WATER YEAR DATA SUMMARY

1999 and 2000

May 2001

Minnesota
Department of Natural Resources
Waters

www.dnr.state.mn.us/waters

WATER YEAR DATA SUMMARY

1999 and 2000

October 1, 1999 - September 30, 2000

by the DNR Waters Staff
St. Paul, MN

May 2001

Minnesota
Department of Natural Resources
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Introduction

This publication provides a review and summary of basic hydrologic data gathered through DNR Waters programs. There are four major areas of data collection including climatology, surface water, ground water and water use. These areas follow the hydrologic cycle (see diagram) and provide important facts concerning the distribution and availability of Minnesota s water resources.

Basic hydrologic data are essential to a variety of water resource programs and related efforts. The extent of our knowledge depends on the quality and quantity of hydrologic data. Analysis and use of data are vital to understanding complex hydrologic relationships. With expanding technologies, there is a greater need for even more data of higher quality.

The DNR Waters web site at **www.dnr.state.mn.us/waters** provides a wealth of information on Minnesota's lakes, rivers and streams, wetlands, ground water and climate, much more than can be included in this summary report. Maps, publications, forms, educational resources and answers to common water resources questions can be found on the site. Visitors will find access to lake level data, stream flow information and ground water level data. The site, which is updated regularly, is intended to help the citizens of Minnesota become better stewards of the state's water resources by providing comprehensive information about those resources.

This report is a continuation of Water Year reports published by DNR Waters in 1979, 1980, 1991, 1993, 1995, 1997 and 1999. This edition is also available on our web site.

Water Year

The climatology, surface water and ground water data presented are for Water Years 1999 and 2000.

WY 1999: October 1, 1998 - September 30, 1999
WY 2000: October 1, 1999 - September 30, 2000

Use of water year as a standard follows the national water supply data publishing system that was started in 1913. This convention was adopted because responses of hydrologic systems after October 1 are practically all a reflection of precipitation (snow and rain) occurring within that water year.

Water use data is reported and presented on a calendar year basis.

Acknowledgements

We wish to express our gratitude to the listed authors and others who contributed to this publication.
Special thanks to Doug Schaffer, Barb Weber and especially Jim Zicopula for assistance with layout and design.

COVER PHOTOGRAPH:
Mississippi River Headwaters, Lake Itasca - Courtesy of the Minnesota Office of Tourism.

Glen Yakel, *Editor* Kent Lokkesmoe, *Director*

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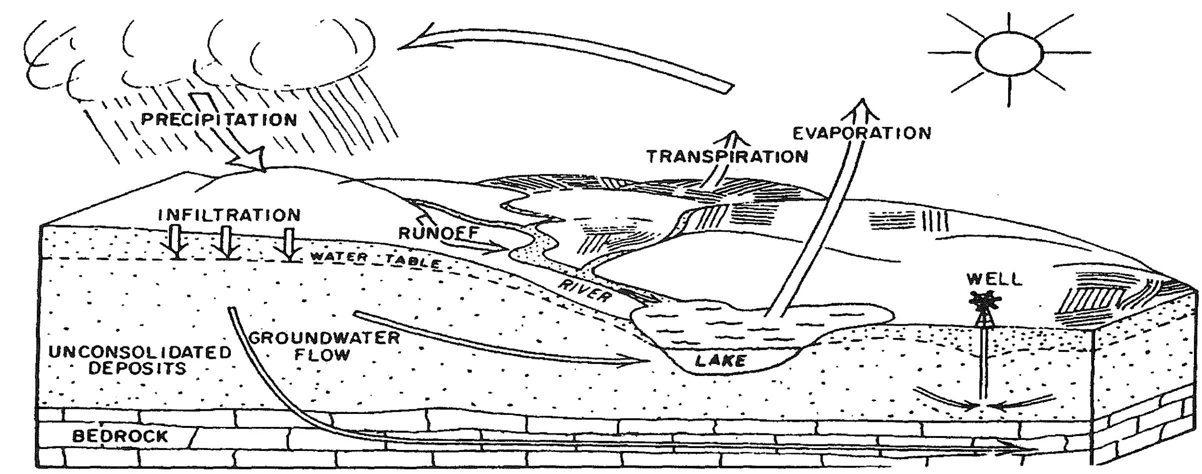
Hydrologic Cycle

