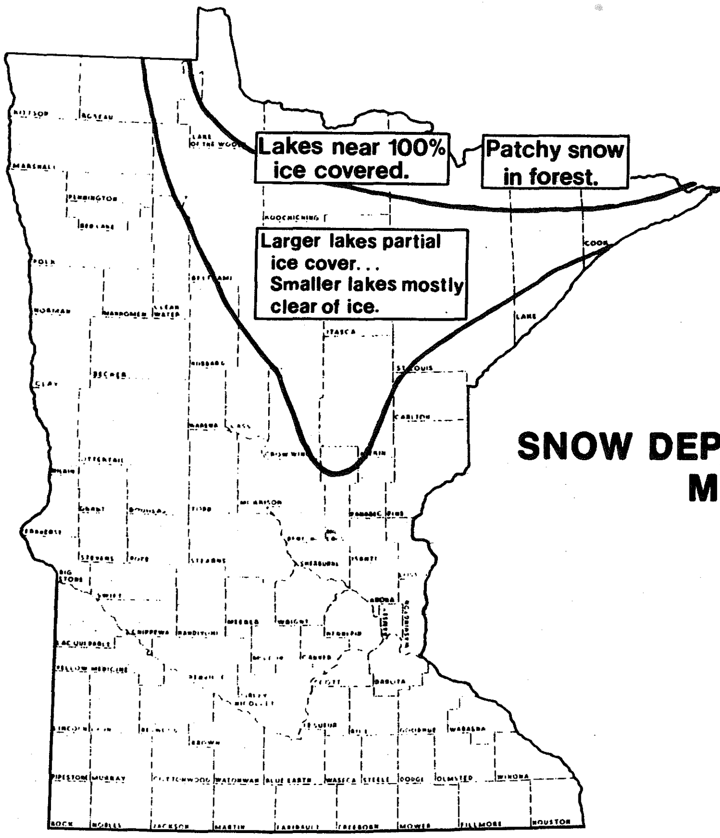


SNOW DEPTH APRIL 19, 1978

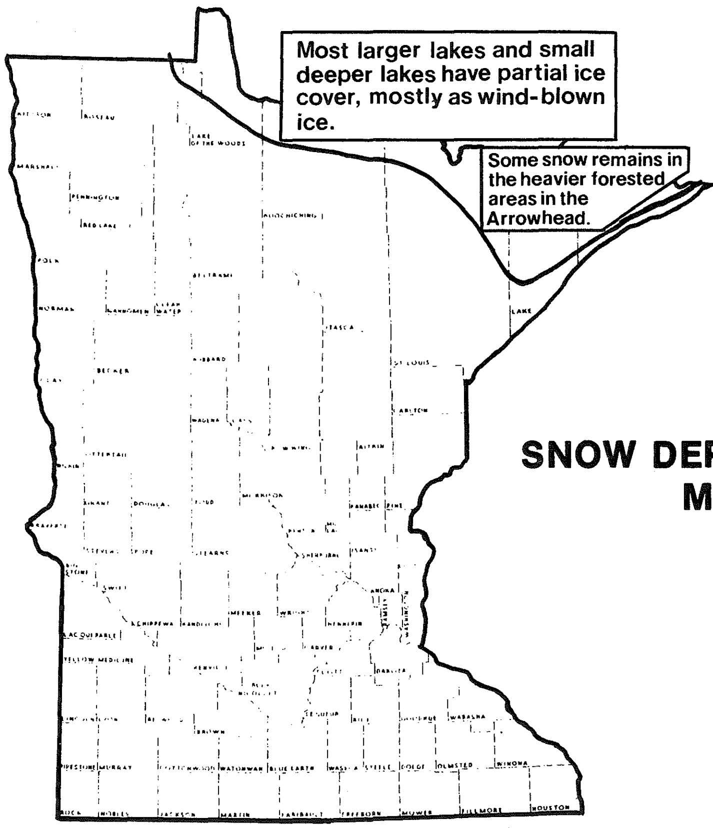


SNOW DEPTHS AND LAKE ICE APRIL 26, 1978





SNOW DEPTHS AND LAKE ICE
MAY 3, 1978



SNOW DEPTHS AND LAKE ICE
MAY 10, 1978

FLASH FLOODS OF THE 1978 HYDROLOGIC YEAR

The iso-hyetal maps serve as a historical record of the major flash floods that occurred in Minnesota during 1978. Most of the flash floods occurred in southeast and the east-central part of the state with 14 to 16 separate areas which received 6 inches or more rainfall in a 24-hour period. It is difficult to give the exact number of flash flood areas because on the night of June 30th and morning of July 1st there were quite a few areas receiving 6 inches or more of rain. The number of flash floods occurring in 1978 is above normal based on our records beginning in the early 1970's. Other years that had a high number of flash floods were 1972 and 1975, during which the occurrence of the 15-inch 24 hour rainfall in central Minnesota and 13-inch 24 hour rainfall in the Clay County flood, respectively, should be noted.

The most disasterous flash flood in 1978 was the Rochester flood on July 5th and 6th. More than 5 inches of rain fell in 3 hours along and through the headwaters of all the streams above Rochester: the resultant runoff caused over 100 million dollars in property damage and 4 deaths.

Information on the 1978 Red River Valley spring flood from snow melt is noted in publications of the National Weather Service and U.S. Geological Survey.

The flash flood maps are prepared by the State Climatology Office. The data in the most part was received from the various established precipitation networks; however, special calls to individuals known to have a rain gage were used to supplement other records in some areas lacking in data. In some cases a "mass-curve" or "intensity-duration curve" were prepared for some storms. For additional information, contact the State Climatologist, DNR, State Climatology Office.

INDEX OF 1978 FLASH FLOODS
(Chronologically by Section)

SOUTH-CENTRAL

June 14	**Albert Lea**

SOUTHEAST

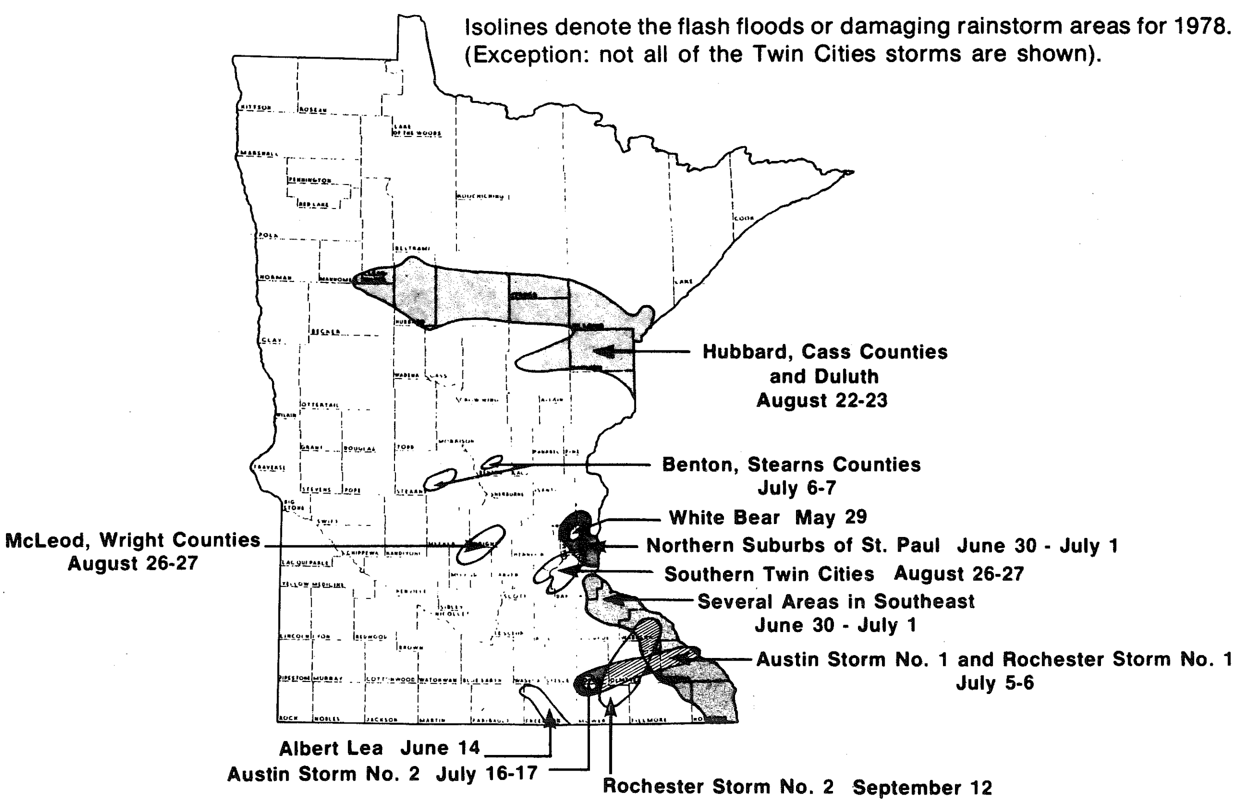
June 30 - July 1	Several Areas in Southeast
July 5-6	Rochester Storm No. 1 - Austin Storm No. 1
July 16-17	Austin Storm No. 2
September 12	Rochester Storm No. 2

EAST-CENTRAL

May 27	Twin Cities
May 28	Western Suburbs of Minneapolis
May 29	White Bear
June 25	Twin Cities
June 30 - July 1	Northern Suburbs of St. Paul
July 6	Western Suburbs of Minneapolis
July 6-7	Benton, Stearns Counties
August 26-27	McLeod, Wright Counties and Southern Twin Cities
August 26-27	Southern Twin Cities

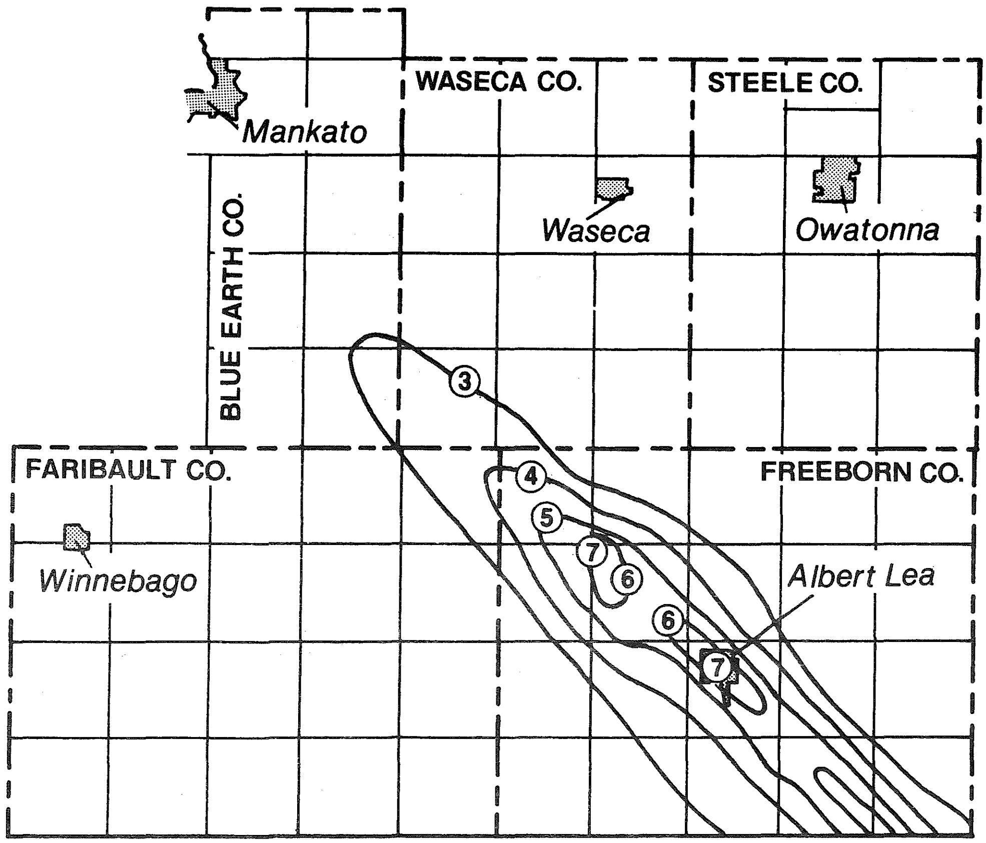
NORTH-CENTRAL-NORTHEAST

August 22-23	Hubbard, Cass Counties and Duluth



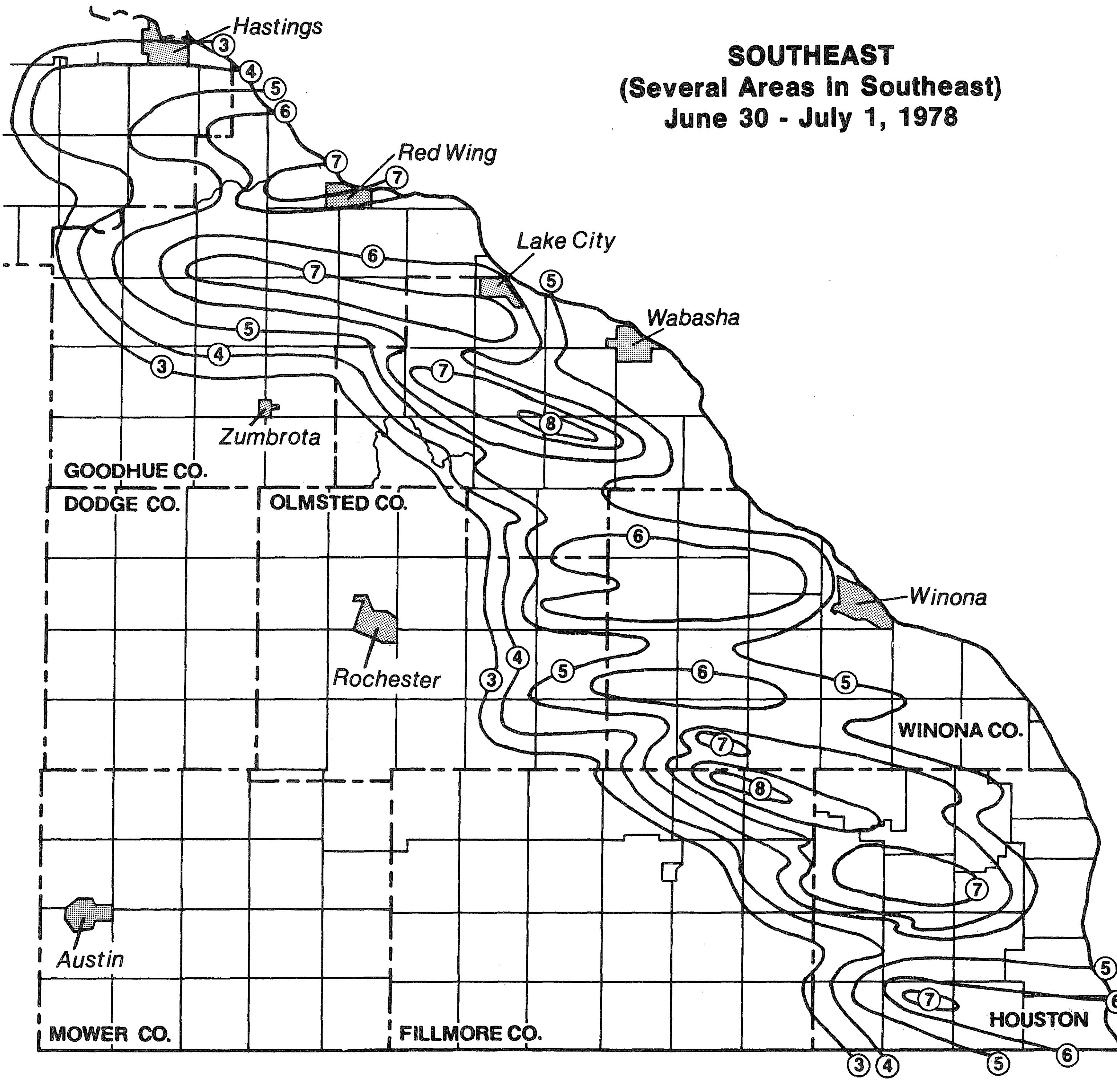
Isolines denote the flash floods or damaging rainstorm areas for 1978. (Exception: not all of the Twin Cities storms are shown).

SOUTH-CENTRAL
(Albert Lea)
June 14, 1978



The Albert Lea flash flood occurred between 7 P.M. and midnight CDST on June 14, 1978. Two areas received over 7 inches of rainfall. Albert Lea reported 7.50 inches, and an area about 2 miles east of Freeborn in northwest Freeborn County reported 7.30 inches. More than 4 inches of rain fell on a 6 to 8 mile wide band from northwest Freeborn County through Albert Lea and Glenville into Iowa. This covers an area of 200 square miles. The isohyet map was plotted from 53 Future Farmers of America reports.

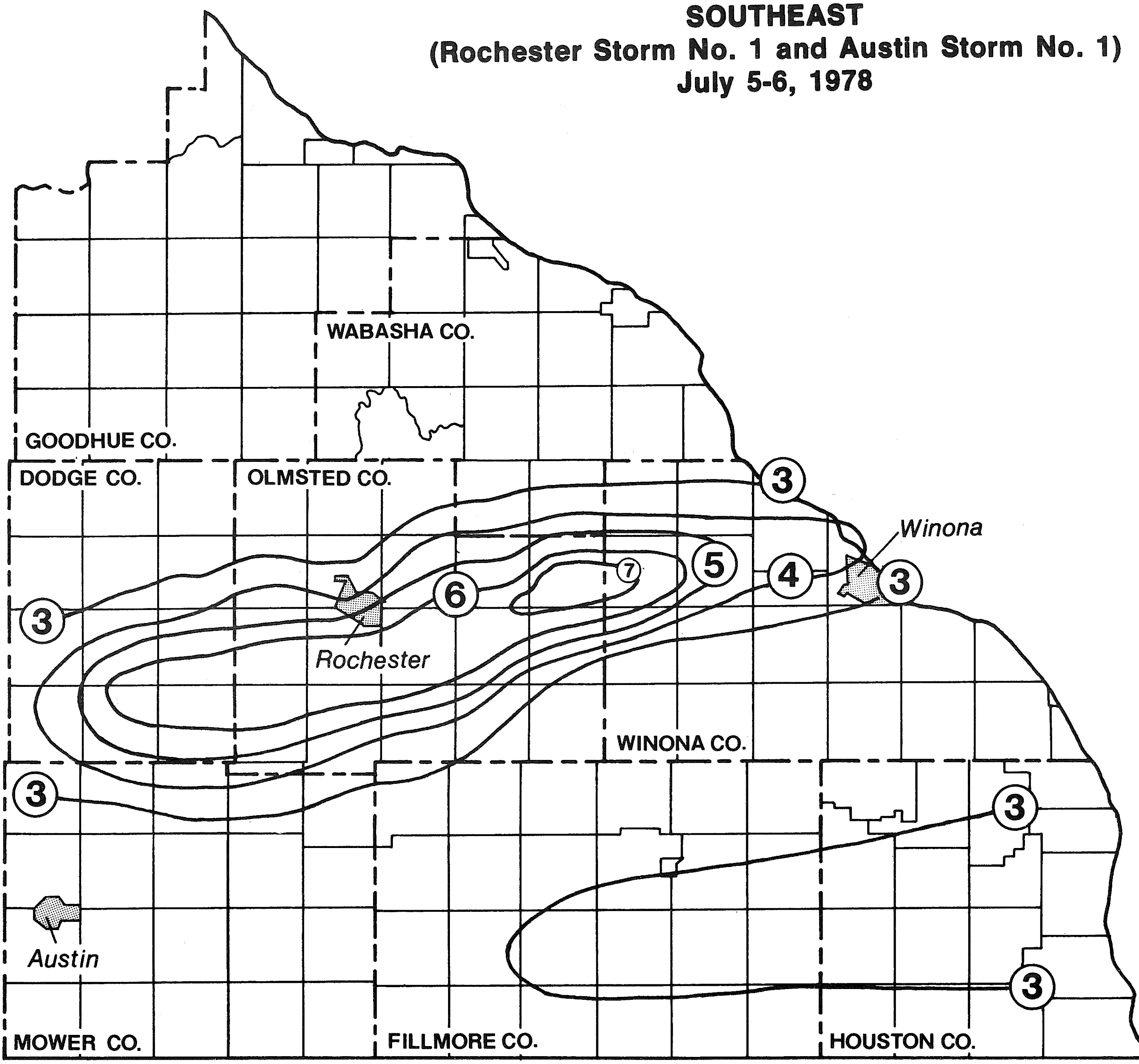
SOUTHEAST
(Several Areas in Southeast)
June 30 - July 1, 1978



East and southeast Minnesota experienced widespread flash flooding on June 30 thru July 1, 1978. These floods differed from the usual flash flood pattern. A typical pattern has only one localized area of high- intensity precipitation, generally from a single cell. Seven to nine separate areas in east and southeast Minnesota had over 6 inches of precipitation on June 30-July 1 from several storm cells forming during a 14-hour period. Numerous heavy thunderstorms moved east to southeast from a 140-mile long line extending from western Ramsey County (the Twin Cities) to western Houston County (25 miles west of the Iowa-Minnesota- Wisconsin border). Radar shows heavy showers occurred from about 6 P.M. CDST June 30 until 1 A.M. July 1, and moderate showers continued across the area until approximately 7 A.M. July 1.