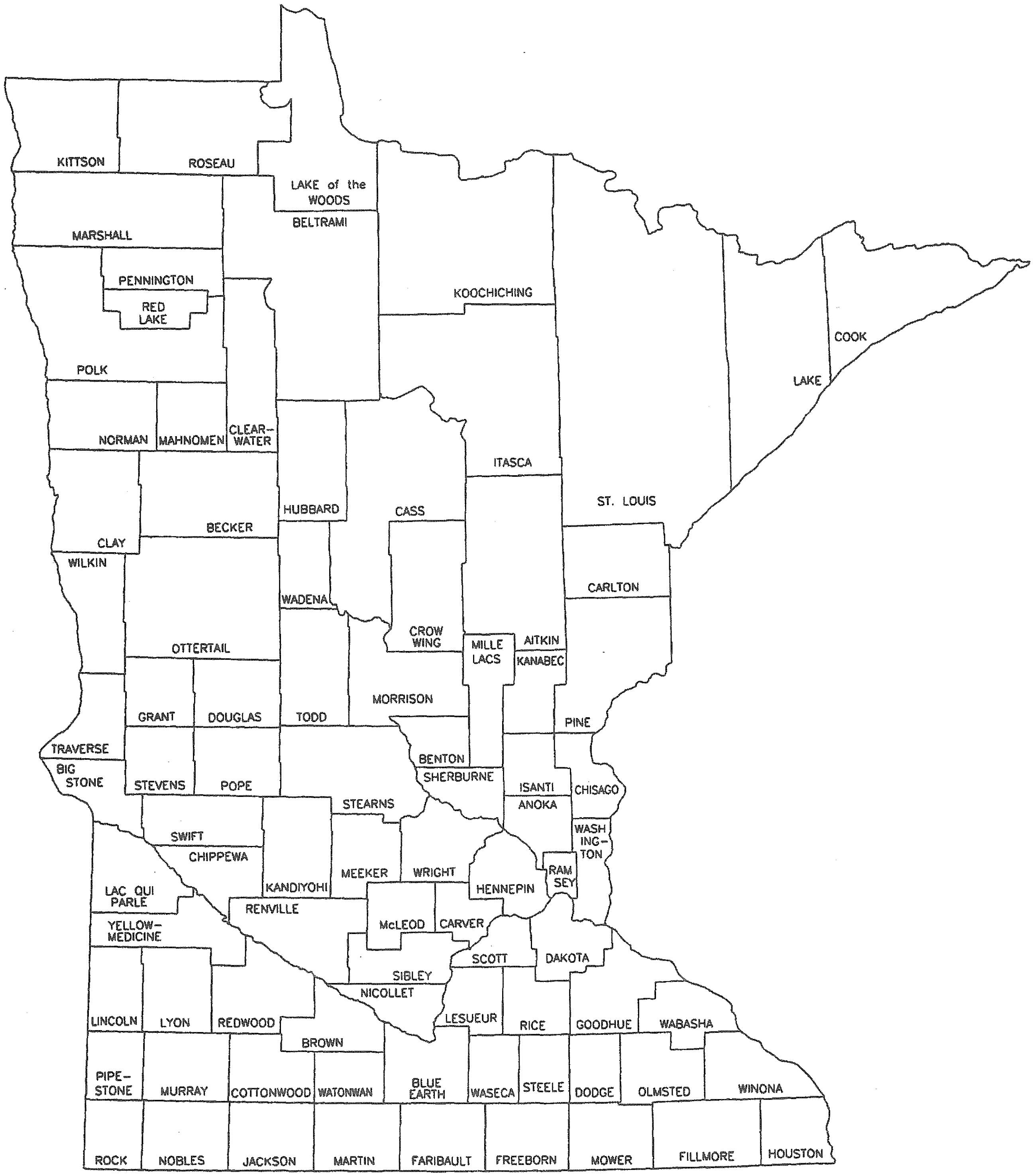


The hydrologic cycle is a concept used to explain the movement of water around the earth. This movement is continuous and has no beginning or end. Change at any point in the cycle will be reflected later in the cycle.

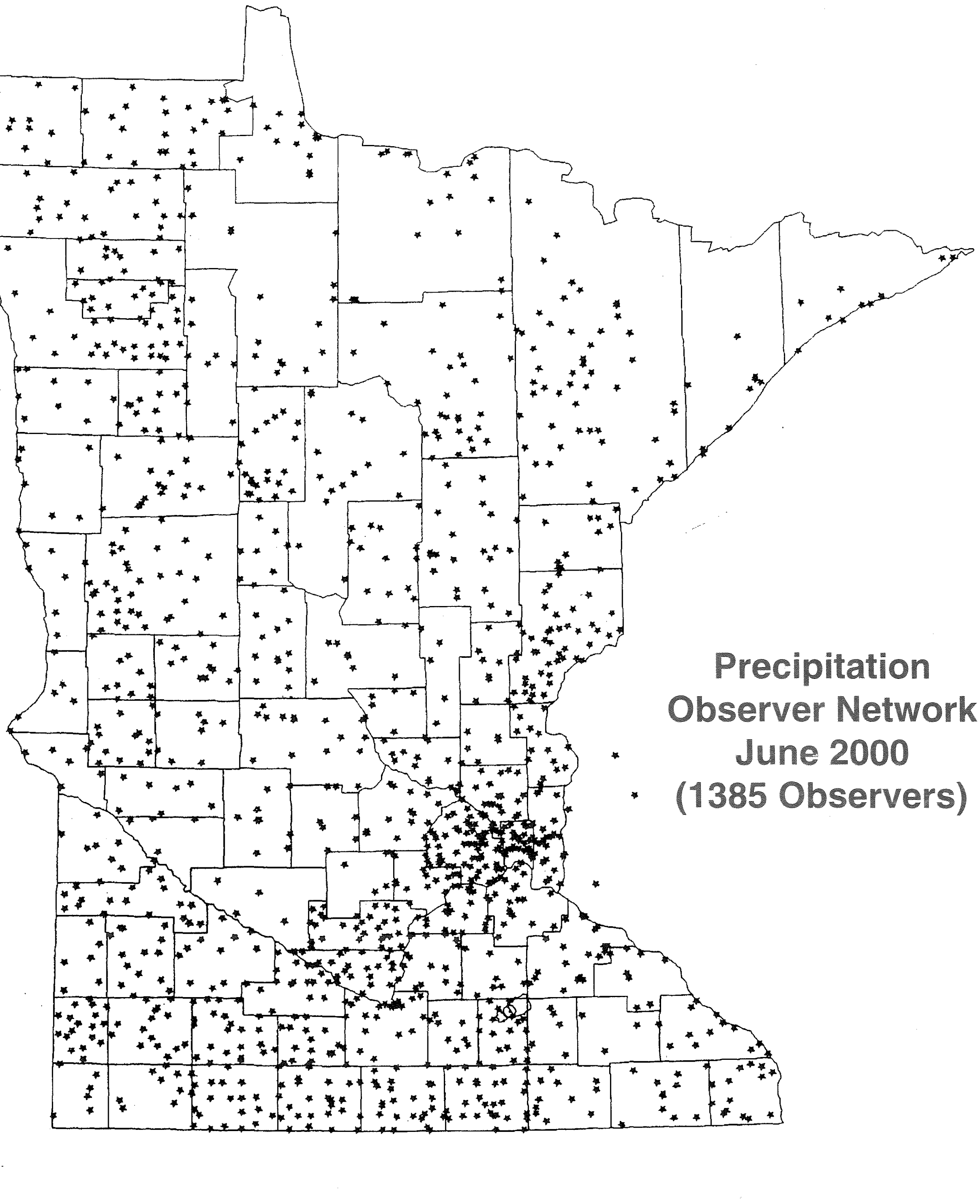
Surface water, which predominately exists in oceans, is evaporated into the atmosphere by the energy of the sun. It returns to the earth as precipitation (rain or snow). As precipitation falls, it may be intercepted by vegetation and evaporate or it may reach the ground surface. Water that reaches the surface may either soak into the soil or move downslope. As it soaks into the soil (infiltration), it may be held in the soil or continue to move downward and become ground water. Ground water may be stored in the ground, returned to the surface as a spring, flow into a concentrated body such as a stream or lake, or be returned to the atmosphere by plant transpiration. Water that does not infiltrate the soil moves downslope, until concentrated areas form a stream. Streams lead to lakes and into other streams, which ultimately return the water to the oceans.

At any point where water is on the ground surface, it is subject to evaporation into the atmosphere or infiltration into the soil.

Minnesota Counties



Chapter One CLIMATOLOGY



Precipitation
Observer Network
June 2000
(1385 Observers)

Introduction

The State Climatology Office exists to gather and analyze climate data for the benefit of the State of Minnesota and its citizens. A variety of organizations and individuals provide climate data. These organizations rely primary on the efforts of volunteer observers. The data are consolidated into a unified data base and climate information is distributed to many users.

A review of climate information can assist in explaining a prior event or condition. Climate information aids long-range planning efforts by characterizing what is typical or extreme, likely or unlikely. Users of climate information include government agencies (local, state, federal), academic institutions, media, private sector professionals and the general public. Specifically, engineers use temperature and precipitation data to design roads and storm sewers. Wildlife managers use temperature and snow depth information to identify survival conditions for wildlife. Foresters use temperature, humidity and wind data to identify fire danger conditions. Agricultural specialists use temperature and precipitation data to determine the types of crops that will grow in Minnesota. Others relying upon climate information include hydrologists, foresters, meteorologists, attorneys, insurance adjusters, journalists and recreation managers.

Climate Data Sources:

Soil and Water Conservation Districts
National Weather Service
University of Minnesota
Department of Natural Resources
Twin Cities Area Volunteer Observers (Backyard Network)
Metropolitan Mosquito Control District
Minnesota Association of Watershed Districts
Metropolitan Waste Control Commission
Deep Portage Conservation Reserve
Minnesota Power and Light Company
Emergency Management
Citizen Volunteers

"Normal"

The word 'normal' in this chapter refers to a 30-year mathematical average of measurements made over the period 1961-1990. In the year 2001, this averaging period will transition to 1971-2000 according to standards adopted by climatologists around the world. Many individuals tend to (erroneously) perceive normal weather as what they should expect. Dr . Helmut E. Landsberg, former Director of Climatology of the U.S. Weather Bureau, summarized this misconception as follows: "The layman is often misled by the word. In his every-day language the word normal means something ordinary or frequent...When (the meteorologist) talks about 'normal', it has nothing to do with a common event...For the meteorologist the 'normal' is simply a point of departure or index which is convenient for keeping track of weather statistics."

Water Year 1999

October 1, 1998 — September 30, 1999

Highlights

• Mild Autumn, 1998
• Mild Winter, 1998 — 1999
• Wet Spring, 1999
• BWCA Superstorm — July 4, 1999
• Dry Spell Begins in Southwest Minnesota — Summer 1999

Autumn 1998

In late summer/early autumn of 1998, the northwest and southeast parts of Minnesota were quite wet, while the northeast and southwest were dry. As autumn progressed, the northeast received much needed rains while the southeast experienced dry conditions over a region that had a damp growing season (Figure 1).

The statewide average temperature was two to four degrees above normal during October and November, continuing a year-long trend of warmth. A November 10 storm brought heavy snow, damaging winds and record-breaking low temperatures to many locations, however, the end of November was extraordinarily warm.