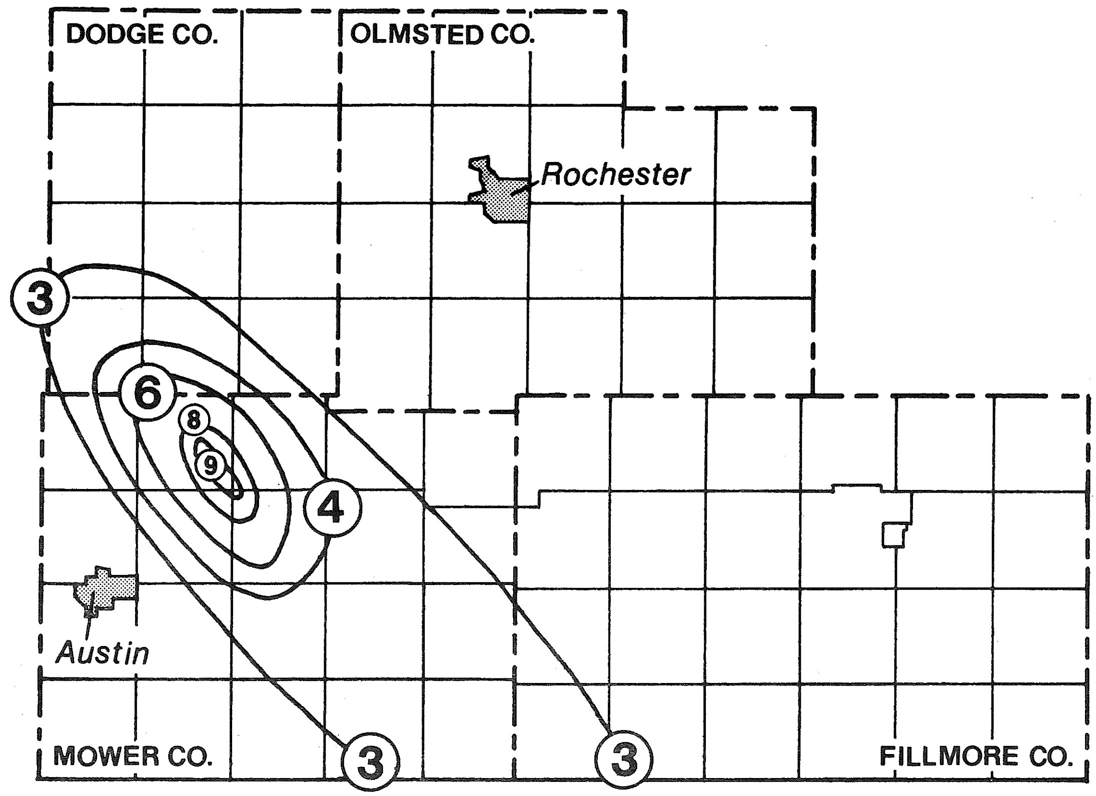
Portions of Ramsey, Dakota, Goodhue, Wabasha, Olmsted, Winona, Fillmore, and Houston Counties received over 6 inches of precipitation. A 6 or more inch rainfall is a 100-year or greater storm for this area. Greater than 8 inches of precipitation was reported in Mount Pleasant and Highland Townships in Wabasha County and in Arendahl and Rushford Townships in Fillmore County. The largest recorded amount was 8.68 inches. A 2850 square mile area received greater than 4 inches of precipitation in Minnesota. Generally, the heaviest and most extensive rainfalls were across Goodhue, Wabasha, Winona, and Houston Counties. Northern Ramsey, central Washington, eastern Dakota, eastern Olmsted, and northeastern Fillmore also had extensive rainfalls. The above map was prepared from 115 precipitation reports. Flash flood areas for Ramsey and Washington Counties are drawn on a separate map.

SOUTHEAST
(Rochester Storm No. 1 and Austin Storm No. 1)
July 5-6, 1978



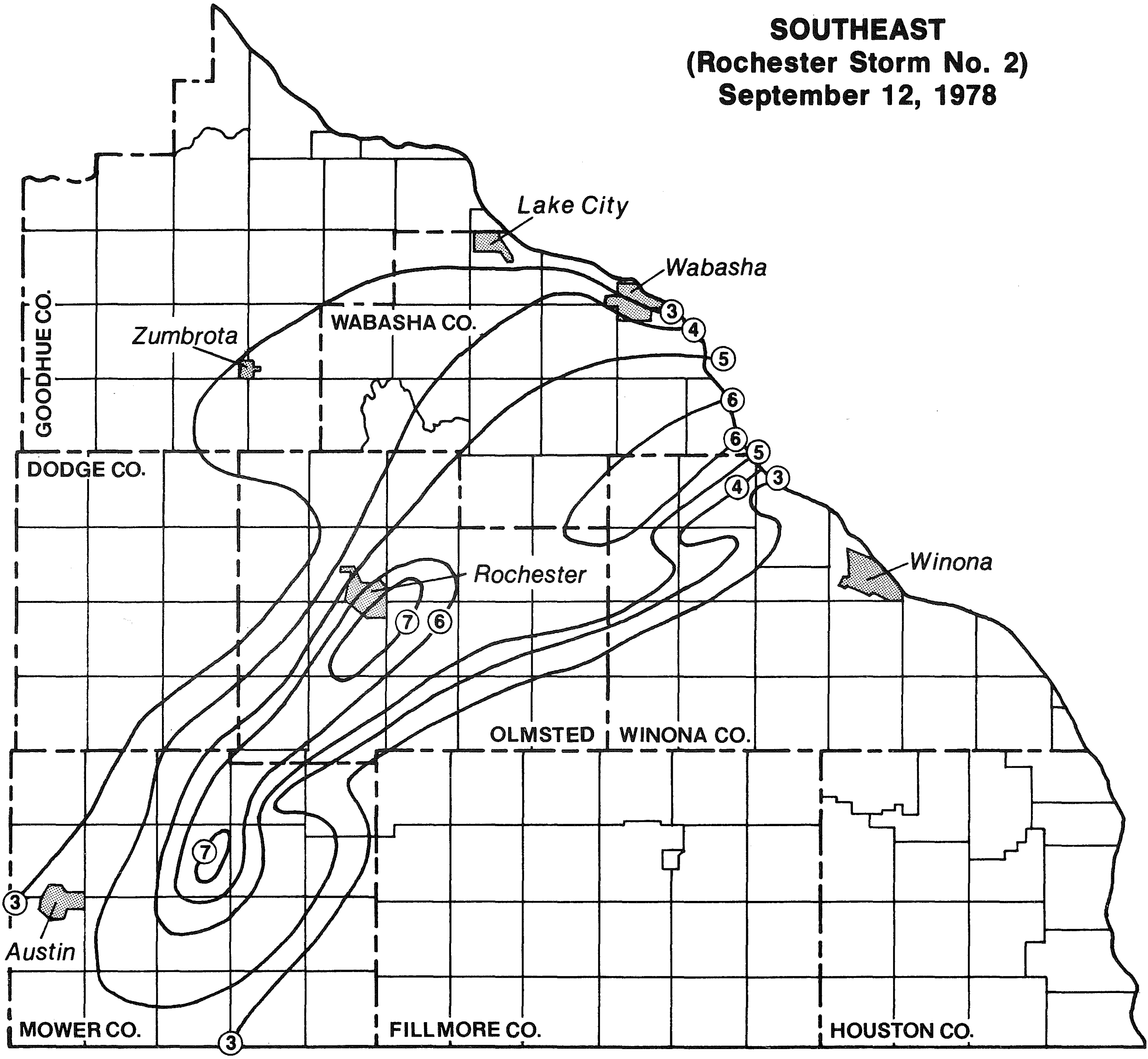
The flash flood for Rochester, Minnesota occurred from heavy rains of 6 inches or more. The storm began at Rochester airport at 5:53 P.M. CDST on July 5, 1978 and ended at 1:50 A.M. CDST on July 6, 1978. The National Weather Service weighing rain gage recorded in a 3-hour period, 5:53 P.M. CDST to 8:53 P.M. CDST, 4.99 inches of rain, which is well above the 100- year return period. The heaviest amount, 7.30 inches, occurred in Quincy Township in eastern Olmsted County. The 4-inch or more rainfall band was about 12-15 miles wide and 74 miles long and covered an area of 700 square miles. The line which oriented east-northeast began 25 miles west-southwest of Rochester and ended 50 miles east on the Minnesota-Wisconsin border. The map was prepared from 64 Future Farmer of America reports and 16 National Weather Service reports.

SOUTHEAST
(Austin Storm No. 2)
July 16-17, 1978



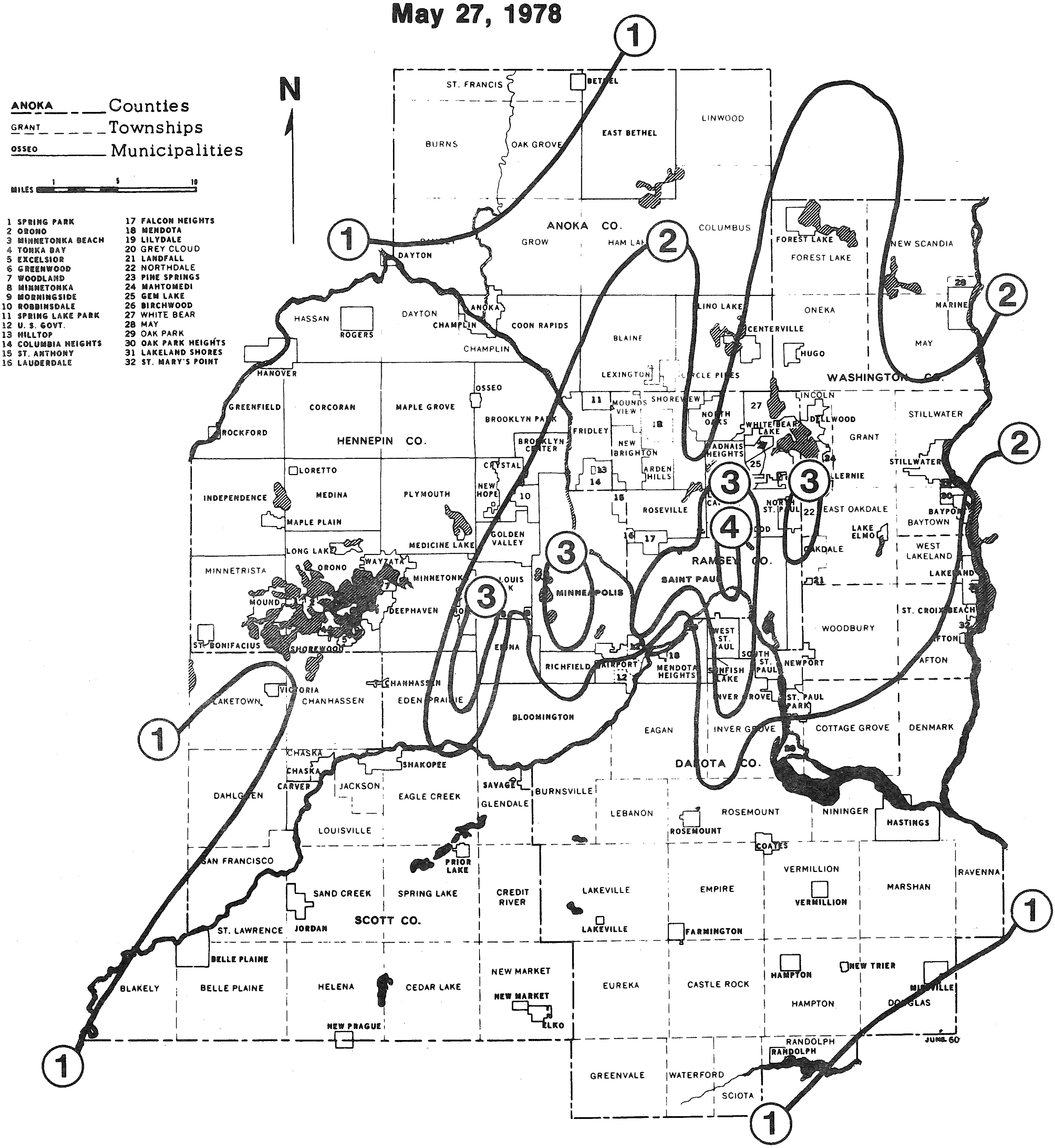
The flash flood at Austin, Minnesota, occurred from heavy rains of 8 inches or more. The rain began at approximately 9:00 P.M. CDST on July 16 and ended during the early morning hours of July 17. This was the second flash flood to occur in the headwaters of the Cedar River, north of Austin, in 11 days. Both floods resulted in record breaking flood levels at Austin.The largest amount of rain reported was 9.50 inches in Watham Township (2 miles southwest of Sargeant) in northwestern Mower County. The 4-inch or greater rainfalls were oriented northwest to southeast and covered an area of 160 square miles.

SOUTHEAST
(Rochester Storm No. 2)
September 12, 1978



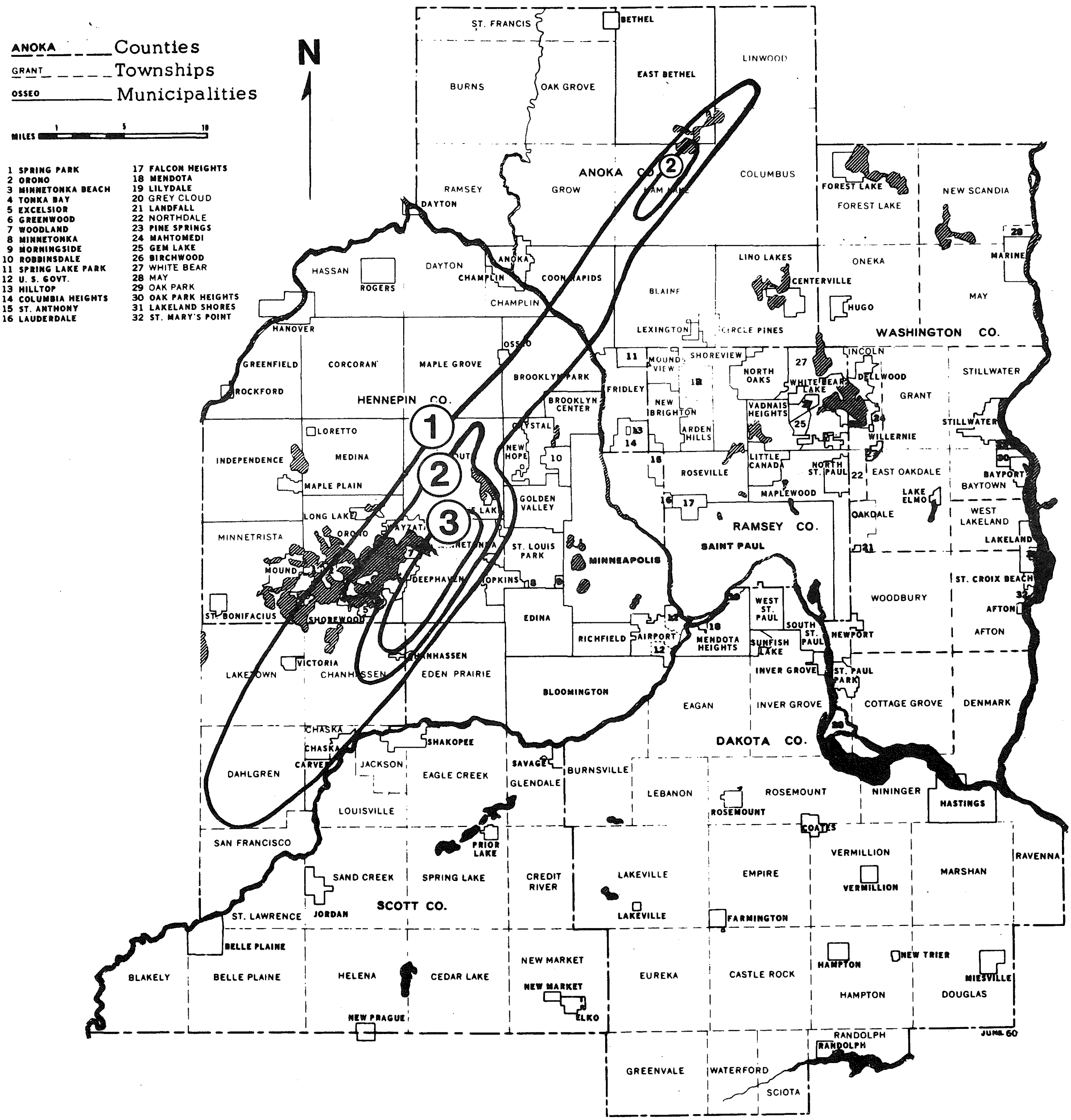
The flash flood at Rochester, Minnesota occurred from heavy rains greater than 6 inches. The storm began about 10AM CDST September 12, 1978 and ended about midnite. The hourly amounts for the first 6 hours, 10AM to 4PM, were 0.98", 0.16", 0.94", 0.64", 1.80" and 1.23". The heaviest amount of rainfall reported was 7.07 inches in downtown Rochester. The 4-inch or more rainfall band in Minnesota was about 12-24 miles wide and 80 miles long and covered 1200 square miles. This was the second flash flood for Rochester during the summer. The July 5-6 flash flood recorded near 5 inches of rain in 3 hours and this flood was over 5 inches in a 6 hour period.

EAST-CENTRAL
(Twin Cities)
May 27, 1978



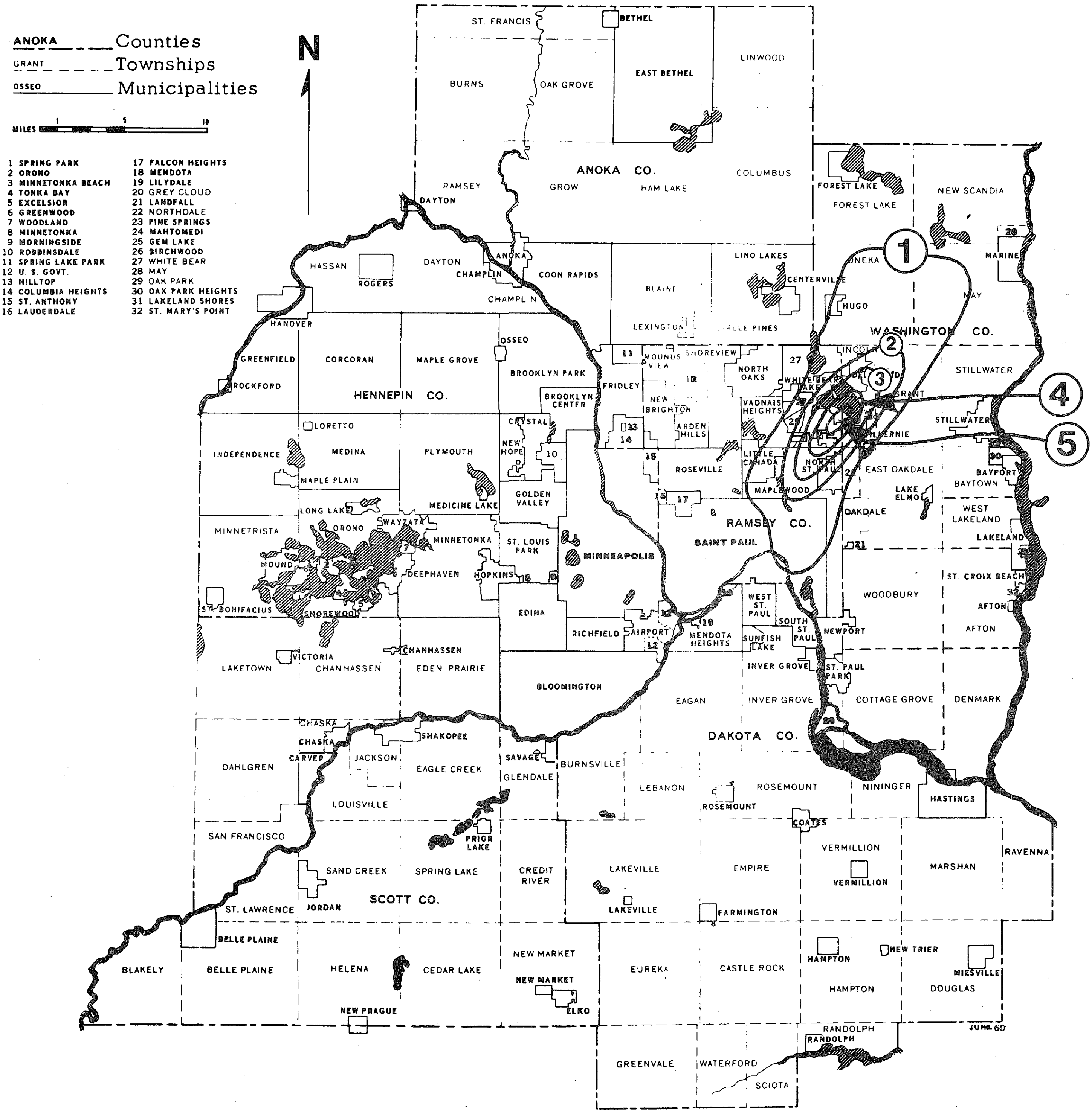
High-intensity rains of 3 inches or more occurred during the afternoon of May 27, 1978. Most of the rains fell between 2:15 P.M. and 3:45 P.M. CDST. Parts of Minneapolis, St. Paul, Hopkins, St. Louis Park, Edina, and North St. Paul received the heavier amounts.

EAST-CENTRAL
(Western Suburbs of Minneapolis)
May 28, 1978



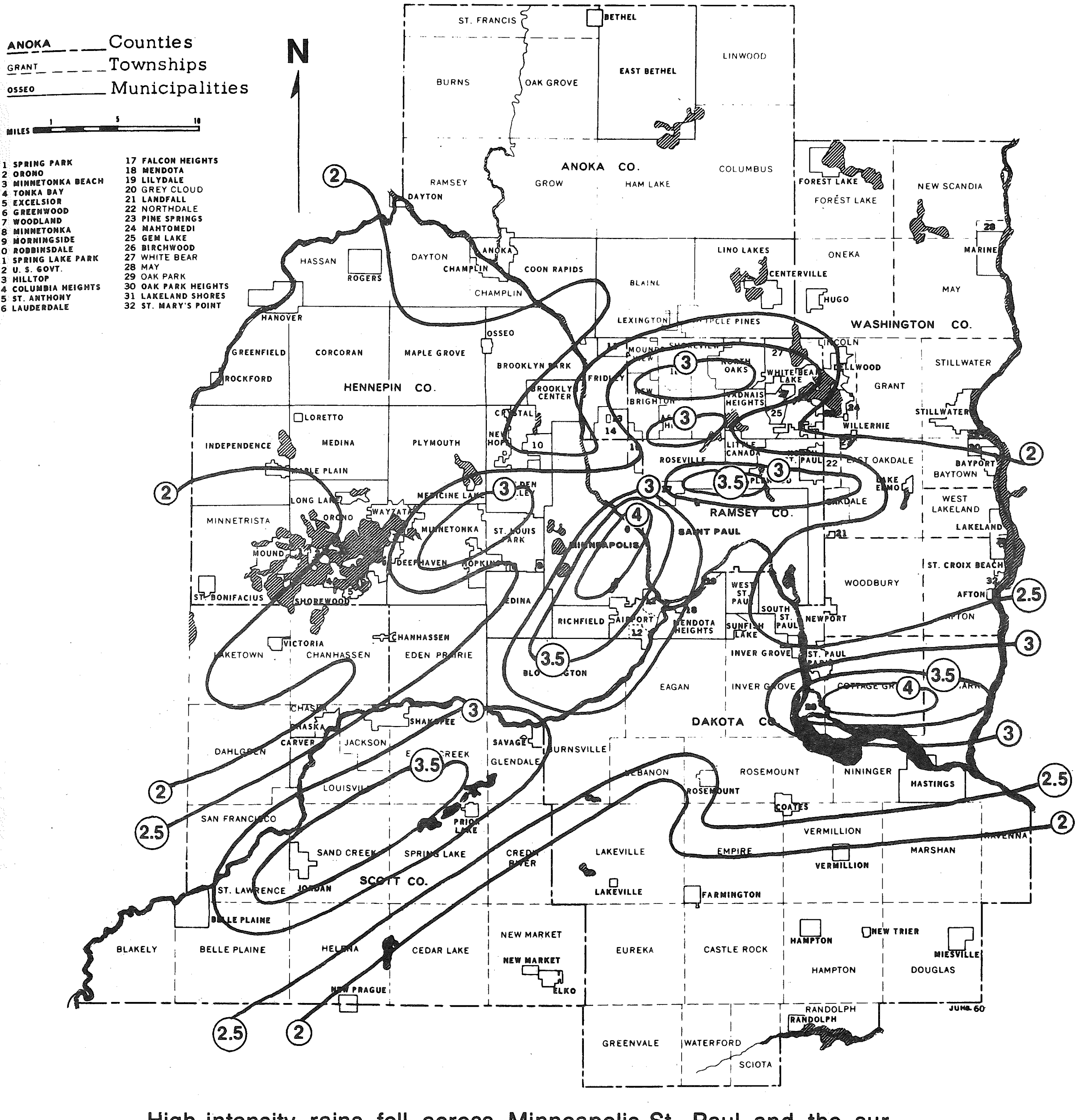
Heavy rains occurred during the late afternoon on May 28, 1978, along a narrow strip beginning in northeast Carver County and extending northeast through Hennepin and Anoka Counties. Most of the rain fell between 5:30 P.M. to 7:00 P.M. The heaviest rainfalls, 2 inches to more than 3 inches, fell in Minnetonka and Plymouth Townships in Hennepin County.

EAST-CENTRAL (White Bear) May 29, 1978



A flash flood occurred between 4:00 P.M. and 6:00 P.M. CDST on May 29, 1978. The heaviest rain of about 3 to 5 inches occurred mostly in the White Bear and North St. Paul area. The greatest intensity as measured by a recording rain gage in the area was 3 inches of rainfall in 40 minutes. At this time the rain gage was overturned by flood waters. Had this rate continued for 60 minutes it would have been 4.5 inches per hour. The U.S. Weather Bureau technical publication shows this to be more than a 100-year storm.

EAST-CENTRAL (Twin Cities) June 25, 1978

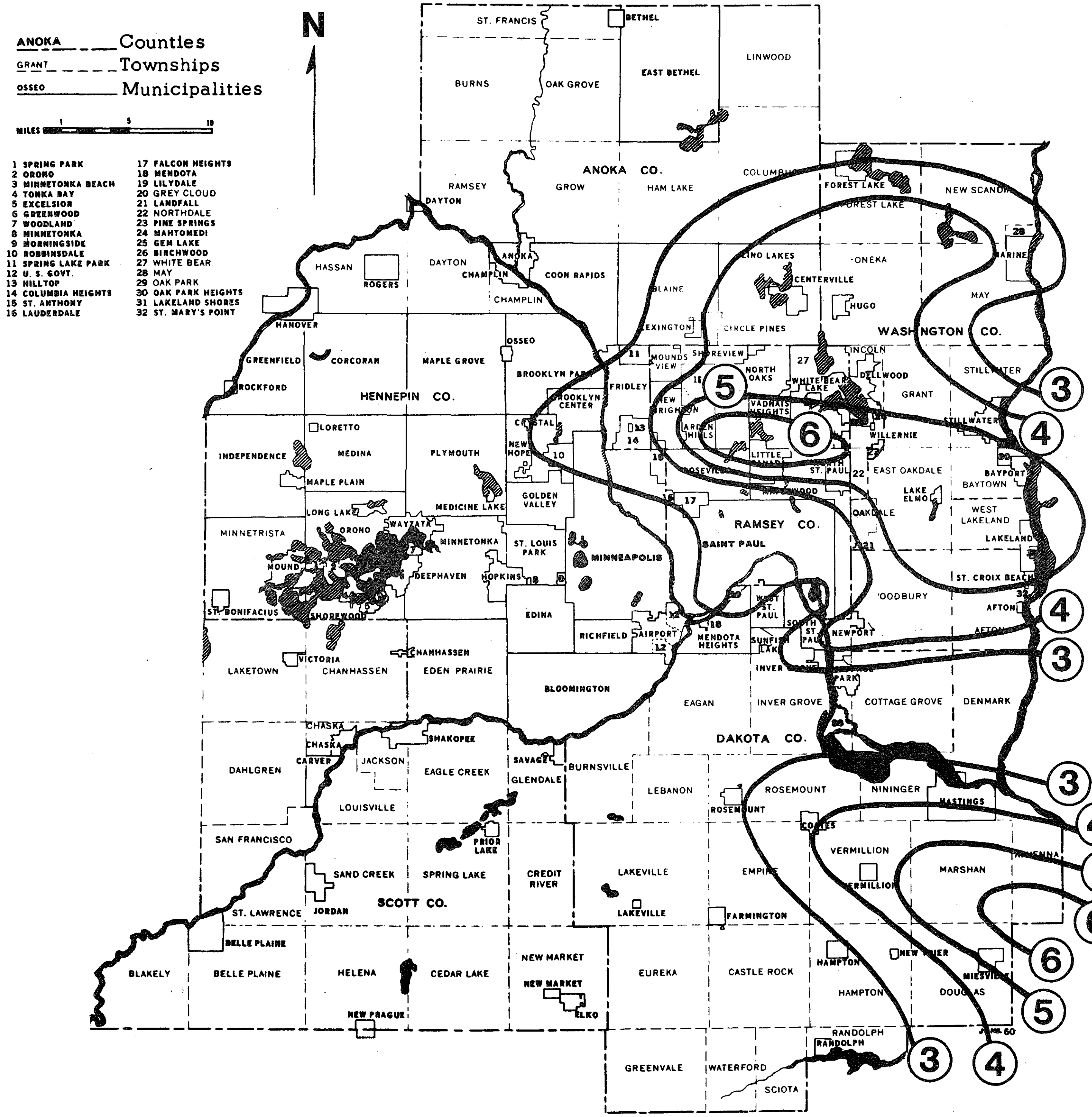


High-intensity rains fell across Minneapolis-St. Paul and the surrounding area from about 10:00 A.M. to noon CDST on Sunday, June 25, 1978. Much of this precipitation fell in one hour. Parts of the metropolitan area had rainfall intensities greater than the 50-year return period intensities. An area in south Minneapolis received 3.21 inches of rain in one hour which exceeds the 100-year return period for one-hour storms.

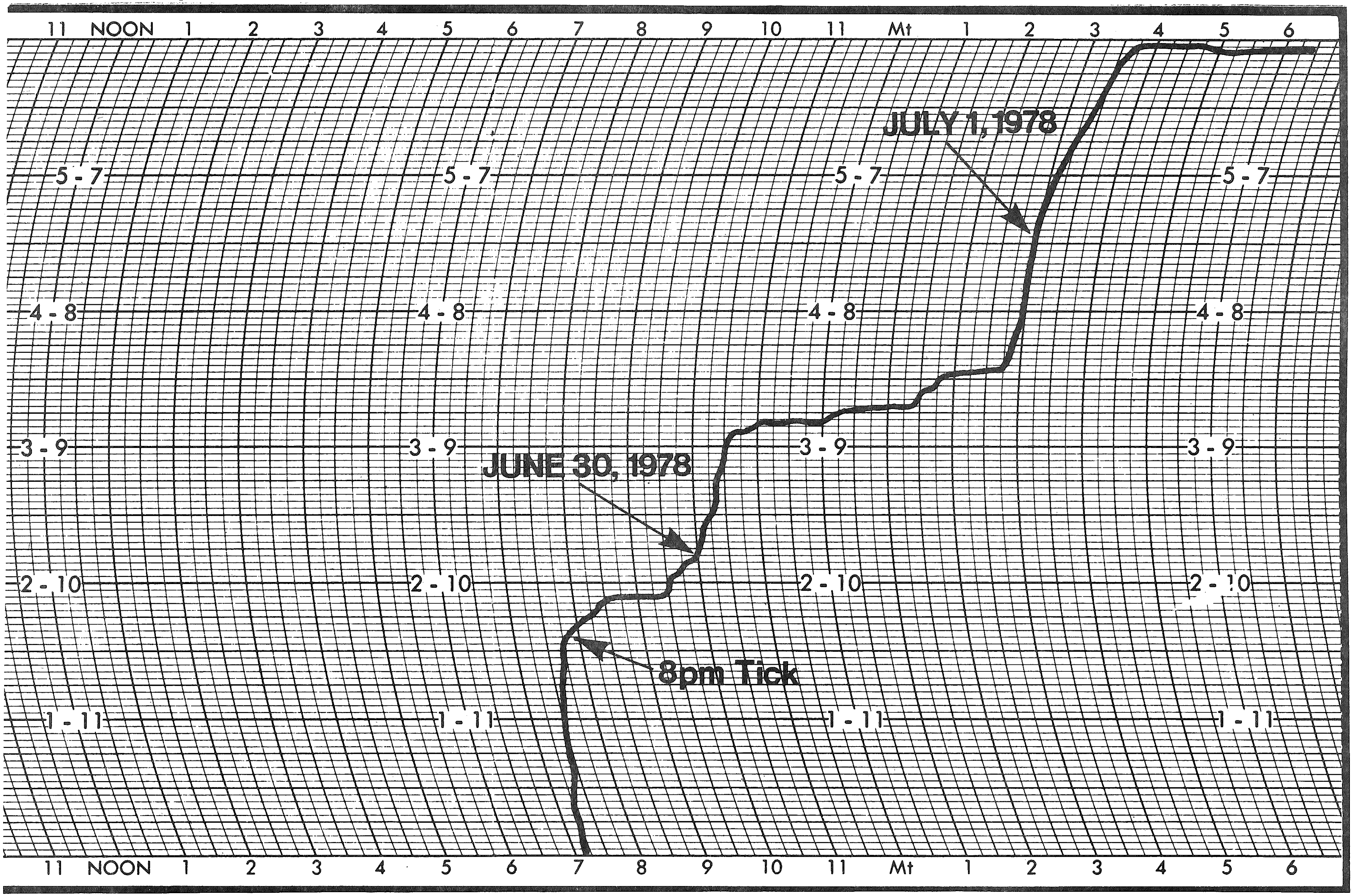
CLIMATOLOGY

EAST-CENTRAL (Northern Suburbs of St. Paul) June 30 - July 1, 1978

SEE THE FOLLOWING PAGE FOR THE WEIGHING RAIN GAUGE TRACE



Portions of the northern suburbs of St. Paul received heavy rains on the evening of June 30 and July 1, 1978. The largest observed rainfall was 6.70 inches in north central Ramsey County. Northern Ramsey County and north and central Washington County, a 400 square mile area, received greater than 4 inches of precipitation. Heavy rainshowers began in the area at approximately 7 P.M. CDST June 30 and continued intermittantly until 4 A.M. July 1. These rainshowers were the northern part of a 140-mile long line of showers that extended from the Twin Cities to the Minnesota-Wisconsin-Iowa border.

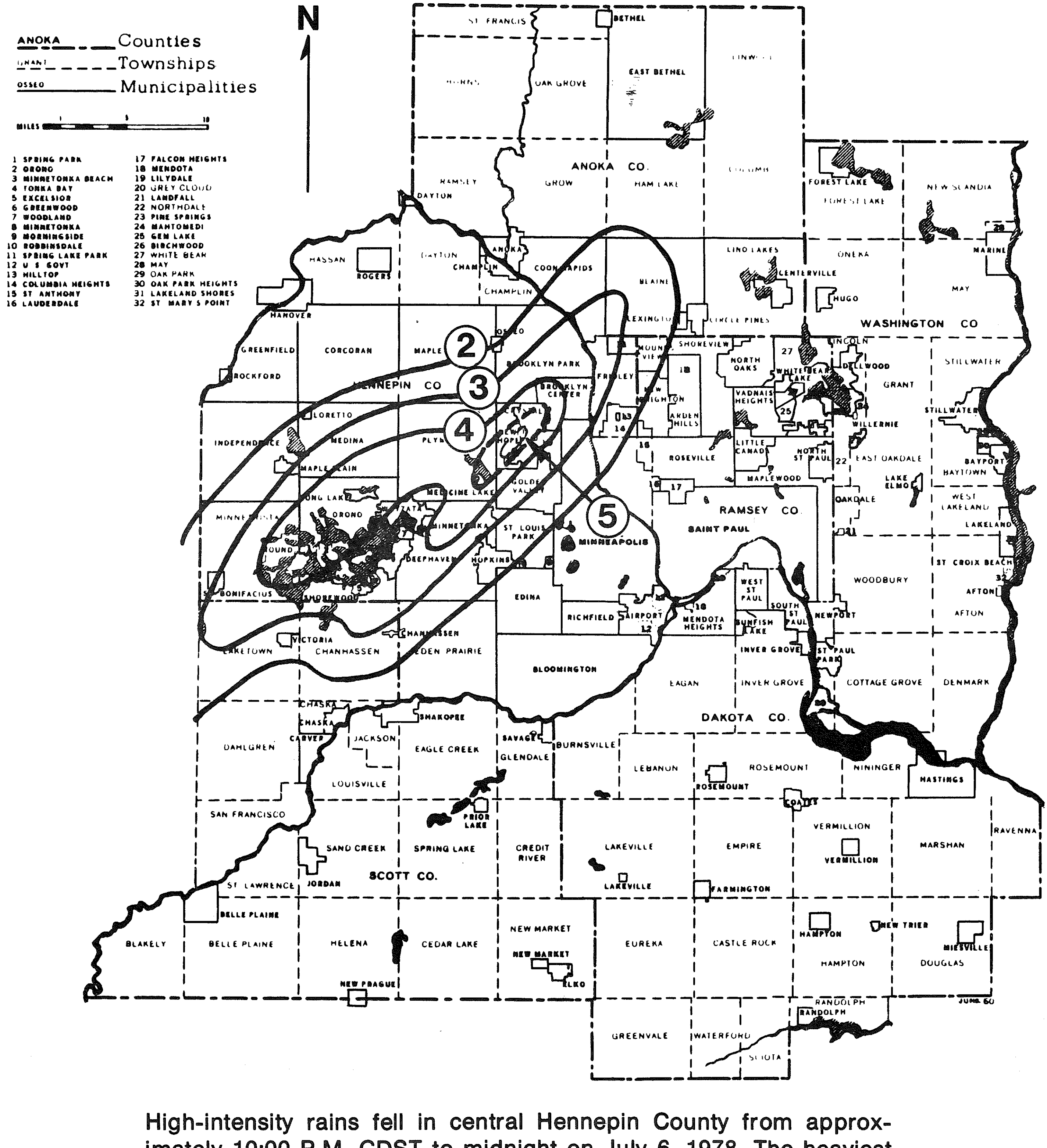


PRECIPITATION RECORD FROM 12" DUAL WEIGHING RAIN GAUGE

RAMSEY COUNTY

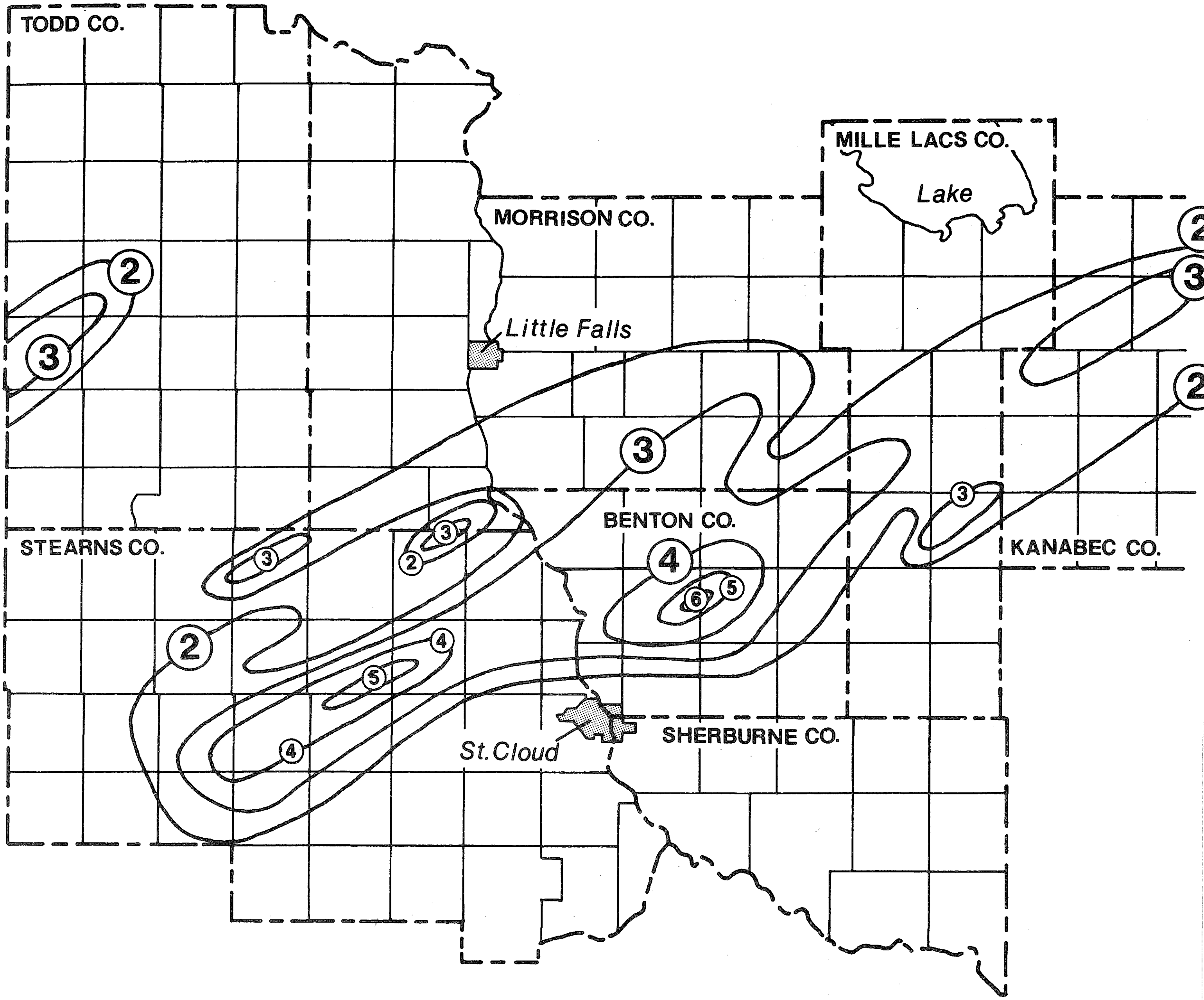
SHOREVIEW: TWP - 030N RGE - 23W SEC - 35