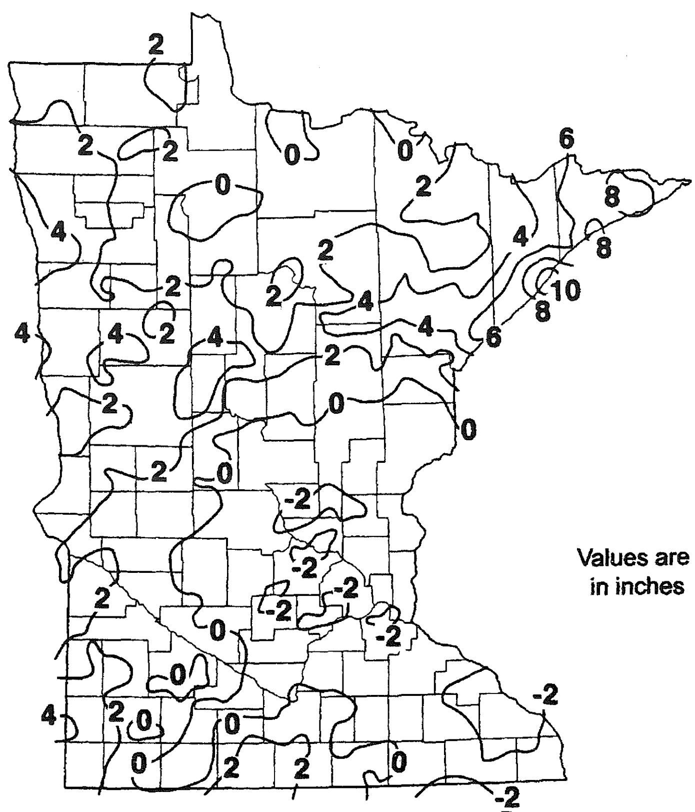
Winter 1998-1999

Many high-temperature records were broken during the first half of December, when statewide temperatures were 15 to 20 degrees above normal. The balmy weather led to unusually high December flows in many streams. Although precipitation was light, mild temperatures allowed tributaries to continue flowing when they would otherwise be ice-bound in a more typical year. Temperatures dropped below normal by mid-month, rapidly freezing the snow-free landscape. Historical ice-in records for lakes are sketchy, however, many lakes experienced very late freeze-up.

January 1999 brought frequent snowfalls to much of western and southern Minnesota. While no single event made headlines, the accumulation was above the median, except in some north central and northeastern parts of the state. Temperatures started out cold, but moderated by late month, resulting in a monthly mean near normal.

Figure 1

Departure from Normal Precipitation
September - November 1998



Spring 1999

Much of Minnesota experienced temperatures eight to ten degrees above normal during February. Warm weather and a lack of snowfall diminished the snow pack, and the threat of spring snowmelt flooding in all but the lower (northerly) reaches of the Red River of the North. By month's end, only parts of the northeast and northwest reported snow depths greater than eight inches.

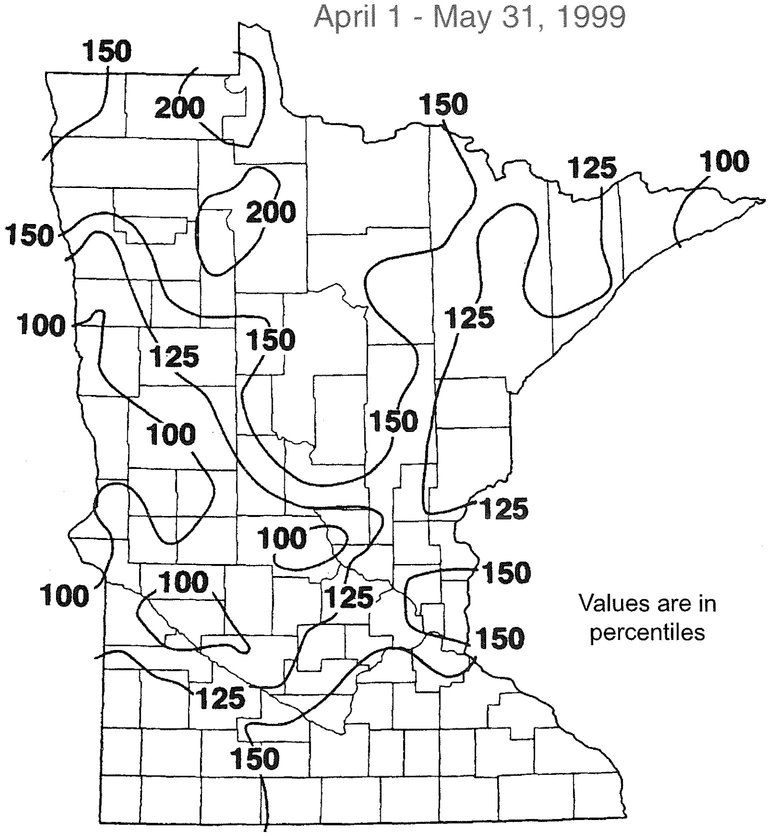
The warmth of December and February, combined with a near-normal January, produced a second consecutive mild winter in Minnesota. March was generally mild and dry, with the exception of a notable snowfall event that affected the central and southern reaches of the state on March 8-9. 16 inches of snow were measured at the Twin Cities International Airport, which ties for eighth place among historical 24-hour snowfall amounts.

April brought heavy precipitation in the north which, combined with snowmelt, led to moderate to major flooding in the lower Red River and its tributaries. As the moisture moved south, many southern communities recorded three inches of rain for the second week of April. The second half of April was dry except for the extreme southeast. A combination of sunny skies, strong winds and low relative humidity increased the potential for wildfires.

The wildfire threat ended in the first half of May when precipitation amounts of four to six inches led to minor flooding and delayed agricultural field work. Much of Minnesota received over 150 percent of normal precipitation for the April-May period (Figure 2), with some communities reporting near record totals. Near to above average winter and spring temperatures produced lake ice-out dates of approximately one to two weeks ahead of average.