EAST-CENTRAL
(Western Suburbs of Minneapolis)
July 6, 1978



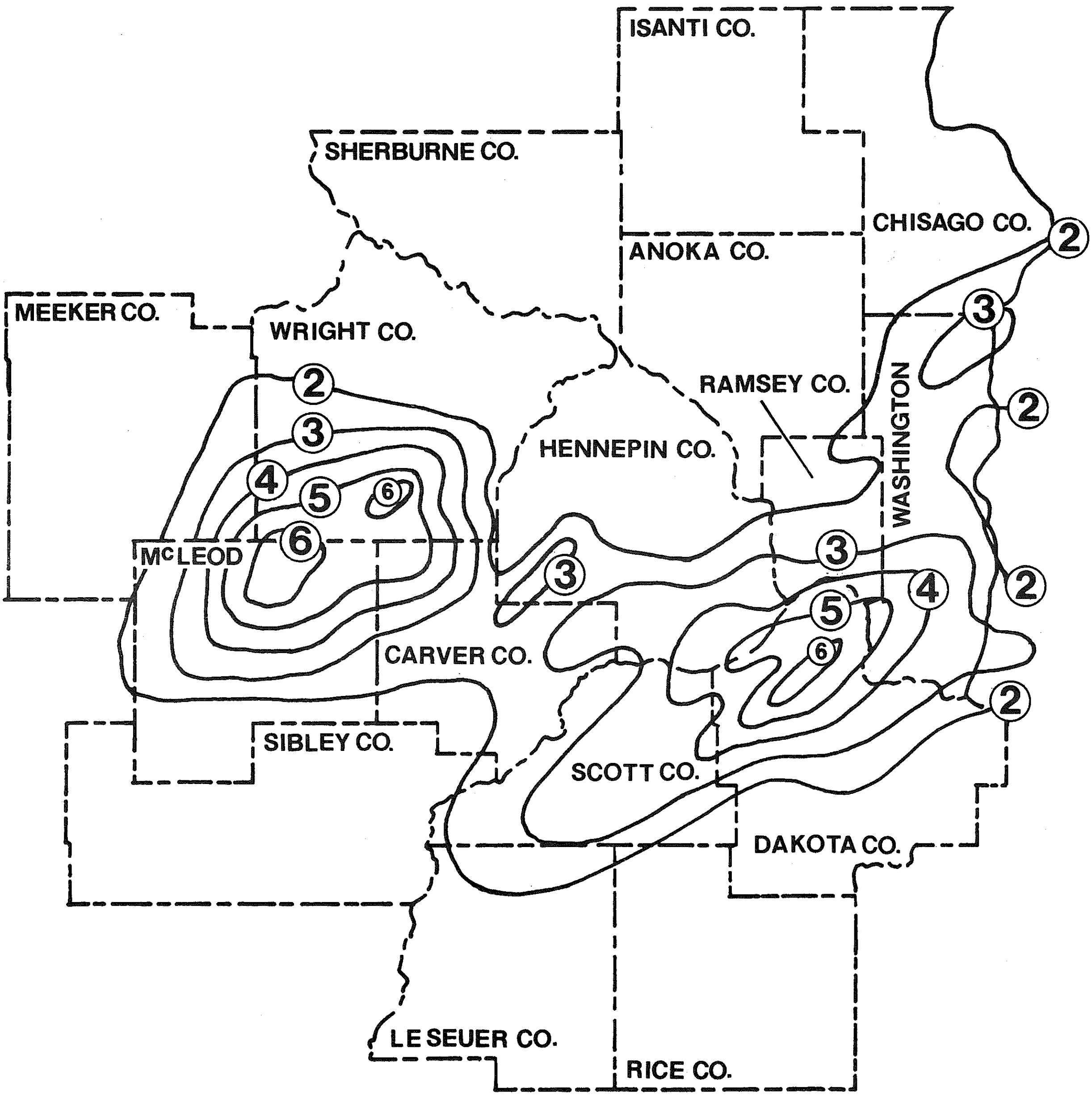
High-intensity rains fell in central Hennepin County from approximately 10:00 P.M. CDST to midnight on July 6, 1978. The heaviest rains, more than 4 inches, fell in the Lake Minnetonka to Crystal-New Hope area. A 120 square mile area received greater than 4 inches of precipitation. Rainfalls of greater than 3.50 inches in 2 hours exceed the 100-year return period.

EAST-CENTRAL
(Benton, Stearns Counties)
July 6-7, 1978



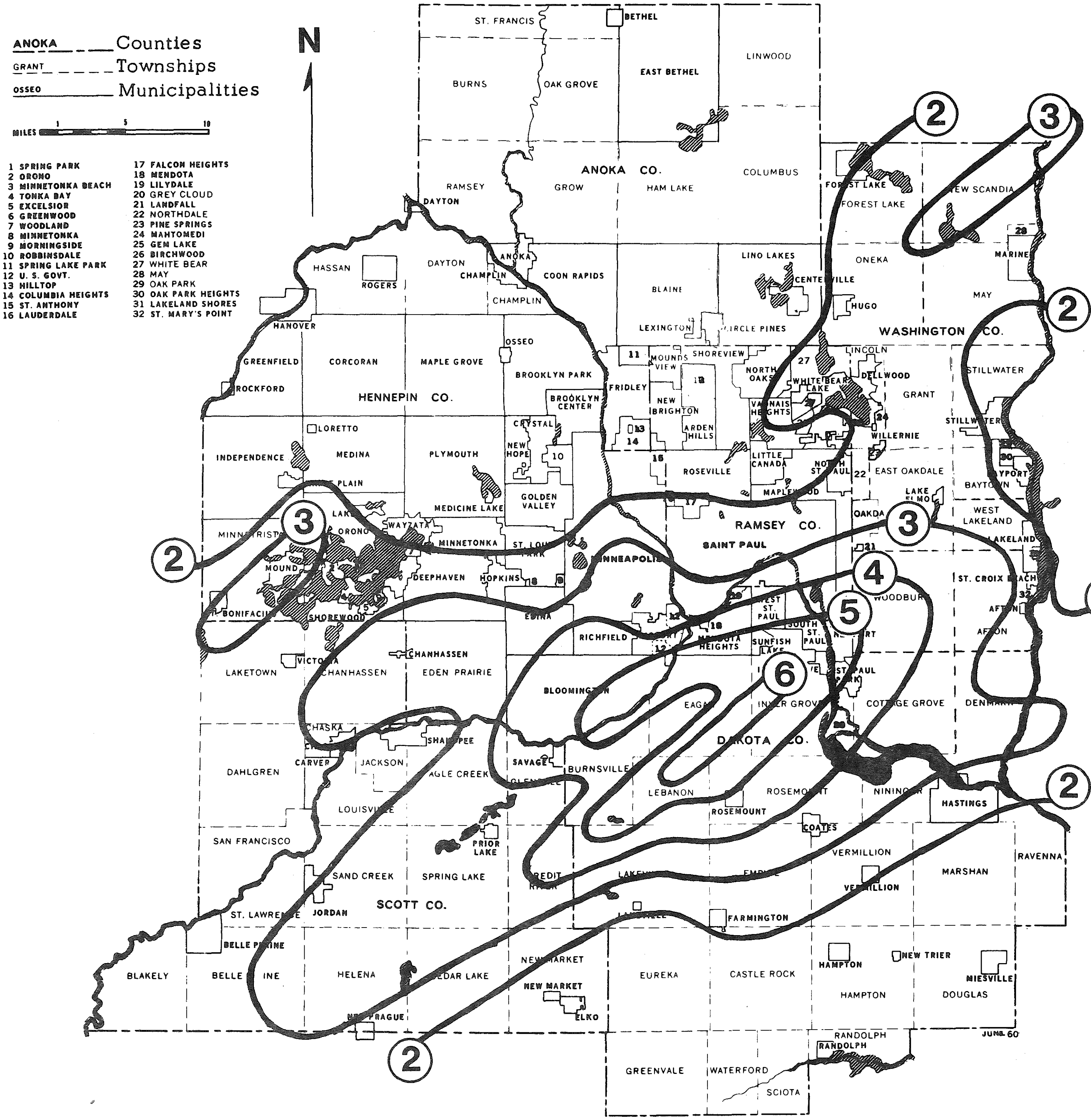
Benton and Stearns Counties received heavy rains on the evening of July 6-7, 1978. The rainshowers began at approximately 6:00 P.M. in Stearns County and at 6:45 P.M. CDST in Benton County. Radar indicates that maximum rainfall intensities occurred at approximately 7:00 P.M. The rain ended at about 9:00 P.M. The largest amounts, greater than 5 inches, were reported in Mayhew Lake Township in Benton County and Avon and Albany Townships in Stearns County. A 110 square mile area received greater than 4 inches of precipitation.

EAST-CENTRAL
(McLeod, Wright Counties and Southern Twin Cities)
August 26-27, 1978



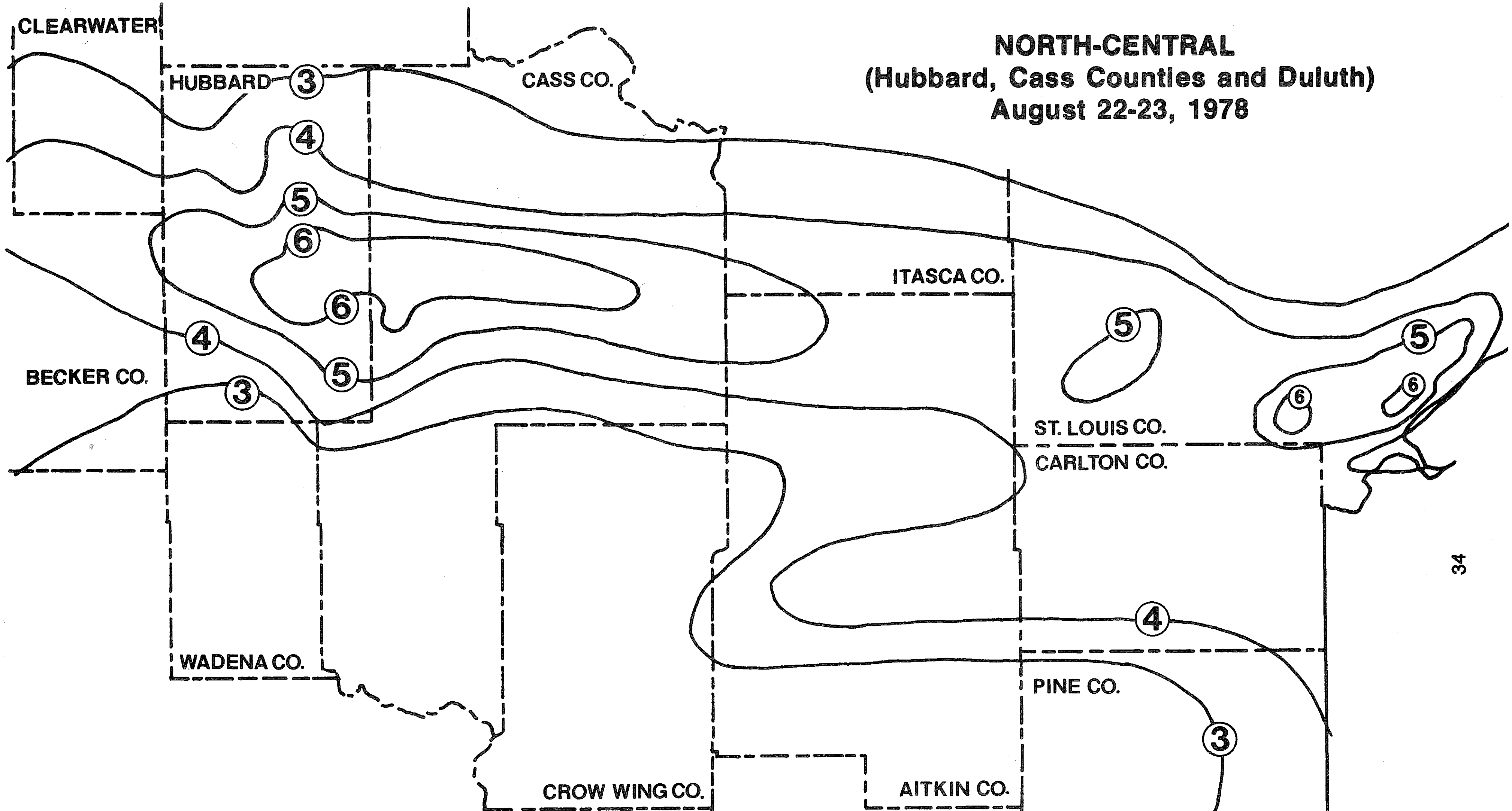
Flash floods occurred in central and east central Minnesota during the evening of August 26 and early morning hours of August 27. The rains began in northern McLeod and southern Wright counties at 8 P.M. CDST and ended at about 2 A.M. August 27. Two small areas received more than 6 inches of rainfall: one area in northern McLeod County and another in southern Wright County. The heavy rains in the southern part of the Twin Cities began just before midnight and continued for about 6 hours. Rainfall amounts of 6 inches or more were received in Apple Valley and Eagan. The 4 inch or more rainfalls covered 365 square miles in McLeod and Wright counties and 265 square miles in the southern Twin Cities area. The map was prepared from 255 reports taken by volunteer observers throughout the area.

EAST-CENTRAL
(Southern Twin Cities)
August 26-27, 1978



A flash flood occurred in the Twin Cities area during the evening of August 26 and early morning hours of August 27. The heavy rains in the southern part of the Twin Cities began just before midnight and continued for about 6 hours. Rainfall amounts of 6 inches or more were received in Apple Valley and Eagan. The 4 inch or more rainfalls covered 265 square miles in the Twin Cities area.

NORTH-CENTRAL
(Hubbard, Cass Counties and Duluth)
August 22-23, 1978



The flash flood in north central Minnesota began in the early afternoon of August 22 in the Bemidji area and about 6 P.M. in the Duluth area. The rain continued for approximately 12 hours. The greatest amount in one hour at Duluth was 0.86 inches. Two areas received more than 6 inches: an area beginning in east central Hubbard County extending east across the southern part of Leech Lake into Cass County and a second very local area to the west and southeast of the Duluth Airport. The largest amount of rain reported was 6.80 inches near Walker. The 4 inch or greater rainfalls were oriented toward the east at about 100 degrees and covered an area of 4100 square miles.

LAKE LEVELS IN MINNESOTA

In this first year of publication, considerable thought was given concerning just what information on lake hydrology should be included, and in what format. Lake level observations are made on only a fraction of Minnesota's lakes, and these observations are, with a few notable exceptions, generally sporadic. A wide variety of units of government and private individuals gather this information.

Currently, the Division of Waters is pulling together the historic and and current lake level information on the roughly 700 lakes which, at one time or another, have been gauged. Most lake gauging has been done using staff gauges fastened either to permanent structures, such as dams or bridge abutments, or on temporary posts. The frequency of these observations varies from weekly to annual readings. The most typical frequency of observations is weekly, except during winter. Typically, this frequency of observations results in about twenty to thirty spot readings of water surface elevation on a lake between the months of May and November.

The list which follows contains water surface elevation readings for one hundred Minnesota lakes, for water years 1977 and 1978. Where possible the change in high and low readings from WY 1977 to WY 1978 is given. The reader should bear in mind that these lake levels are not the high and low elevations actually experienced at the lakes, because continuous water level gauging equipment was not used. However, these observations do yield valuable information on the prevailing lake level ranges these years.

Of special interest to the Division of Waters, and to many lake property owners across the state, was the general rise in lake levels experienced in 1978. This trend was a direct result of the climatic rebound from the severe drought of 1976. Precipitation was noticeably up in 1977, and sharply higher in the first few months of water year 1978. As a result of this wet fall, subsequent winter and spring precipitation was converted to surface run-off with particular efficiency. Water year 1978 was also notable for numerous high intensity rainfalls which occurred in the spring and summer. These events contributed further to the rise in lake levels experienced in this year.

LAKE	WY 1977 PEAK	WY 1977 LOW	WY 1978 PEAK	WY 1978 LOW	CHANGE IN PEAK	CHANGE IN LOW
Aitkin County						
Pine Lake (1-176)	1254.55 (May 3)	1253.81 (Oct. 14)	1255.31 (Apr. 28)		0.76	–
Anoka County						
Coon Lake (2-42)	902.20 (Apr. 15)	901.92 (Mar. 16)	904.13 (Jul. 17)	902.61 (Jan. 17)	1.93	0.69
Linwood Lake (2-26)	899.50 (Mar. 16)	899.17 (Apr. 15)	900.10 (Oct. 14)	898.86 (Aug. 23)	0.60	–0.31
Rice (2-8) and Baldwin (2-13)	878.70 (Apr. 1)	878.30 (Jul. 28)	883.53 (Jul. 17)	878.91 (Oct. 14)	4.83	0.61
Becker County						
Upper Cormorant (3-588)	1353.43 (Jul. 5)	1352.97 (Aug. 21)	1354.13 (May 2)	1353.31 (Oct. 1)	0.70	0.34
Big Cormorant (3-576)	1352.42 (Jul. 16)	1351.43 (Nov. 15)	1352.23 (Nov. 13)	1351.99 (Oct. 23)	–0.19	0.56
Cotton Lake (3-286)	1440.70 (Apr. 7)	1439.68 (Aug. 16)	1442.13 (Jul. 10)	1439.86 (Oct. 3)	1.43	0.18
Height of Land (3-195)	1452.86 (Sept. 30)	1452.10 (Mar. 4)	1454.26 (Apr. 24)	1452.86 (Oct. 3)	1.40	0.76
Sallie Lake (3-359)	1328.74 (Apr. 26)	1328.16 (Aug. 26)	1329.98 (Apr. 24)	1328.36 (Sept. 29)	1.24	0.20
Beltrami County						
Long Lake (4-76)	1325.00 (Oct. 5)	1324.52 (Aug. 26)	1325.04 (Nov. 19)	1324.86 (Nov. 2)	0.04	0.34
Rhoda Lake	1318.65 (Sept. 29)	1317.77 (Nov. 15)	1318.99 (May 30)	1318.65 (Oct. 10)	0.34	0.88
Turtle River Lake (4-111)	1308.88 (Sept. 29)	1307.30 (Dec. 18)	1309.74 (Apr. 27)	1308.28 (Mar. 19)	0.86	0.98
Blue Earth County						
Crystal Lake (7-98)	970.49 (June 20)	969.79 (Sept. 12)	970.37 (Apr. 18)		–0.12	–
Eagle Lake (7-60)	986.20 (Apr. 12)		986.28 (Apr. 17)		0.08	–
Licy Lake (7-101)	966.09 (Apr. 12)		966.36 (Apr. 18)		0.27	–
Madison Lake (7-44)	1013.07 (Apr. 12)		1013.51 (Apr. 17)		0.44	–
Cass County						
Ten Mile Lake (11-413)	1378.38 (May 5)		1380.05 (Sept. 15)	1379.37 (May 4)	1.67	–
Chisago County						
Center Lake No. (13-32)	896.90 (May 16)	896.31 (Jul. 28)	398.01 (Sept. 14)	897.19 (Jan. 17)	1.11	0.88
Center Lake So. (13-27)	896.82 (May 16)		897.78 (Apr. 20)	897.25 (Aug. 23)	0.96	–
Chisago Lake (13-12)	896.67 (May 16)	895.62 (Aug. 22)	896.14 (Oct. 11)	895.94 (Nov. 23)	–0.53	0.32
Comfort Lake (13-53)	885.87 (Jul. 28)	885.42 (May 16)	886.89 (June 19)	885.35 (Mar. 16)	1.02	–0.07
No. Lindstrom Lake (13-35)	896.65 (May 16)	896.06 (Jul. 28)	897.26 (Aug. 23)	896.71 (Apr. 20)	0.61	0.65
Rush Lake (13-69)	913.13 (May 26)	912.91 (Mar. 16)	914.88 (Apr. 26)	913.79 (Aug. 23)	1.75	0.88
Cottonwood County						
Talcot Lake (17-60)	1406.00 (Apr. 18)		1406.40 (Apr. 18)		0.40	–
Crow Wing County						
Long Lake (18-372)	1196.34 (Jul. 17)	1196.09 (Jul. 3)	1197.27 (Jul. 16)	1196.79 (May 20)	0.93	0.70
Edward Lake (18-305)	1205.67 (Jul. 5)	1205.15 (Sept. 20)	1205.88 (Jul. 5)	1205.23 (Oct. 3)	0.21	0.08
Dakota County						
Marion Lake (19-26)	979.54 (Apr. 23)	977.75 (Sept. 13)	978.39 (Apr. 21)	978.21 (Jul. 31)	–1.15	0.46
Keller Lake (19-25)	933.18 (Mar. 16)	931.68 (Sept. 13)	934.36 (Sept. 19)	931.77 (Nov. 16)	1.18	0.09
Crystal Lake (19-27)	932.19 (May 17)	931.50 (Sept. 13)	932.40 (Sept. 15)	931.76 (Nov. 16)	0.21	0.26
Alimagnet Lake (19-21)	955.74 (Sept. 1)	953.92 (Sept. 20)	955.31 (Jul. 31)	954.20 (Nov. 15)	–0.43	0.28
Douglas County						
Agnes (21-53) – Henry (21-51)	1377.37 (Sept. 27)	1376.95 (Apr. 25)	1377.70 (Apr. 27)	1377.52 (June 21)	0.33	0.57
Freeborn County						
Albert Lea Lake (24-14)	1209.44 (Apr. 22)	1209.24 (Apr. 12)	1209.77 (Mar. 28)	1209.20 (Oct. 19)	0.33	–0.04
Hubbard County						
Belle Taine Lake (29-146)	1424.18 (Oct. 7)	1422.98 (Aug. 25)	1424.86 (Apr. 23)	1423.54 (Oct. 10)	0.68	0.56
Little Sand Lake (29-150)	1427.59 (June 3)	1426.39 (Oct. 8)	1427.79 (May 29)	1427.34 (Oct. 14)	0.20	0.95
Isanti County						
Skogman Lake (30-22)	942.58 (Apr. 15)	941.46 (Nov. 5)	944.24 (Jul. 17)	943.04 (Oct. 14)	1.66	1.58
Itasca County						
Bowstring Lake (31-813)	1317.98 (May 4)		1320.60 (May 4)		2.62	–
Dora Lake (31-882)	1317.87 (May 4)		1320.31 (May 4)		2.44	–

LAKE	WY 1977 PEAK		WY 1977 LOW		WY 1978 PEAK		WY 1978 LOW		CHANGE IN PEAK	CHANGE IN LOW
Itasca County (Continued)										
Round Lake (31-896)	1318.01	(May 4)			1321.40	(May 4)			3.39	–
Sand Lake (31-826)	1317.72	(May 4)			1320.46	(May 4)			2.74	–
Sisseebakwet Lake (31-554)	1329.65	(May 3)			1329.77	(May 4)			0.12	–
Split Hand Lake (31-353)	1260.89	(May 3)			1261.35	(May 3)			0.46	–
Little Split Hand Lake (31-341)	1258.39	(May 3)			1259.81	(May 3)			1.42	–
Wabansa Lake (31-392)	1319.27	(May 3)			1319.28	(May 4)			0.01	–
Jackson County										
Heron Lake No. (32-57)	1400.06	(Apr. 18)	1399.50	(Sept. 17)	1402.84	(Apr. 18)	1401.36	(Nov. 4)	2.78	1.86
Heron Lake So. (32-57)	1399.66	(Apr. 11)	1398.98	(June 13)	1404.12	(Jul. 10)	1399.66	(Oct. 3)	4.46	0.68
Kanabec County										
Knife Lake (33-28)	1044.51	(Jul. 6)	1042.75	(Aug. 11)	1045.26	(Jul. 7)	1043.76	(Aug. 11)	0.75	1.01
Kandiyohi County										
Andrew Lake (34-206)	1189.38	(June 16)	1188.32	(June 30)	1189.75	(May 31)	1189.49	(Apr. 19)	0.37	1.17
Calhoun Lake (34-62)	1154.63	(Apr. 19)			1156.57	(Apr. 19)	1156.03	(Aug. 28)	1.94	–
Crow River Mill Pond (34-158)	1203.78	(May 31)	1201.78	(Dec. 10)	1203.88	(Nov. 9)	1203.04	(Mar. 20)	0.10	1.26
Green Lake (34-79)	1156.88	(Apr. 15)	1154.73	(Apr. 19)	1157.06	(Apr. 19)	1156.48	(Aug. 28)	0.18	0.75
Big Kandiyohi Lake (34-86)	1099.90	(Apr. 17)	1098.92	(Sept. 22)	1100.55	(Apr. 19)			0.65	–
Le Sueur County										
German Lake (40-63)	1015.74	(Apr. 21)	1014.88	(Aug. 22)	1015.78	(May 8)	1015.04	(Oct. 20)	0.04	0.16
Sakatah Lake (40-2)	999.41	(June 16)	998.01	(Nov. 26)	1000.05	(Apr. 10)	999.35	(Aug. 10)	0.64	1.34
Tetonka Lake (40-31)	999.32	(June 16)	997.82	(Nov. 26)	1000.10	(Apr. 10)	999.32	(Oct. 7)	0.78	1.50
Martin County										
Okamanpeedan (46-51)	1225.00	(Apr. 18)	1224.34	(June 4)	1227.48	(Apr. 18)			2.48	–
Meeker County										
Francis Lake (47-2)	1047.29	(Apr. 28)	1046.76	(Oct. 2)	1048.31	(Apr. 24)	1047.29	(Oct. 9)	1.02	0.53
Murray County										
Shetek Lake (51-46)	1482.63	(June 24)	1478.86	(Nov. 7)	1483.34	(Apr. 8)	1482.05	(Oct. 28)	0.71	3.19
Nicollet County										
Little Lake (52-24)	972.43	(Apr. 13)			973.51	(Apr. 17)			1.08	–
Middle Lake (52-23)	974.05	(Apr. 13)			974.31	(Apr. 17)			0.26	–
Otter Tail County										
West Battle Lake (56-239)	1331.25	(Jul. 5)	1330.82	(Apr. 26)	1332.54	(May 28)	1331.01	(Oct. 2)	1.29	0.19
Pelican Lake (56-786)	1316.92	(Apr. 26)			1318.20	(May 2)			1.28	–
Pickerel Lake (56-475)	1328.14	(June 1)	1327.64	(Sept. 6)	1329.08	(Jul. 13)	1328.82	(Aug. 20)	0.94	1.18
Pine County										
Grindstone Lake (58-123)	1093.27	(Jul. 6)	1092.53	(Sept. 20)	1094.12	(Jul. 8)	1092.77	(Oct. 25)	0.85	0.24
Island Lake (58-62)	1075.24	(Sept. 30)	1073.88	(Aug. 26)	1076.13	(Apr. 26)	1075.28	(Oct. 1)	0.89	1.40
Sand Lake (58-81)	1068.20	(Apr. 29)	1067.27	(Aug. 24)	1071.12	(Ju. 12)	1068.00	(Oct. 6)	2.92	0.73
Ramsey County										
Bald Eagle Lake (62-2)	910.75	(Apr. 22)	909.70	(Dec. 20)	912.30	(Jul. 13)	910.30	(Oct.)	1.55	0.60
Otter Lake (2-3)	910.00	(May 30)	908.90	(Feb. 10)	912.08	(Jul. 3)	909.50	(Oct. 1)	2.08	0.60
Beaver Lake (62-16)	951.30	(Sept. 2)	948.20		952.60	(Jul. 5)	950.20	(Feb. 15)	1.30	2.00
Birch Lake (62-24)	919.10	(Apr. 20)	918.50	(Dec. 30)	920.10	(Aug. 3)	918.75	(Mar. 10)	1.00	0.25
Keller-Gervais Kohlman (62-10,7,6)	858.90	(Sept. 28)	857.10	(Feb. 10)	862.37	(Jul. 3)	857.10	(Mar. 10)	3.47	0.00
Phalen Lake (62-13)	858.75	(Sept. 30)	850.30	(Feb. 20)	862.31	(Jul. 3)	857.10	(Mar. 10)	3.56	6.80
Island Lake (62-75)	945.20	(Sept. 30)	943.90	(Aug. 4)	947.20	(Jul. 3)	945.05	(Mar. 10)	2.00	1.15
Johanna Lake (62-78)	877.45	(Sept. 3)	875.00	(Feb. 10)	881.27	(Jul. 3)	876.90	(Mar. 10)	3.82	1.90
Josephine Lake (62-57)	885.60	(Sept. 28)	882.80	(Nov. 18)	885.65	(Jul. 3)	883.55	(Oct. 5)	2.05	0.75
Long Lake (62-67)	865.20	(Sept. 3)	864.10	(Oct. 1)	866.90	(Jul. 3)	864.40	(Feb. 15)	1.70	0.30
McCarron Lake (62-54)	841.40	(Sept. 1)	839.00	(Feb. 10)	841.55	(Sept. 3)	840.85	(May 5)	0.15	1.85
Owasso Lake (62-56)	886.70	(June 3)	885.45	(Feb. 10)	888.79	(Jul. 4)	886.60	(Oct. 5)	2.09	1.15
Pike Lake (62-69)	867.90	(Aug. 30)		(Jan. 12)	869.85	(Jul. 3)	866.90	(Feb. 15)	1.95	–
Round Lake (62-70)	903.20	(Aug. 30)	899.70	(Feb. 10)	903.10	(Jul. 3)	901.60	(Mar. 10)	–0.10	0.90

LAKE	WY 1977 PEAK	WY 1977 LOW	WY 1978 PEAK	WY 1978 LOW	CHANGE IN PEAK	CHANGE IN LOW
Ramsey County (Continued)						
Silver Lake (62-83)	933.20 (Sept. 1)	930.40 (Feb. 10)	934.40 (Jul. 3)	932.25 (Feb. 15)	1.20	1.85
Silver Lake (62-1)	987.70 (Sept. 30)	986.25 (Feb. 10)	990.48 (Jul. 3)	987.70 (Oct. 1)	2.78	1.45
Snail Lake (62-73)	882.80 (Aug. 30)	880.90 (Feb. 15)	884.20 (Jul. 3)	881.40 (Mar. 18)	1.40	0.50
Spring Lake (2-71)	902.50 (June 30)	899.90 (Feb. 10)	903.55 (Jul. 26)	900.35 (Feb. 15)	1.05	0.45
Turtle Lake (62-61)	891.65 (Jul. 10)	890.50 (Feb. 10)	892.41 (Jul. 25)	891.10 (Dec. 15)	0.76	0.60
Valentine Lake (62-71)	878.60 (Sept. 30)	876.20 (Feb. 10)	881.10 (Jul. 3)	877.50 (Sept. 11)	2.50	1.30
Wabasso Lake (62-82)	885.60 (Jul. 6)	884.05 (Feb. 10)	886.65 (Jul. 3)	885.20 (Sept. 30)	1.05	1.15
Wakefield Lake (62-11)	886.20 (Aug. 30)	881.40 (Feb. 10)	885.85 (Jul. 3)	883.90 (Mar. 10)	–0.35	2.50
Whitebear Lake (82-167)	922.75 (Apr. 20)	922.00 (Feb. 10)	923.95 (Jul. 20)	922.50 (Dec. 1)	1.20	0.50
St. Louis County						
Longyear Lake (69-857)	1480.70 (Sept. 26)	1485.15 (Jan. 12)	1488.95 (Apr. 12)	1487.58 (Mar. 17)	0.25	2.43
Scott County						
Prior Lake (70-72)	898.83 (Mar. 17)	897.95 (Jul. 29)	898.26 (Sept. 14)	897.48 (June 20)	–1.57	–0.47
Sibley County						
High Island Lake (72-50)	991.11 (Apr. 14)		992.75 (Apr. 11)		1.64	–
Titlow Lake (72-42)	982.89 (Apr. 14)		984.52 (Aug. 20)		1.63	–
Stearns County						
Big Fish (73-106)	1196.08 (Aug. 31)	1195.30 (May 15)	1197.42 (Aug. 20)	1196.52 (Jul. 1)	1.39	1.22
Todd County						
Osakis Lake (77-215)	1320.83 (Apr. 25)		1323.20 (Apr. 27)	1322.83 (June 21)	2.37	–
Waseca County						
Elysian Lake (81-95)	1014.96 (Apr. 12)		1016.96 (Apr. 17)		2.00	–
Washington County						
Big Carnelian Lake (82-49)	862.66 (Nov. 24)	862.47 (Nov. 7)	862.65 (Aug. 10)	862.64 (Apr. 20)	–0.01	0.17
Big Marine Lake (82-52)	940.94 (Nov. 7)	940.60 (Nov. 24)	941.64 (Aug. 10)	941.45 (Apr. 20)	0.70	0.85
Jane Lake (82-104)	921.00 (Jul. 28)		923.28 (Jul. 17)	921.41 (Nov. 15)	2.28	–
Oneka Lake (82-140)	928.94 (May 16)	928.47 (Jul. 28)	929.61 (Sept. 14)	928.13 (Nov. 16)	0.67	–0.34
Wright County						
Sylvia Lake (86-289)	1049.11 (Apr. 28)	1048.67 (Aug. 24)	1050.38 (June 25)	1049.99 (Oct. 1)	1.27	1.32

GROUND WATER INVESTIGATIONS

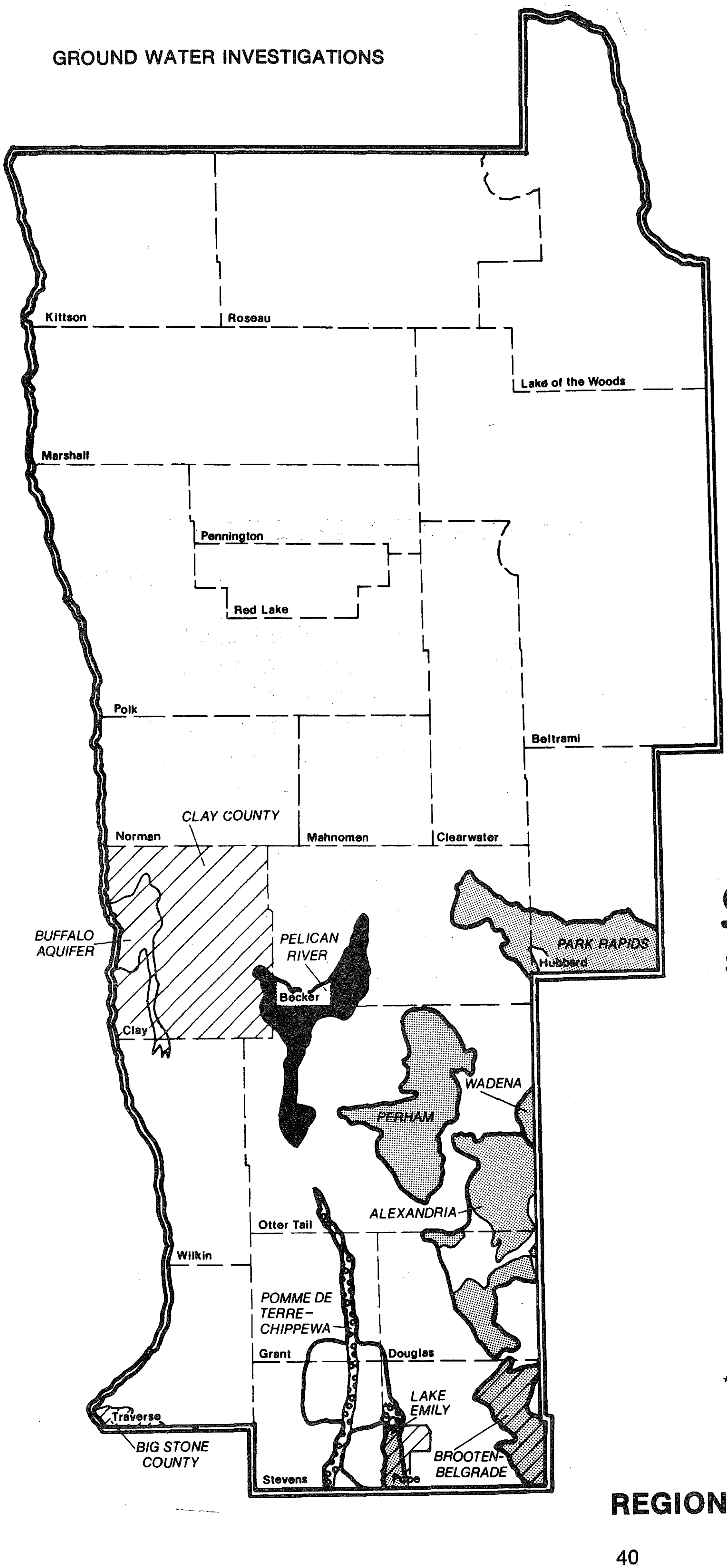
A. STUDIES

The earliest recorded ground-water study in Minnesota was the U.S. Geological Survey, Water-Supply Paper 256, Geology and Underground Waters of Southern Minnesota (Hall, Meinzer, Fuller, 1911). Subsequent ground-water reports describe results of investigations conducted by the Minnesota Geological Survey: The Geology and Water Resources of Northwestern Minnesota (Allison, 1932), The Geology and Underground Waters of Southern Minnesota (Thiel, 1944), and The Geology and Underground Waters of Northeastern Minnesota (Thiel, 1947).

Ground-water studies completed in Minnesota during the past 35 years have been largely a result of the Department of Natural Resources - U.S. Geological Survey Cooperative Program. Ground-water studies funded by this coop program include municipal water-supply studies, mining area studies, irrigation area studies, regional reconnaissance studies, and ground-water monitoring programs. During 1978, eight different areal ground-water studies were being conducted under this coop program:

1. Pelican River Sands
2. Buffalo Aquifer
3. Todd County Sand Plains
4. Four-County Sand Plains
5. Big Stone County
6. Eight-County SW Minn.
7. Lake Williams
8. Twin Cities Ground Water Model

In addition, the U.S. Geological Survey, in a 100% federally-funded project, is studying the Paleozoic Bedrock Aquifers in southeast Minnesota. See the figures on pages 40-44 for study locations



GROUND-WATER STUDIES*

SURFICIAL AQUIFERS:

Study Completed

Study in Progress

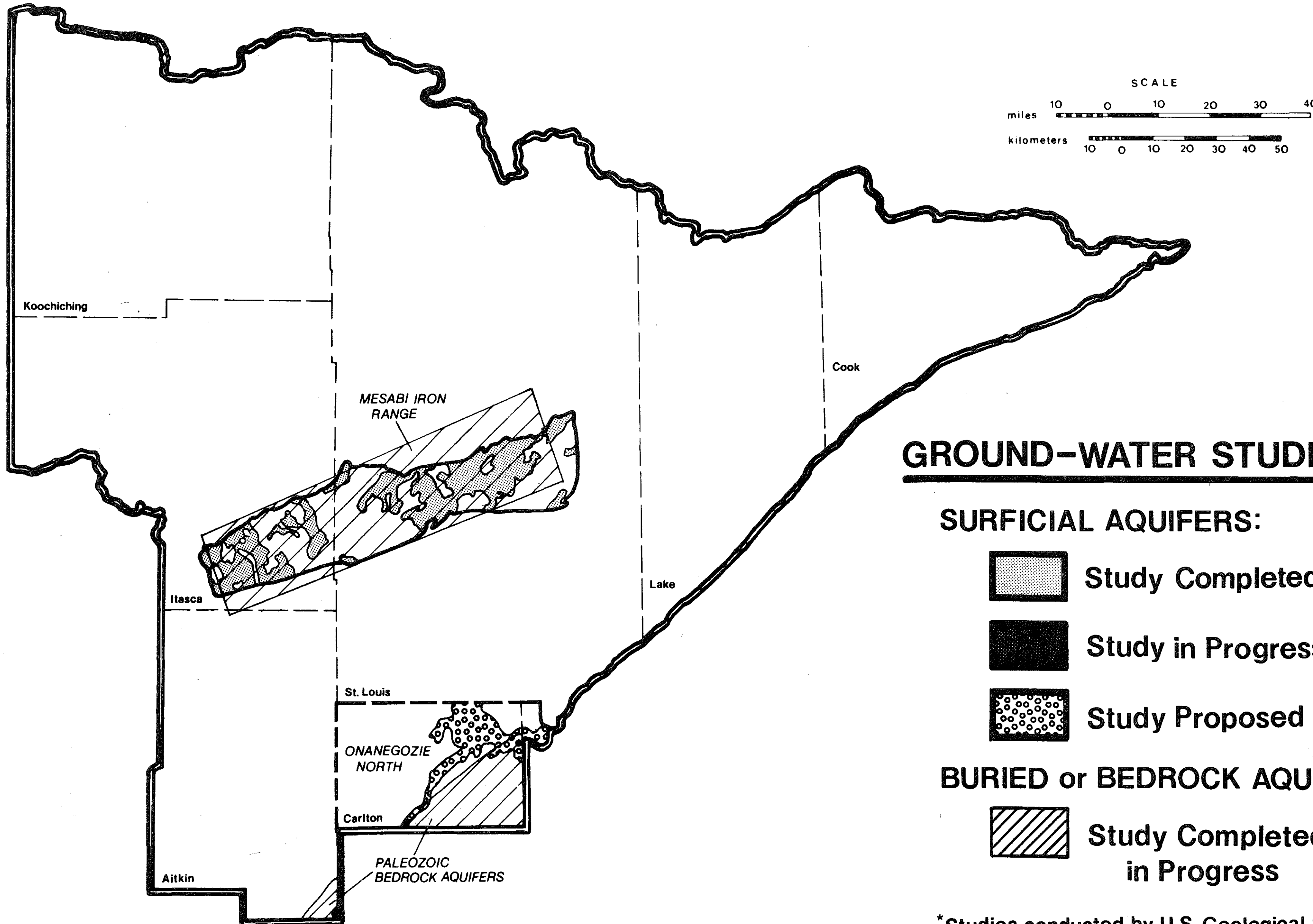
Study Proposed

BURIED or BEDROCK AQUIFERS:

Study Completed or in Progress

*Studies conducted by U.S. Geological Survey independently, or as part of USGS-DOW Co-op Program.