Figure 2

Percent of Normal Precipitation
April 1 - May 31, 1999



Summer 1999

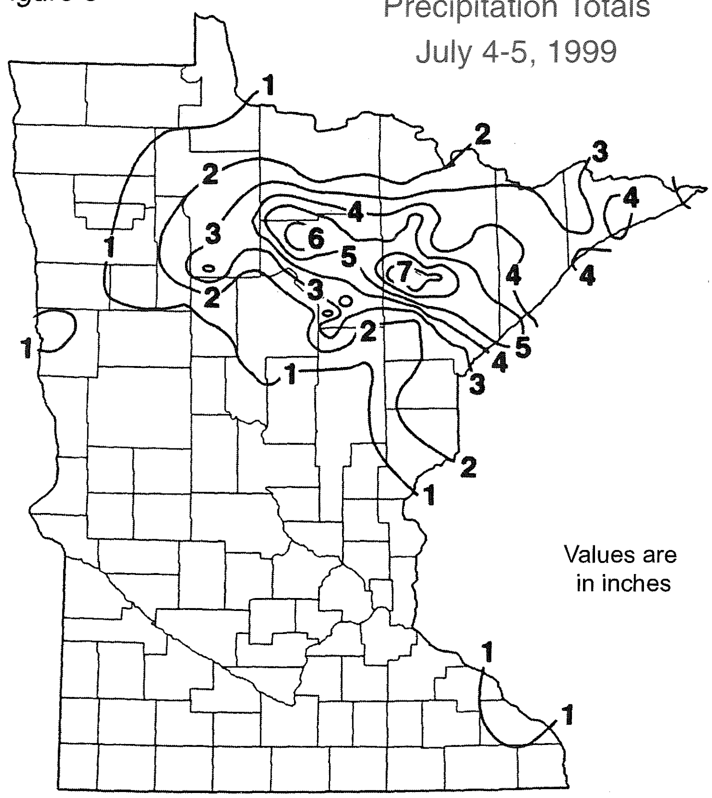
Wet conditions continued into June which featured highly variable temperatures and precipitation amounts at or above normal. The heat and humidity of early July fueled a complex of severe thunderstorms in northern Minnesota on July 4-5. The storms spawned damaging winds that downed millions of trees in the Boundary Waters Canoe Area Wilderness and dropped very heavy rains (Figure 3), leading to significant flooding in parts of St. Louis, Lake and Cook Counties.

July also brought moisture to southeastern Minnesota, with some communities reporting over nine inches for the month. July 29 and 30, 1999 will be remembered as two of the most humid days in state history. Dew points in the mid to upper 70 s were common with some southern locations reaching 80. On July 30, the dew point reached a record 81 degrees at Twin Cities International Airport.

August — September temperatures were unremarkable, averaging near the historical norm. Precipitation was a mosaic of dry and wet except in the southwest where a pattern of dryness developed that would last well into April, 2000. September brought heavy precipitation to the northern part of Minnesota.