REGION 1: GROUND-WATER STUDIES



GROUND-WATER STUDIES*

SURFICIAL AQUIFERS:

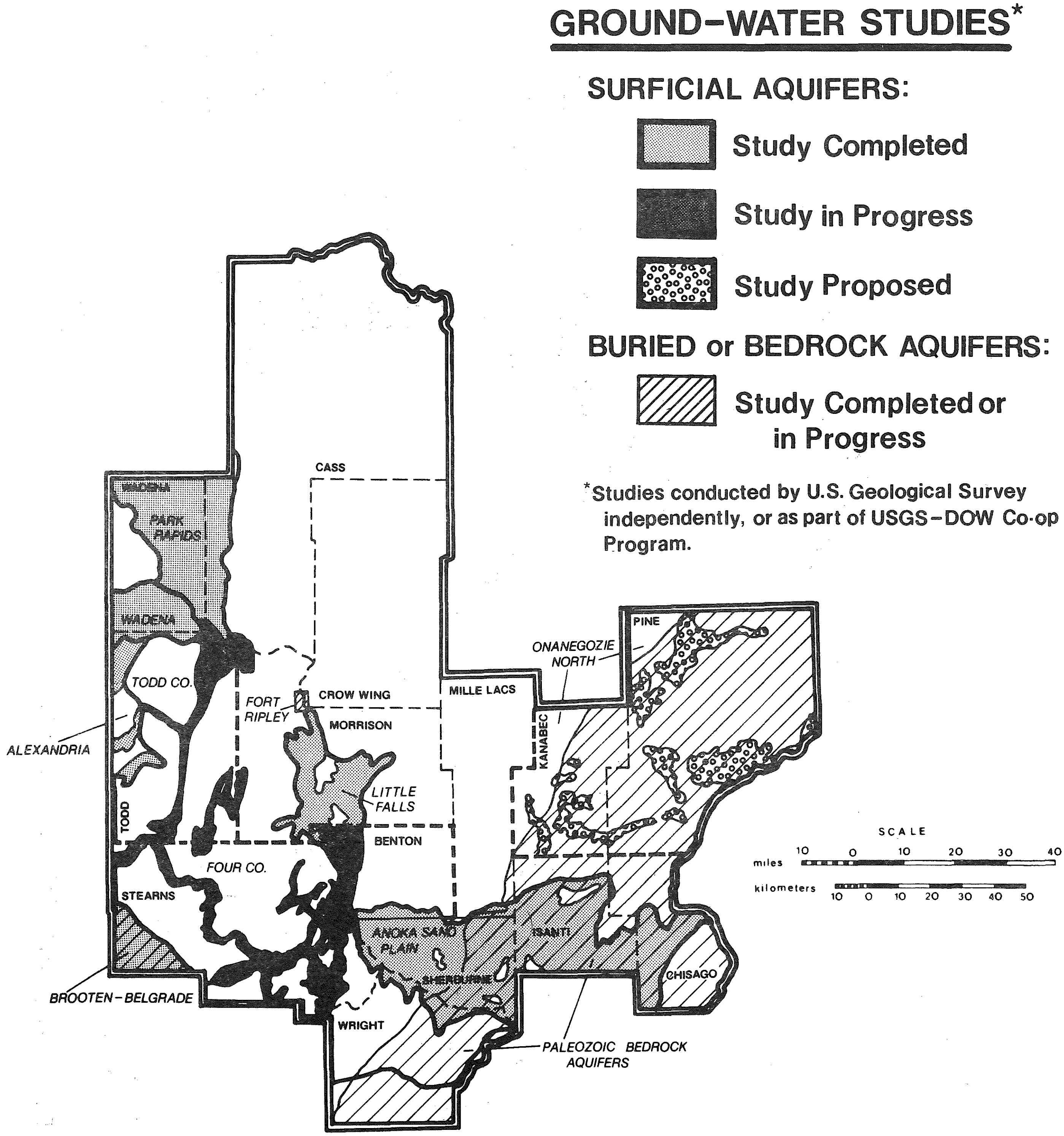
- Study Completed
- Study in Progress
- Study Proposed

BURIED or BEDROCK AQUIFERS:

- Study Completed or in Progress

*Studies conducted by U.S. Geological Survey independently, or as part of USGS-DOW Co-op Program.

REGION 2: GROUND-WATER STUDIES



REGION 3: GROUND-WATER STUDIES

GROUND-WATER STUDIES*

SURFICIAL AQUIFERS:

Study Completed

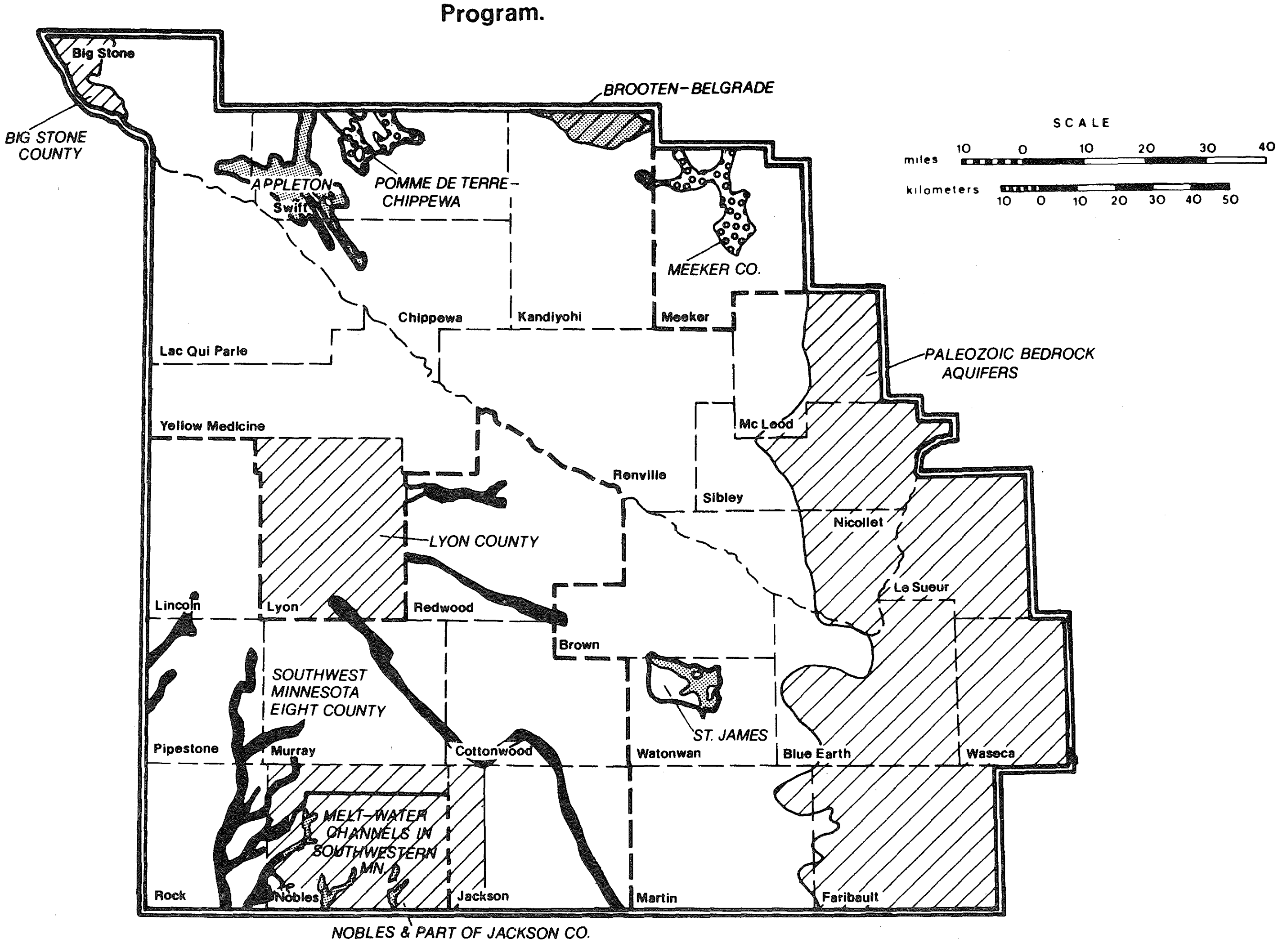
Study in Progress

Study Proposed

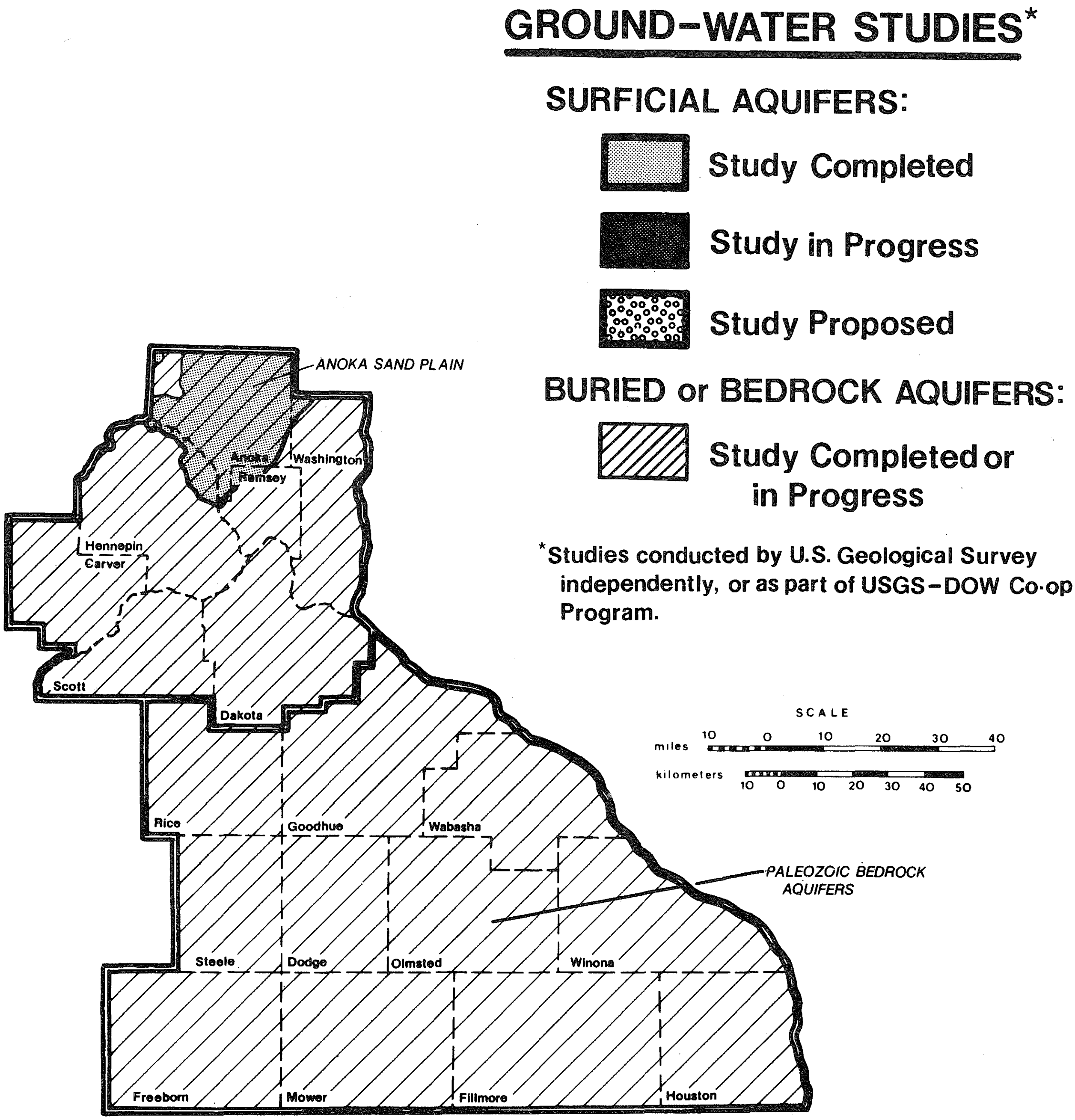
BURIED or BEDROCK AQUIFERS:

Study Completed or in Progress

*Studies conducted by U.S. Geological Survey independently, or as part of USGS-DOW Co-op Program.



REGION 4: GROUND-WATER STUDIES



REGIONS 5 AND 6: GROUND-WATER STUDIES

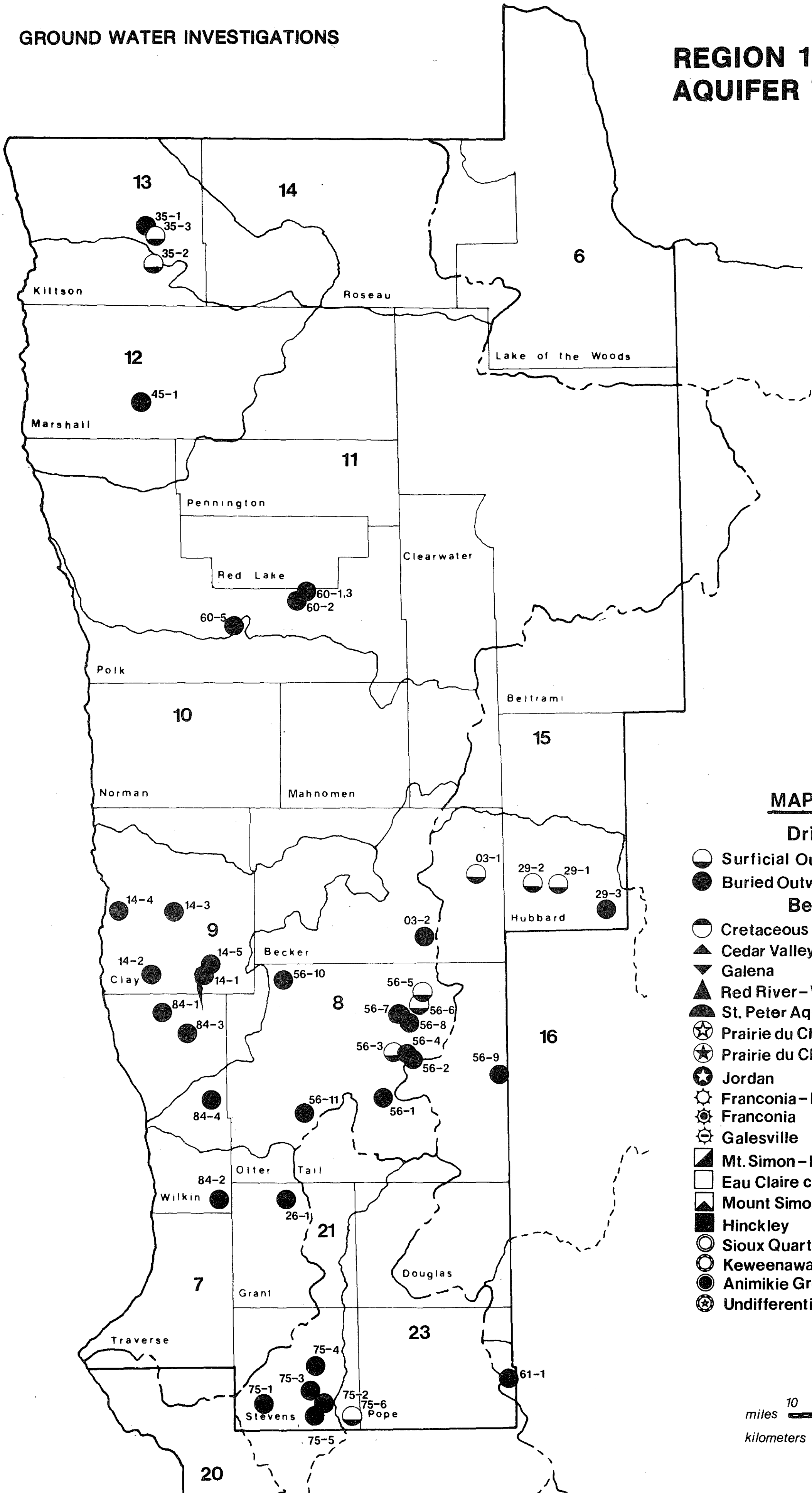
B. DATA COLLECTION - AQUIFER TESTS

The worth of an aquifer as a fully developed source of water depends largely on two characteristics,its ability to store water and its ability to transmit water. These two parameters, referred to as the coefficient of storage (S) and the transmissivity (T), cannot be measured directly. If, however, we remove water from an aquifer, as in an aquifer test, the aquifer responds to the removal of water. This response is measured as drawdown in the pumping well and in nearby observation wells. The amount of drawdown is related to the transmissivity and storage of the aquifer. The relationship between a certain pumping rate (Q) and the drawdown (s) it causes is used to determine the T and S of an aquifer.

An aquifer test is a controlled field experiment made to determine the hydraulic properties of water-bearing rocks. Results from properly conducted aquifer tests can be used in many ways. Well information determined from an aquifer test includes the expected maximum yield, its efficiency potential, observed drawdown (for setting bowls of a turbine pump at proper depth), specific capacity of wells of different diameters, and predictions of the behavior of a well at some time in the future under a given set of conditions. Aquifer properties derived from an aquifer test include the determination of coefficient of storage (S) and transmissivity (T) and permeability, measured and expected interference caused by pumping, area of influence created by cone of depression surrounding a pumping well, aquifer recharge characteristics, aquifer boundary conditions, and expected yield of an aquifer under given drawdown conditions and after given time periods.

The figures on pages **46-50** illustrate the locations and aquifers where the Ground Water Group within the Division of Waters have either analyzed and verifiedhistoric aquifer tests, or conducted and analyzed recent ones. Transmissivity and storage coefficient values have been determined for the specified aquifer at that location. These data can be obtained from the Ground Water Group, Division of Waters, St. Paul.

REGION 1: AQUIFER TEST LOCATIONS



WATERSHED UNITS

6 Lake of the Woods
7 Mustinka—Bois de Sioux
8 Otter Tail
9 Buffalo
10 Wild Rice
11 Red Lake
12 Middle
13 Two
14 Roseau
15 Mississippi Headwaters
16 Crow Wing
20 Big Stone
21 Pomme de Terre
23 Chippewa

Phase I: Compilation derived from files of:
Division of Waters, U.S. Geologic Survey, various Well Drilling Contractors and selected Consulting Engineering Firms. Phase I Compilation only includes data from those files listed as of December 1978.

76-I*

*The first number refers to the County, the second to the Aquifer Test Number in the county. For example, the above number refers to the Aquifer Test File Number I in Swift County. All counties in Minnesota are numbered alphabetically. See text for complete list.

MAP LEGEND

Drift

Surficial Outwash
Buried Outwash

Bedrock

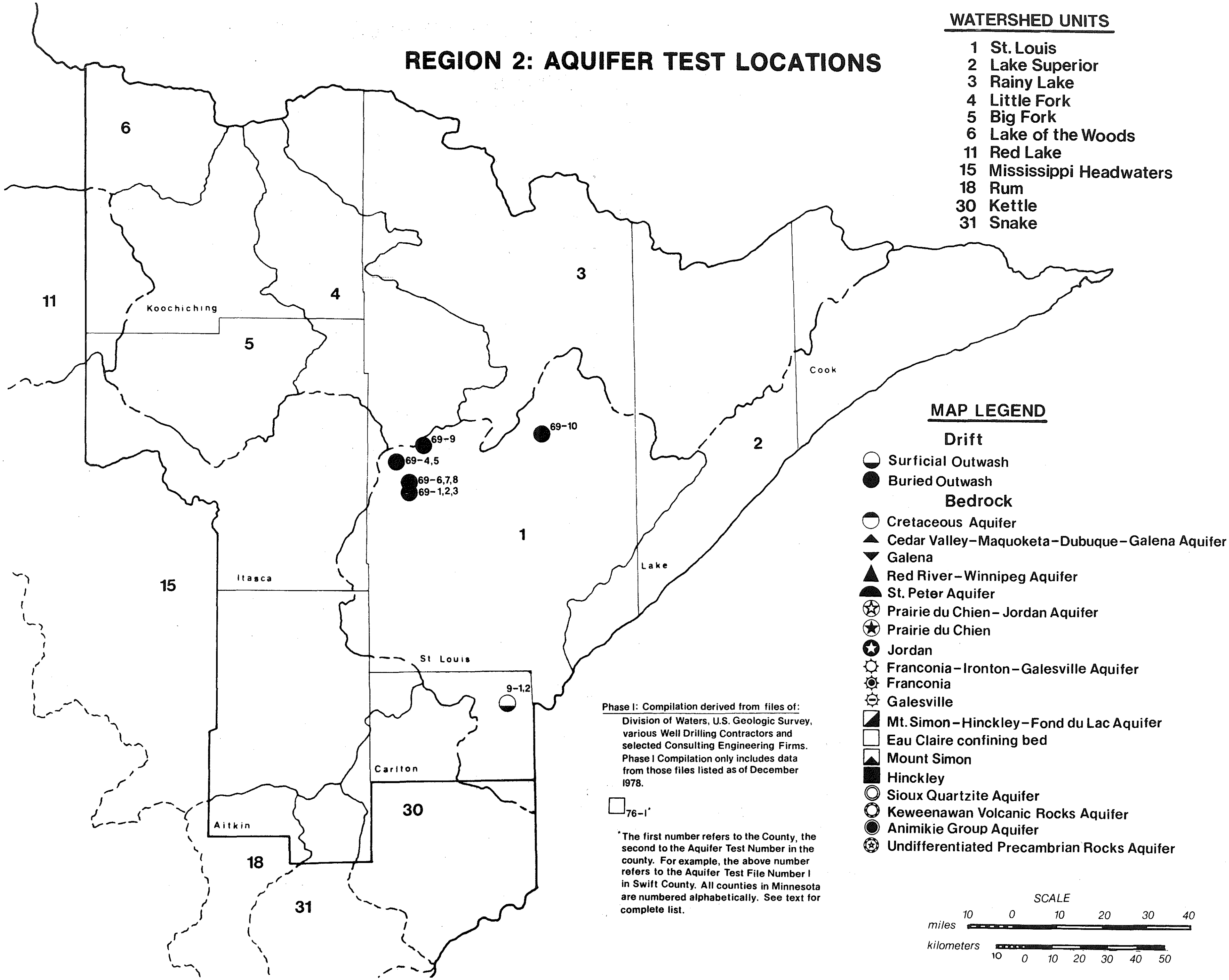
Cretaceous Aquifer
Cedar Valley–Maquoketa–Dubuque–Galena Aquifer
Galena
Red River–Winnipeg Aquifer
St. Peter Aquifer
Prairie du Chien–Jordan Aquifer
Prairie du Chien
Jordan
Franconia–Ironton–Galesville Aquifer
Franconia
Galesville
Mt. Simon–Hinckley–Fond du Lac Aquifer
Eau Claire confining bed
Mount Simon
Hinckley
Sioux Quartzite Aquifer
Keweenawan Volcanic Rocks Aquifer
Animikie Group Aquifer
Undifferentiated Precambrian Rocks Aquifer

SCALE

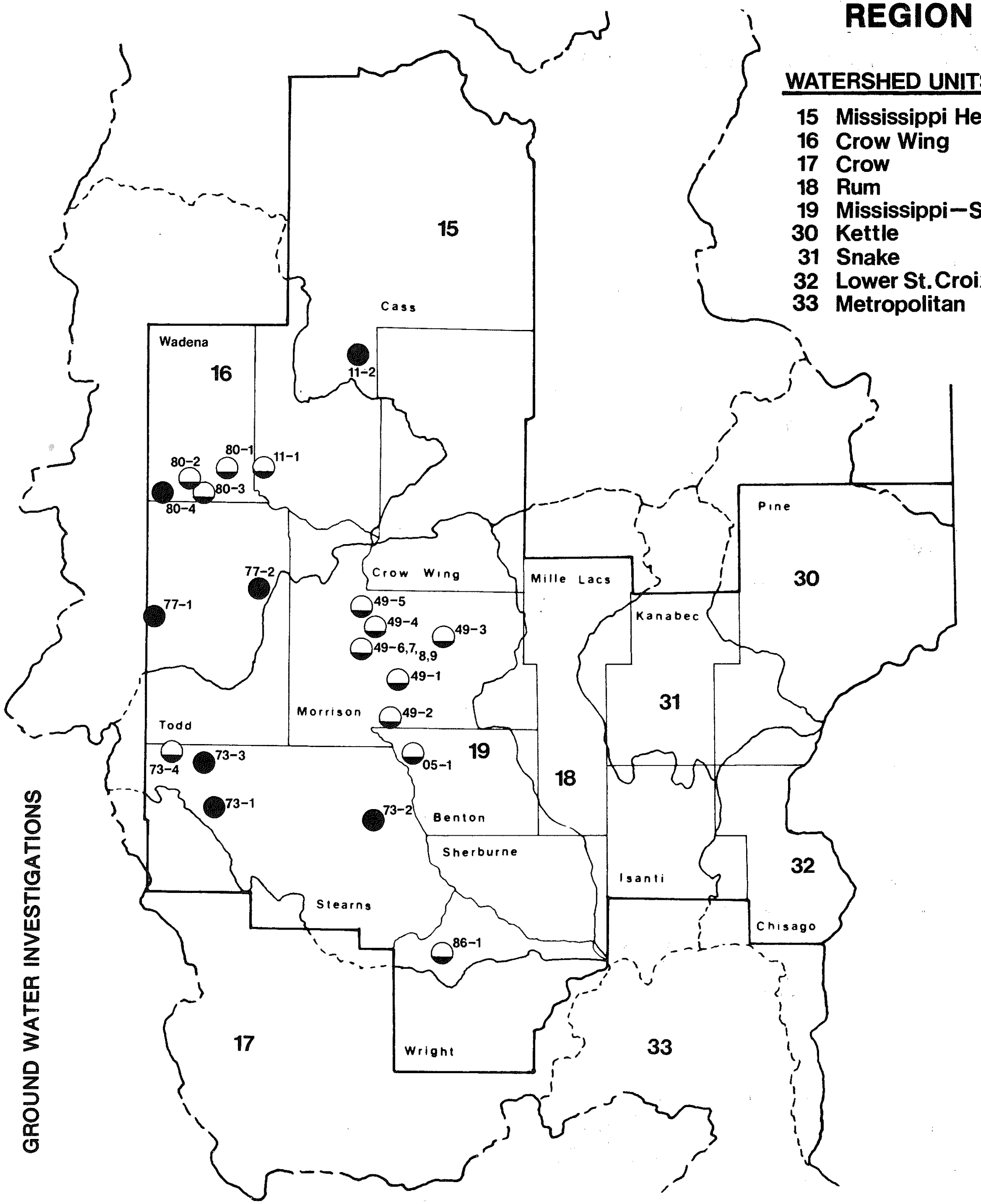
miles 10 0 10 20 30 40

kilometers 10 0 10 20 30 40 50

REGION 2: AQUIFER TEST LOCATIONS



REGION 3: AQUIFER TEST LOCATIONS



WATERSHED UNITS

15 Mississippi Headwaters
16 Crow Wing
17 Crow
18 Rum
19 Mississippi—Sauk
30 Kettle
31 Snake
32 Lower St. Croix
33 Metropolitan

MAP LEGEND

Drift

- Surficial Outwash
- Buried Outwash

Bedrock

- Cretaceous Aquifer
- Cedar Valley-Maquoketa-Dubuque-Galena Aquifer
- Galena
- Red River-Winnipeg Aquifer
- St. Peter Aquifer
- Prairie du Chien-Jordan Aquifer
- Prairie du Chien
- Jordan
- Franconia-Ironton-Galesville Aquifer
- Franconia
- Galesville
- Mt. Simon-Hinckley-Fond du Lac Aquifer
- Eau Claire confining bed
- Mount Simon
- Hinckley
- Sioux Quartzite Aquifer
- Keweenawan Volcanic Rocks Aquifer
- Animikie Group Aquifer
- Undifferentiated Precambrian Rocks Aquifer

Phase I: Compilation derived from files of:
Division of Waters, U.S. Geologic Survey, various Well Drilling Contractors and selected Consulting Engineering Firms. Phase I Compilation only includes data from those files listed as of December 1978.

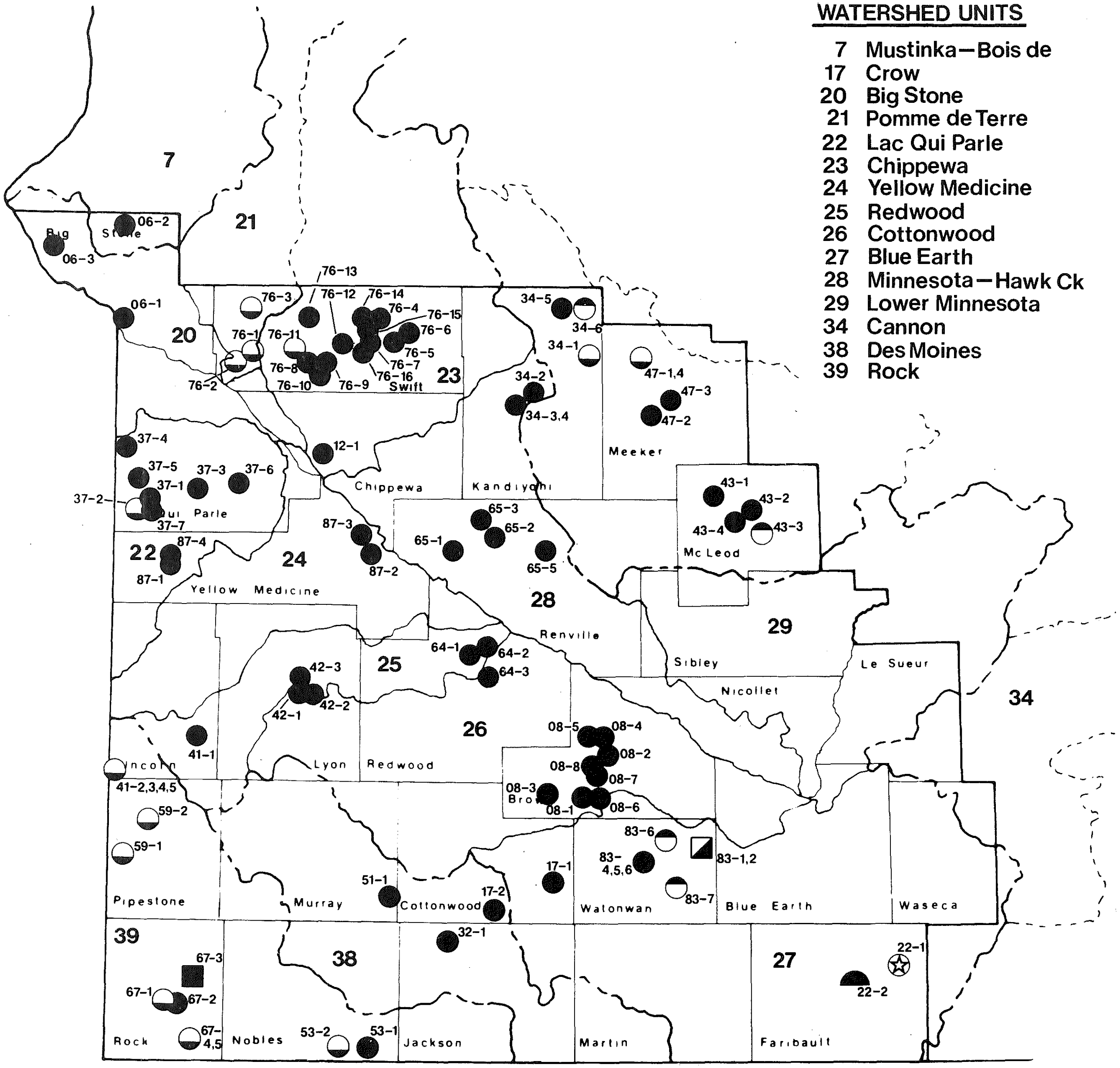
76-1*

*The first number refers to the County, the second to the Aquifer Test Number in the county. For example, the above number refers to the Aquifer Test File Number I in Swift County. All counties in Minnesota are numbered alphabetically. See text for complete list.

SCALE

miles 10 0 10 20 30 40

kilometers 10 0 10 20 30 40 50



WATERSHED UNITS

7 Mustinka—Bois de
17 Crow
20 Big Stone
21 Pomme de Terre
22 Lac Qui Parle
23 Chippewa
24 Yellow Medicine
25 Redwood
26 Cottonwood
27 Blue Earth
28 Minnesota—Hawk Ck
29 Lower Minnesota
34 Cannon
38 Des Moines
39 Rock

MAP LEGEND

Drift

- Surficial Outwash
- Buried Outwash

Bedrock

- Cretaceous Aquifer
- Cedar Valley-Maquoketa-Dubuque-Galena Aquifer
- Galena
- Red River-Winnipeg Aquifer
- St. Peter Aquifer
- Prairie du Chien-Jordan Aquifer
- Prairie du Chien
- Jordan
- Franconia-Ironton-Galesville Aquifer
- Franconia
- Galesville
- Mt. Simon-Hinckley-Fond du Lac Aquifer
- Eau Claire confining bed
- Mount Simon
- Hinckley
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- Keweenawan Volcanic Rocks Aquifer
- Animikie Group Aquifer
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Division of Waters, U.S. Geologic Survey, various Well Drilling Contractors and selected Consulting Engineering Firms. Phase I Compilation only includes data from those files listed as of December 1978.

76-1*

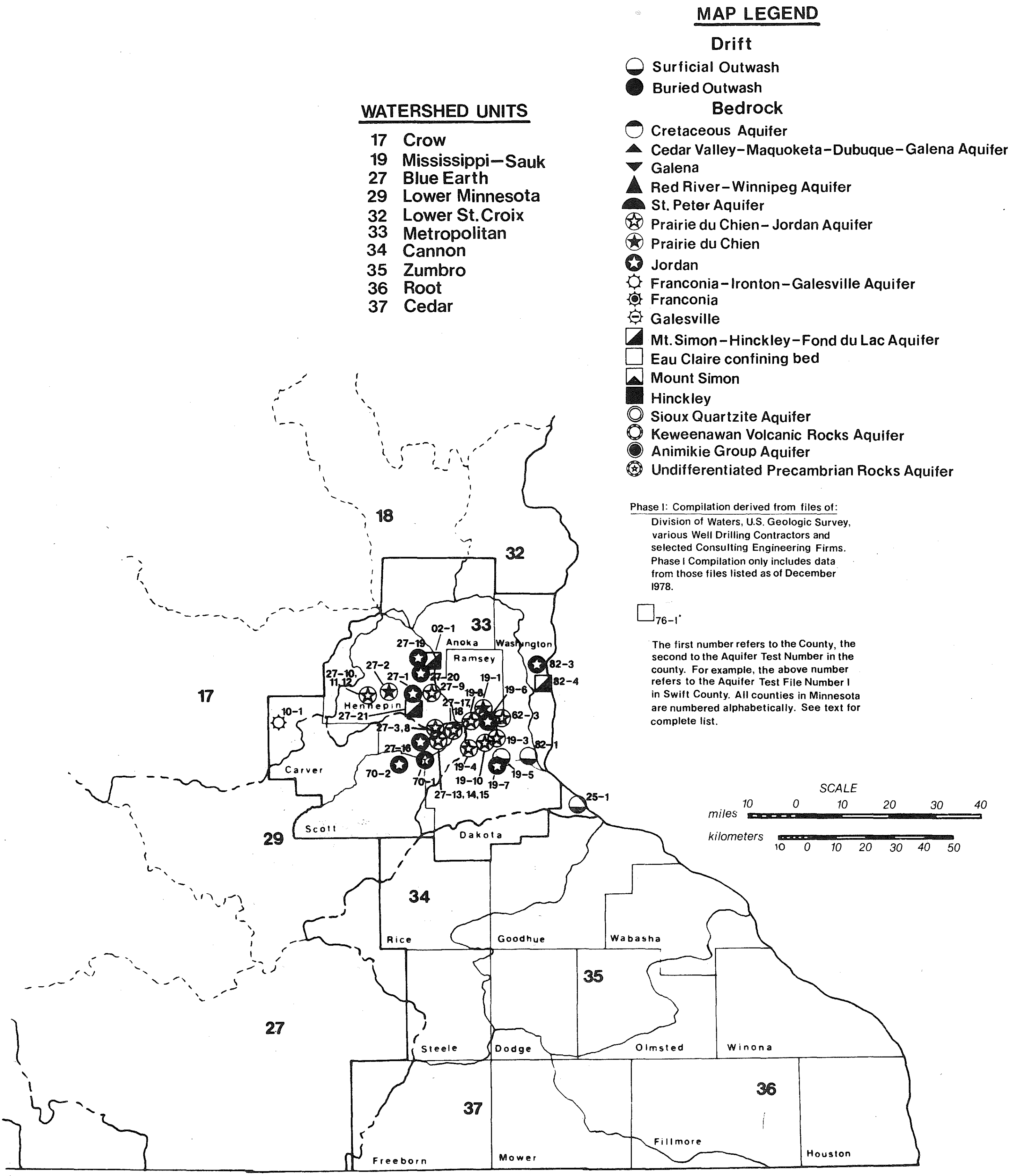
*The first number refers to the County, the second to the Aquifer Test Number in the county. For example, the above number refers to the Aquifer Test File Number I in Swift County. All counties in Minnesota are numbered alphabetically. See text for complete list.

SCALE

miles 10 0 10 20 30 40

kilometers 10 0 10 20 30 40 50

REGION 4: AQUIFER TEST LOCATIONS



REGIONS 5 AND 6: AQUIFER TEST LOCATIONS

C. DATA COLLECTION - OBSERVATION WELLS

Reliance on ground water as a source of water supply in Minnesota has been increasing and this trend will continue. This increased use dictates the need for an effective, reliable ground-water monitoring program. The objectives of a monitoring network are to determine 1) the response of aquifers to stress, 2) the amount of and direction of changes in aquifer storage, 3) changes in ground-water flow patterns and 4) water quality.

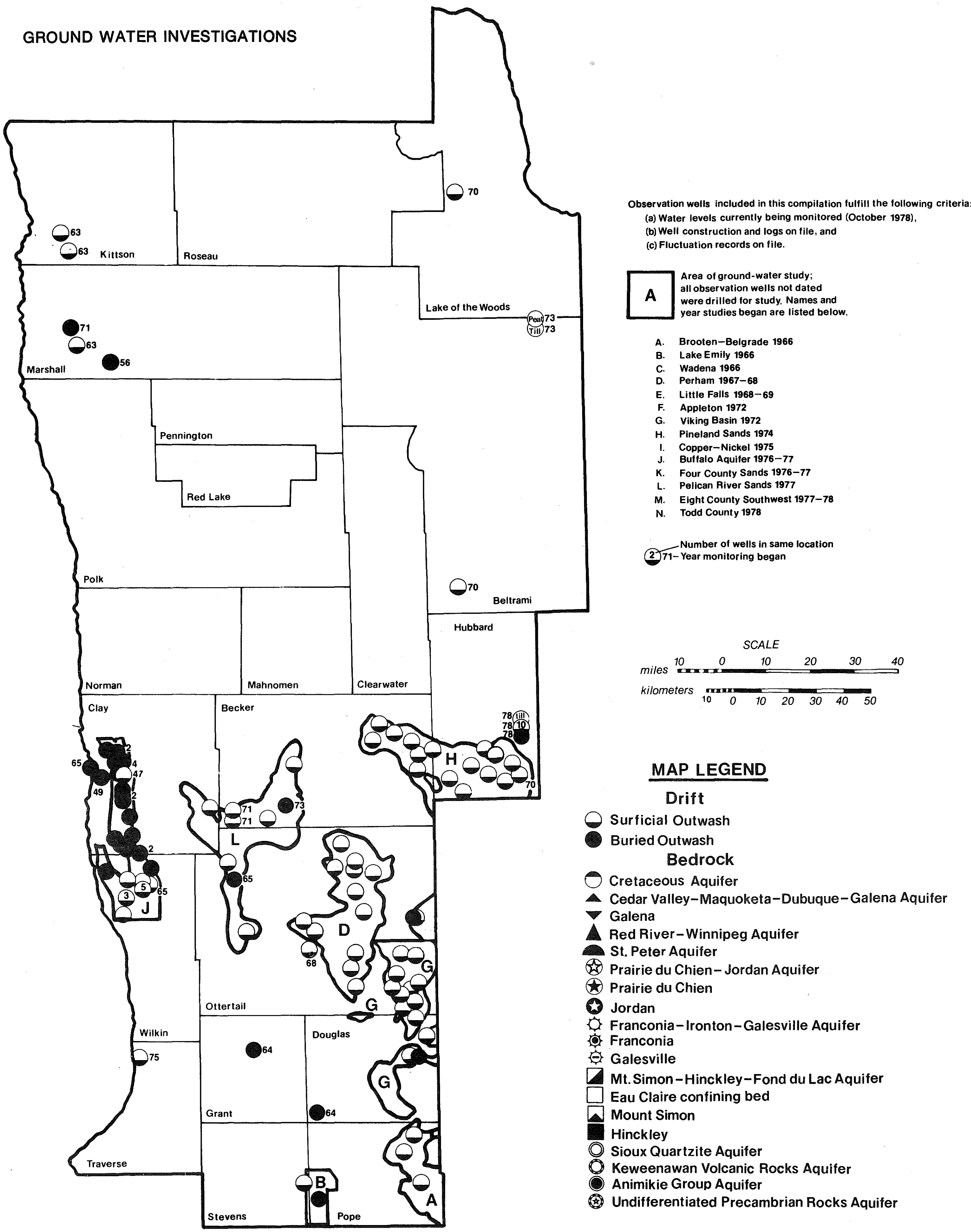
The Division of Water's primary interest and responsibility are in the first three objectives. To meet these objectives an observation well network has been established. Observation well data serve two major functions. The first is the establishment of baseline data free from artificial stress due to heavy pumping or drainage projects. The second is to provide data for water management in areas of heavy withdrawals or where water-use conflicts exist. Water-level fluctuations in baseline function wells reflect natural and climatic conditions. Fluctuations in water management function wells reflect man-made stress.

There are a number of agencies and groups currently monitoring observation wells throughout the state. The Division of Waters Ground Water Group monitors 17 wells in the Metro area and cooperates in monitoring 136 wells with the USGS. Local SWCD personnel monitor wells in several districts. Minnegasco monitors 42 observation wells in conjunction with their gas storage projects. The repository for the data collected will be the Division of Waters ground-water data base. The figures on pages 52-56 show the location and aquifers currently being monitored for water level fluctuations.

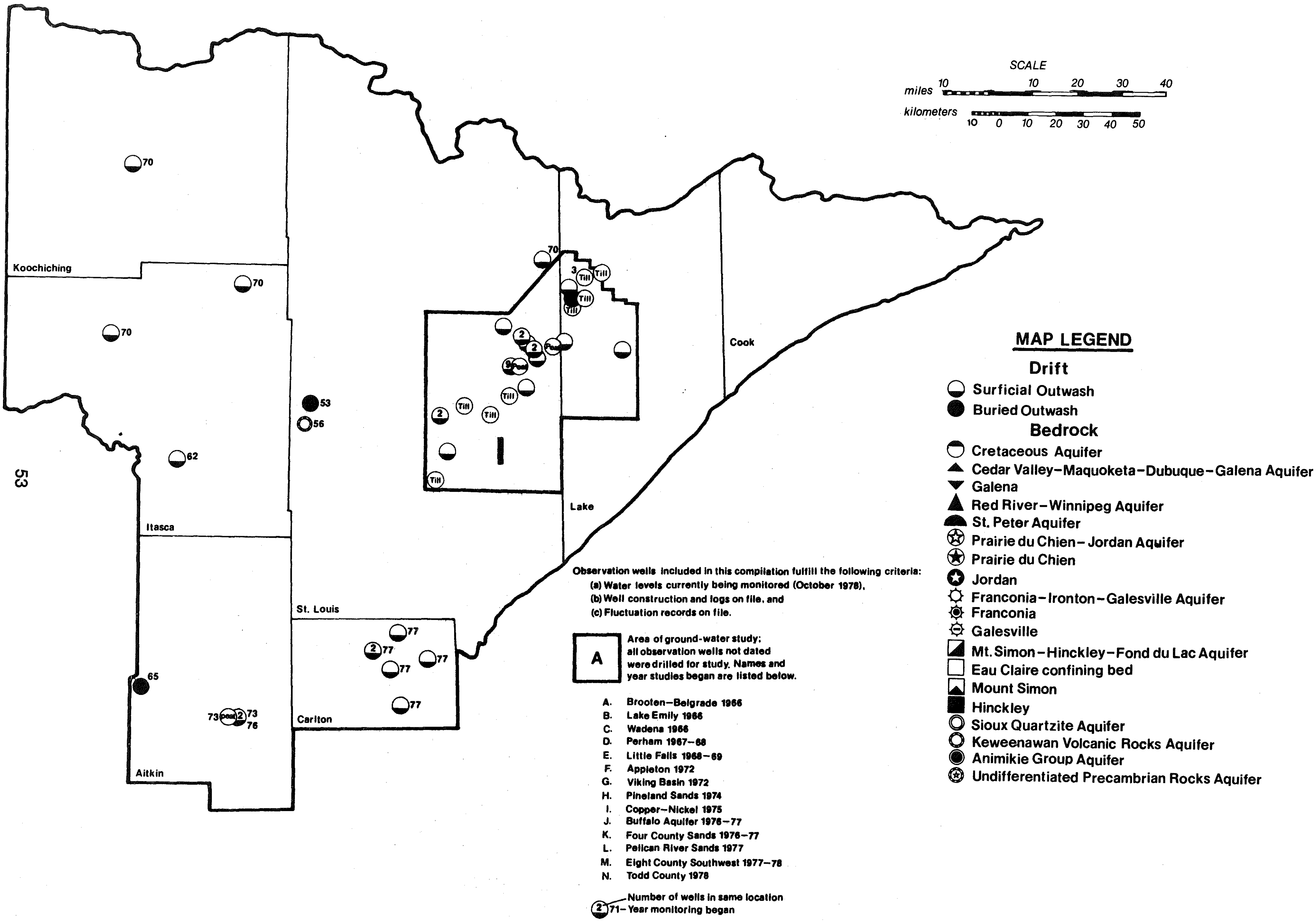
The Ground Water Group is currently engaged in a project to expand the observation well network. Emphasis for additional monitoring is placed in areas experiencing accelerated ground-water pumping, so that ground-water mining can be detected.