Figure 3

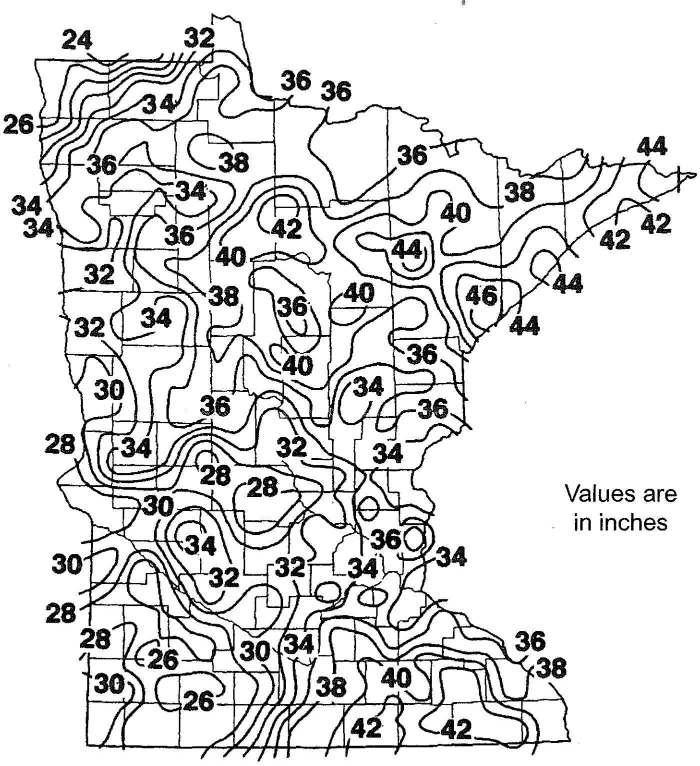
Precipitation Totals
July 4-5, 1999



Values are in inches

Figure 4

Water Year Precipitation
October 1998 - September 1999



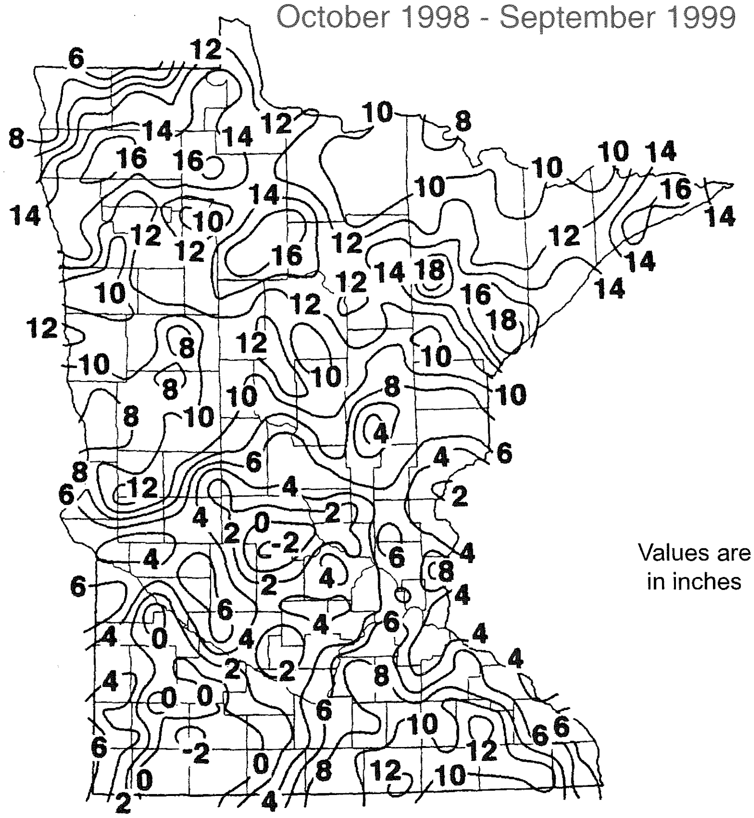
Values are in inches

Water Year 1999

Precipitation totals exceeded 40 inches in some northern and southern counties during the water year (Figure 4). Totals topped historical averages by more than 10 inches in some areas and by more than 16 inches in others (Figure 5). These conditions were a continuation of unusually heavy, statewide precipitation during the 1990's, especially in northwestern Minnesota (see sidebar on page 6). In contrast, southwestern and central Minnesota finished the water year near the historical average, hinting at dry conditions that would follow.

Figure 5

Water Year Precipitation
Departure from Normal
October 1998 - September 1999



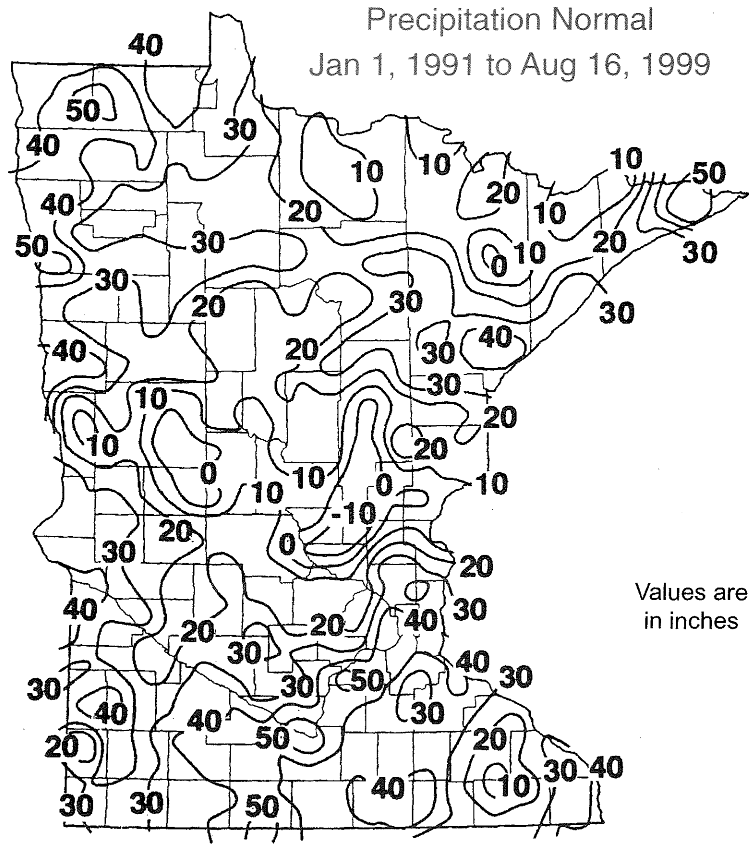
Minnesota's Precipitation Climate At the End of the 20th Century

For many regions, the decade of the 1990 s was the wettest of the century. As a result, we began the 21st century with many of Minnesota s hydrologic systems at high levels, a considerable rebound from the drought of the late 1980 s. In some areas, the heavy 1990 s precipitation led to a welcome recovery from significant water deflicits. For others, it led to high water levels and created serious problems. Across Minnesota, precipitation during the 1990 s exceeded the climatological benchmark (1961-1990 normal) by a significant amount. Figure 6 shows that, for many areas, the cumulative precipitation departure from normal for January 1991 through mid-August 1999 exceeded the historical average by more than 30 inches. In some areas of northwestern, south central, and southeastern Minnesota, the aggregate departure exceeds 40 inches. A 40 inch positive departure in northwestern Minnesota is the equivalent of receiving an additional two years of annual average precipitation.

Climate extremes should not be considered aberrations, but rather treated as an inherent component of our continental climate. The present-day relative abundance of water is uncommon, but periods of wet weather are not without precedent. Nor is it without precedent for the state of the climate to change rapidly between wet and dry regimes.

Figure 6

Cumulative Departure from Precipitation Normal Jan 1, 1991 to Aug 16, 1999



Water Year 2000

October 1, 1999 - September 30, 2000

Highlights

- Dry Autumn, 1999
- Third Consecutive Mild Winter, 1999-2000
- Snow-Scarce Winter
- Late Spring/Early Summer Rains, 2000
- Summer Dryness - Southwest, Central, and Northeast, 2000

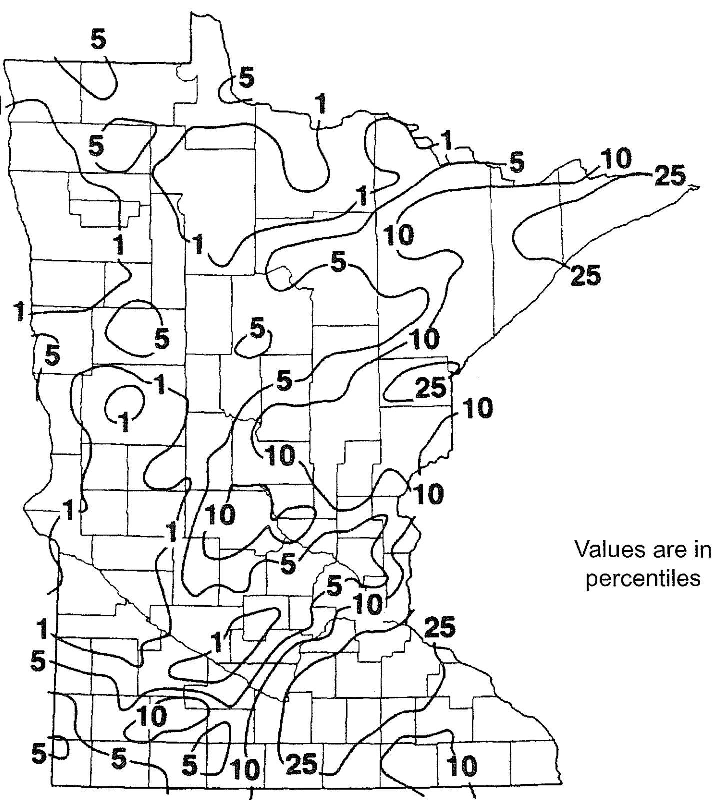
October temperatures began with record-breaking cold (and snow) in the extreme north and south, but finished the month quite mild. November was the warmest ever in some communities with statewide temperatures ranging from seven to nine degrees above the historical average. Numerous daily high temperature records were broken in mid-November.

Autumn 1999

The autumn and early winter of 1999 brought unusually dry conditions to much of Minnesota. Many western counties received less than one inch of precipitation from October through December. In some locations, precipitation totals were more than three inches below normal, and in the 5th percentile or less (Figure 7). The lack of precipitation created deficits in hydrologic systems that normally benefit from autumn replenishment. The northwest welcomed the dryer conditions after several years of high water problems. At the end of 1999, the Palmer Drought Severity Index (a measure of long-term meteorological conditions) indicated that southwest Minnesota was experiencing a moderate drought. Autumn soil moisture was deficient throughout the rooting zone in the southwest, while topsoil moisture was generally short across the rest of the state.

Figure 7

Precipitation Ranking
October - December 1999



Winter 1999 - 2000

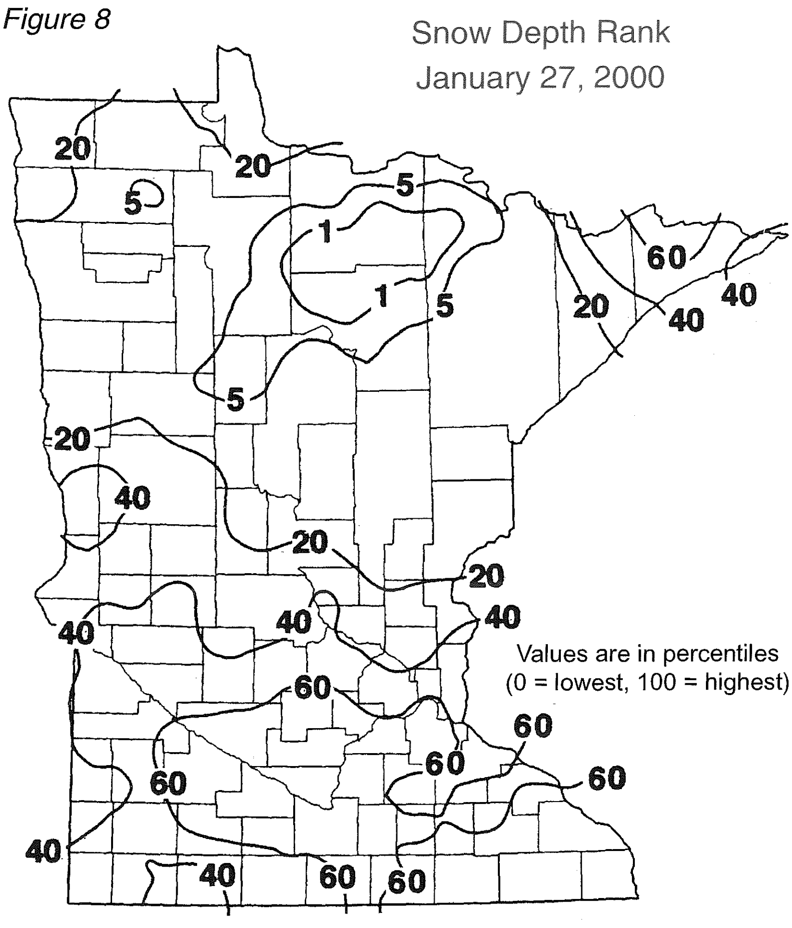
Temperatures ranged from seven to twelve degrees above normal in December, with many record highs observed on the 25th and 29th. Mild (or seasonally mild) temperatures and a lack of precipitation kept the southern two-thirds of Minnesota free of snow and significantly delayed lake ice formation.

Although three significant snowfall events affected parts of Minnesota in January, average temperatures for the month were three to five degrees above normal. Snow depths at month's end were generally less than eight inches across the state. The northern half of Minnesota was far below the median for snow depths in late January, while many areas were at or near record low snow depths for that point in the season (Figure 8). This was the third consecutive snow-deficient winter in northern Minnesota, creating economic hardships for those in snow dependent industries.