The figure on page 57 depicts water-table fluctuations in representative observation wells before and after the mid-1970's drought. The Wadena and Stearns County wells also reveal effects of irrigation withdrawals. However, all wells indicate that the extremely low water levels resulting from the drought in 1976 are recovering in 1978.

For questions regarding records on any of these observation wells, contact the Ground Water Group, Division of Waters, St. Paul.



REGION 1: LOCATION OF GROUND-WATER OBSERVATION WELLS



REGION 2: LOCATION OF GROUND-WATER OBSERVATION WELLS

GROUND WATER INVESTIGATIONS

Observation wells included in this compilation fulfill the following criteria:
(a) Water levels currently being monitored (October 1978),
(b) Well construction and logs on file, and
(c) Fluctuation records on file.

A — Area of ground-water study; all observation wells not dated were drilled for study. Names and year studies began are listed below.

A. Brooten–Belgrade 1966
B. Lake Emily 1966
C. Wadena 1966
D. Perham 1967–68
E. Little Falls 1968–69
F. Appleton 1972
G. Viking Basin 1972
H. Pineland Sands 1974
I. Copper–Nickel 1975
J. Buffalo Aquifer 1976–77
K. Four County Sands 1976–77
L. Pelican River Sands 1977
M. Eight County Southwest 1977–78
N. Todd County 1978

(2) 71 — Number of wells in same location; Year monitoring began

MAP LEGEND

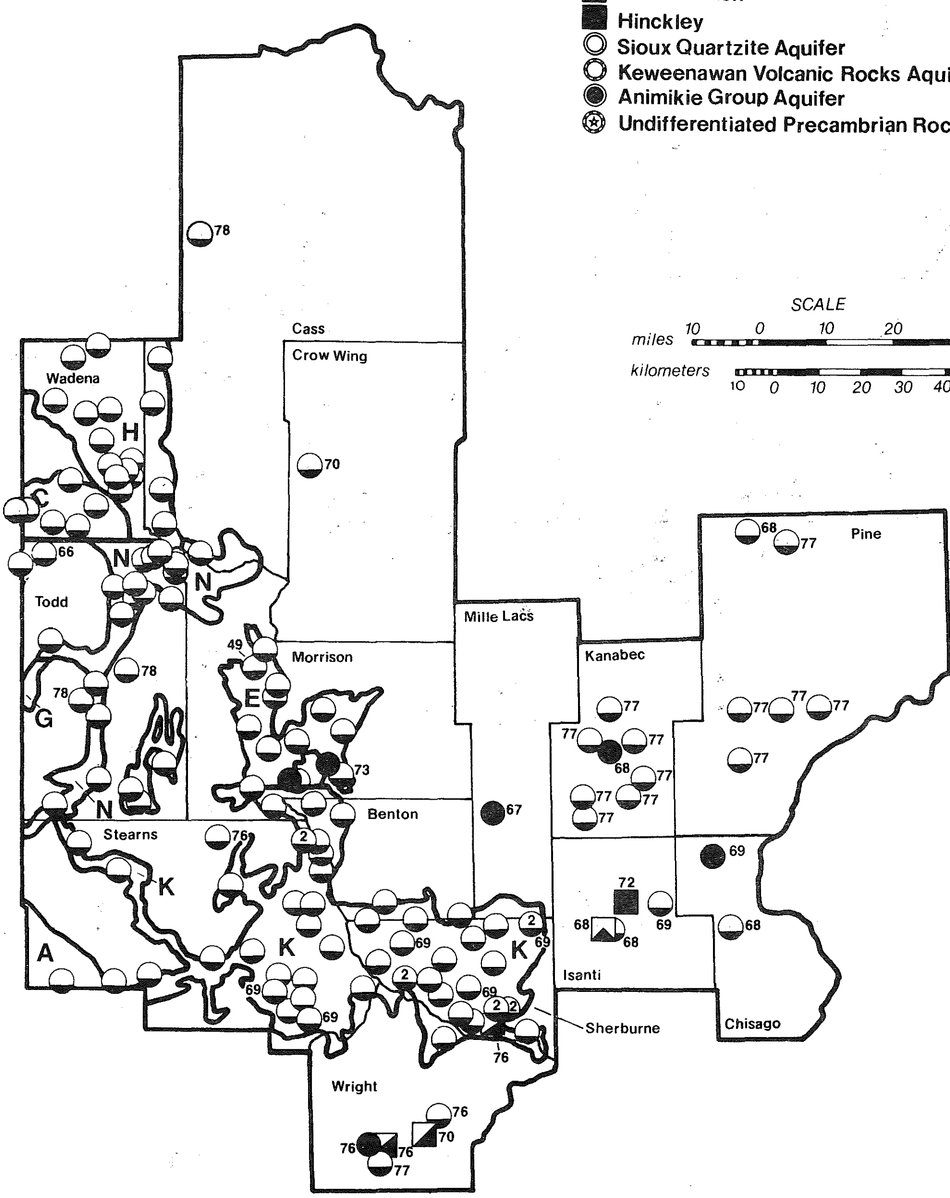
Drift

- Surficial Outwash
- Buried Outwash

Bedrock

- Cretaceous Aquifer
- Cedar Valley–Maquoketa–Dubuque–Galena Aquifer
- Galena
- Red River–Winnipeg Aquifer
- St. Peter Aquifer
- Prairie du Chien–Jordan Aquifer
- Prairie du Chien
- Jordan
- Franconia–Ironton–Galesville Aquifer
- Franconia
- Galesville
- Mt. Simon–Hinckley–Fond du Lac Aquifer
- Eau Claire confining bed
- Mount Simon
- Hinckley
- Sioux Quartzite Aquifer
- Keweenawan Volcanic Rocks Aquifer
- Animikie Group Aquifer
- Undifferentiated Precambrian Rocks Aquifer

SCALE
miles 10 0 10 20 30 40
kilometers 10 0 10 20 30 40 50



REGION 3: LOCATION OF GROUND-WATER OBSERVATION WELLS

MAP LEGEND

Drift

- Surficial Outwash
- Buried Outwash

Bedrock

- Cretaceous Aquifer
- Cedar Valley–Maquoketa–Dubuque–Galena Aquifer
- Galena
- Red River–Winnipeg Aquifer
- St. Peter Aquifer
- Prairie du Chien–Jordan Aquifer
- Prairie du Chien
- Jordan
- Franconia–Ironton–Galesville Aquifer
- Franconia
- Galesville
- Mt. Simon–Hinckley–Fond du Lac Aquifer
- Eau Claire confining bed
- Mount Simon
- Hinckley
- Sioux Quartzite Aquifer
- Keweenawan Volcanic Rocks Aquifer
- Animikie Group Aquifer
- Undifferentiated Precambrian Rocks Aquifer

Observation wells included in this compilation fulfill the following criteria:
(a) Water levels currently being monitored (October 1978),
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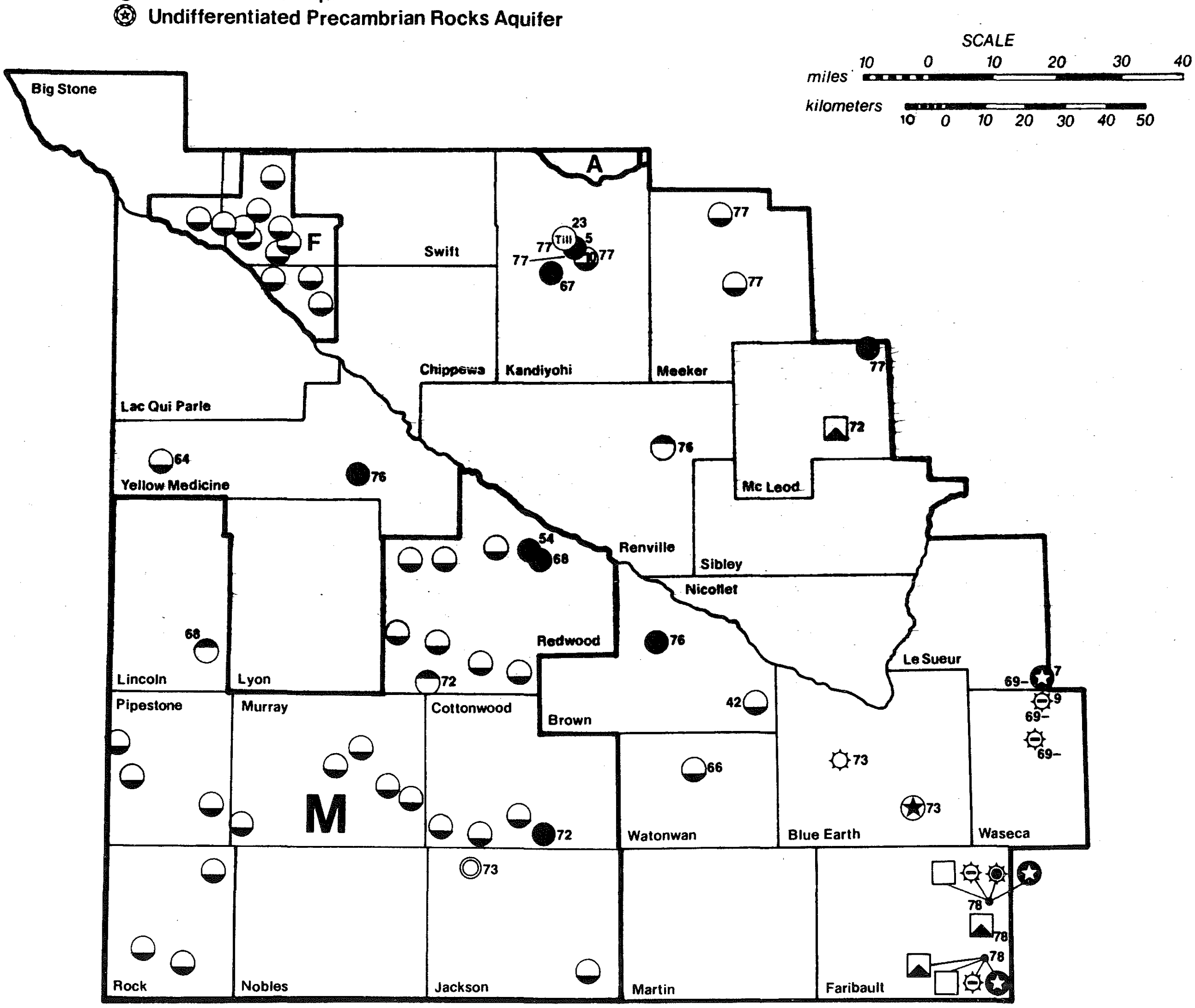
C. Wadena 1966
D. Perham 1967–68
E. Little Falls 1968–69
F. Appleton 1972
G. Viking Basin 1972
H. Pineland Sands 1974
I. Copper–Nickel 1975
J. Buffalo Aquifer 1976–77
K. Four County Sands 1976–77
L. Pelican River Sands 1977
M. Eight County Southwest 1977–78
N. Todd County 1978

2 — Number of wells in same location
71 — Year monitoring began



REGION 4: LOCATION OF GROUND-WATER OBSERVATION WELLS

MAP LEGEND

Drift

- Surficial Outwash
- Buried Outwash

Bedrock

- Cretaceous Aquifer
- Cedar Valley–Maquoketa–Dubuque–Galena Aquifer
- Galena
- Red River–Winnipeg Aquifer
- St. Peter Aquifer
- Prairie du Chien–Jordan Aquifer
- Prairie du Chien
- Jordan
- Franconia–Ironton–Galesville Aquifer
- Franconia
- Galesville
- Mt. Simon–Hinckley–Fond du Lac Aquifer
- Eau Claire confining bed
- Mount Simon
- Hinckley
- Sioux Quartzite Aquifer
- Keweenawan Volcanic Rocks Aquifer
- Animikie Group Aquifer
- Undifferentiated Precambrian Rocks Aquifer

Observation wells included in this compilation fulfill the following criteria:
(a) Water levels currently being monitored (October 1978),
(b) Well construction and logs on file, and
(c) Fluctuation records on file.

A — Area of ground-water study; all observation wells not dated were drilled for study. Names and year studies began are listed below.

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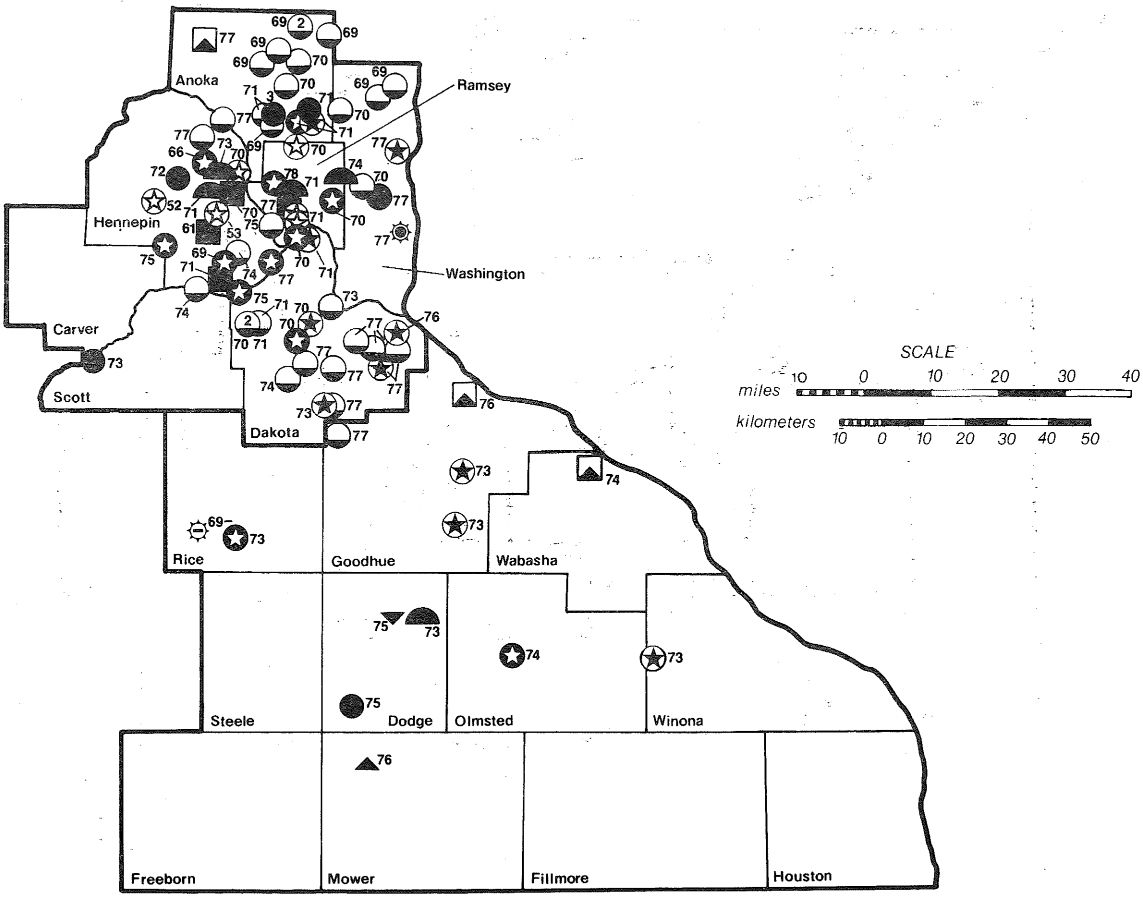
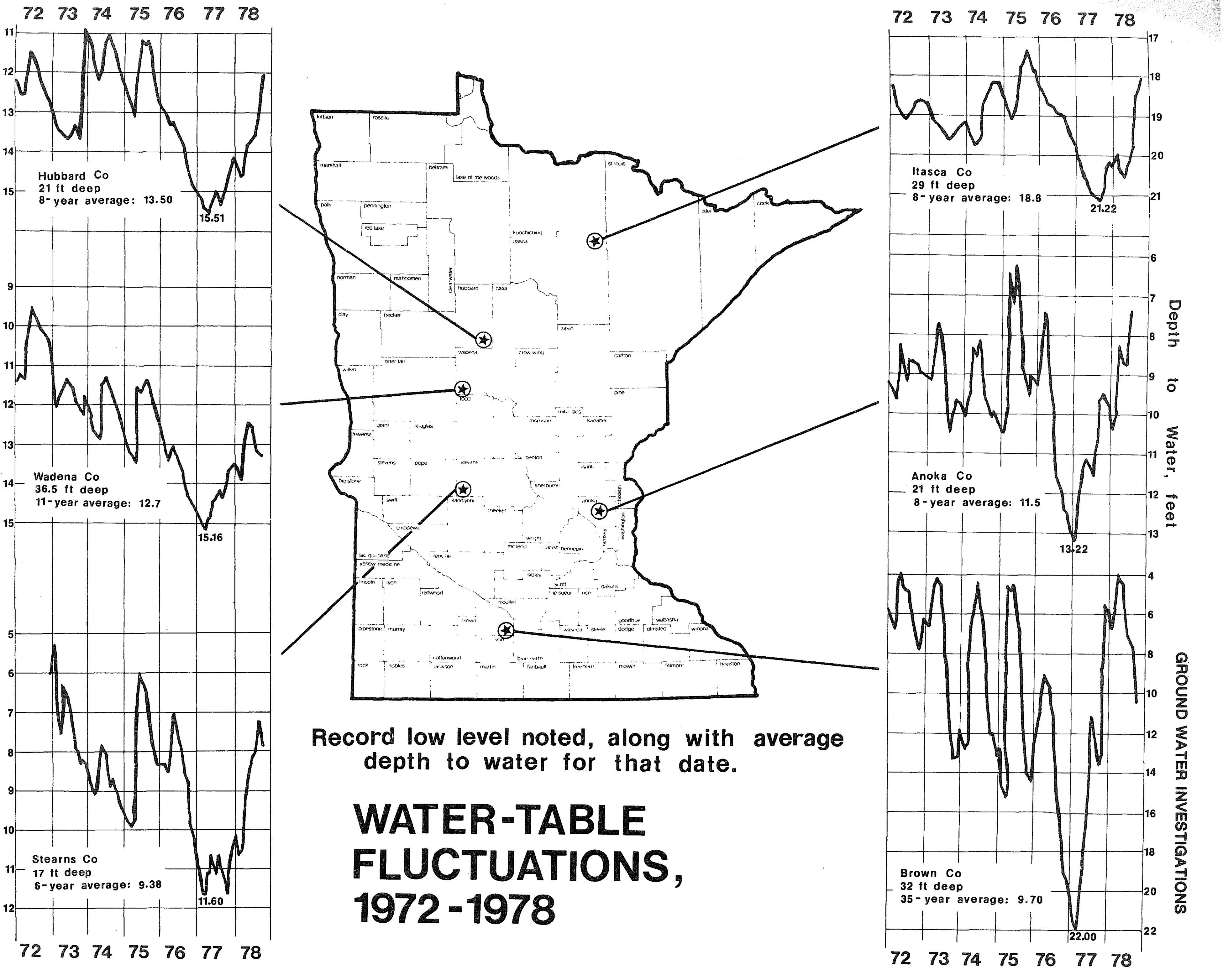
C. Wadena 1966
D. Perham 1967–68
E. Little Falls 1968–69
F. Appleton 1972
G. Viking Basin 1972
H. Pineland Sands 1974
I. Copper–Nickel 1975
J. Buffalo Aquifer 1976–77
K. Four County Sands 1976–77
L. Pelican River Sands 1977
M. Eight County Southwest 1977–78
N. Todd County 1978

(2) 71 — Number of wells in same location; 71 — Year monitoring began



REGIONS 5 AND 6: LOCATION OF GROUND-WATER OBSERVATION WELLS



Record low level noted, along with average depth to water for that date.

WATER-TABLE FLUCTUATIONS, 1972-1978