February precipitation was near to above normal across the state. An unusual thunderstorm passed over the region on February 23 which, along with warm temperatures, led to a rapid loss of snow cover. By the end of the month, nearly all of Minnesota was free of snow cover- a condition that is nearly without precedent in northern Minnesota. Temperatures were extraordinarily warm, averaging nine to twelve degrees above normal. Many daily records were broken, as were all-time monthly highs at some locations.

Temperatures soared into the 60's and 70's during the first week of March, breaking many maximum temperature records. Smaller lakes in southern Minnesota experienced ice-out three to five weeks ahead of average, and the earliest on record for some. The warm, dry weather also advanced the wildfire season by approximately one month.

Figure 8



Winter snowfall totals were light, roughly 50 to 75 percent of average, again creating deficits in surface hydrology. The situation was most acute in the southwest where precipitation totals in some communities were eight inches below normal for the nine-month period of July, 1999 to March, 2000. Two consecutive mild winters are rare in Minnesota, occurring only once before in the 20th century. The three consecutive mild winters of 1997-1998, 1998-1999 and 1999-2000 are without precedent in the climate record.

Spring 2000

Precipitation totals for April were generally below average across the state. Much of southwestern and central Minnesota received less than 60 percent of normal precipitation for the seven-month period of October, 1999 to April, 2000 (Figure 9). The extended dry spell manifested itself in lower lake levels, dry wetlands, reduced stream flow and dry soils. By late April, the National Drought Mitigation Center classified the southwest in the severe drought category and the remainder of southern Minnesota in the first stage drought category. Early spring lake levels, which typically rise significantly from autumn rains and spring snowmelt, rose very little from the previous autumn. Flows in southwest, central and north central streams fell below the 10th percentile in late April.

Figure 9

Percent of Normal Precipitation
October 1999 - April 2000

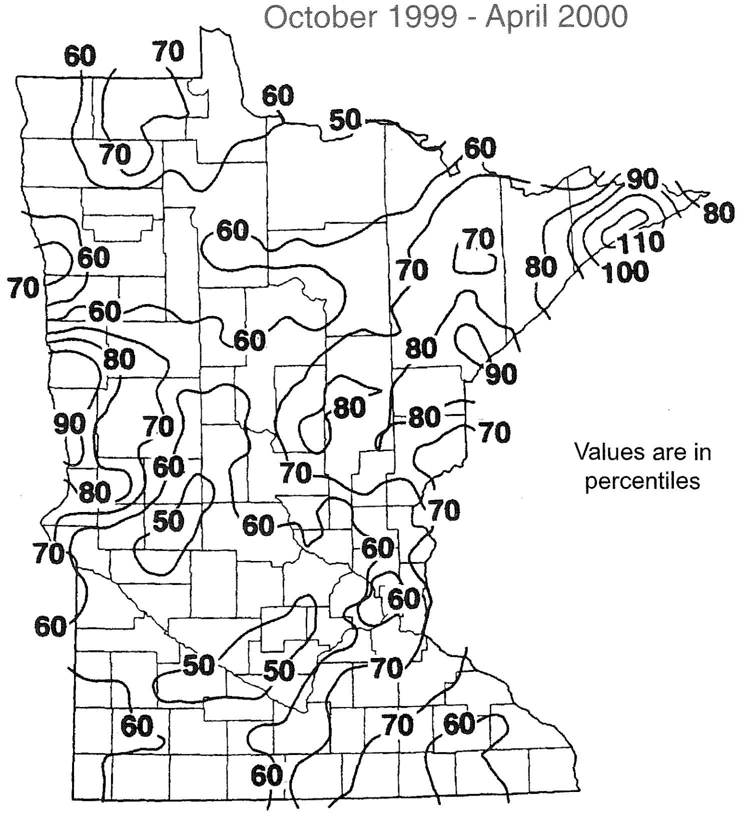
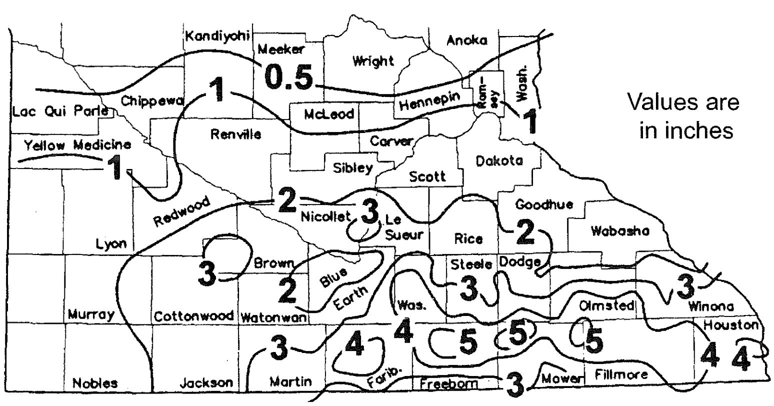


Figure 10

Precipitation Totals
May 17 - 18, 2000



Although not universally distributed, rains abruptly eased or eliminated the concern for drought in May. Precipitation totals in southern Minnesota were three to five inches above normal during the month, with some southeastern communities receiving over twelve inches from mid-May to early June. A rainfall event on May 17-18 brought up to six inches to parts of Mower and Freeborn Counties (Figure 10). A second event on May 31-June 1 brought up to five additional inches of rain to some of the same communities as the earlier event, leading to significant urban and rural flooding and soil erosion. By late May, no region was classified in a drought category, however, the focus on dryness had shifted from the southwest to parts of east central Minnesota.

Summer 2000

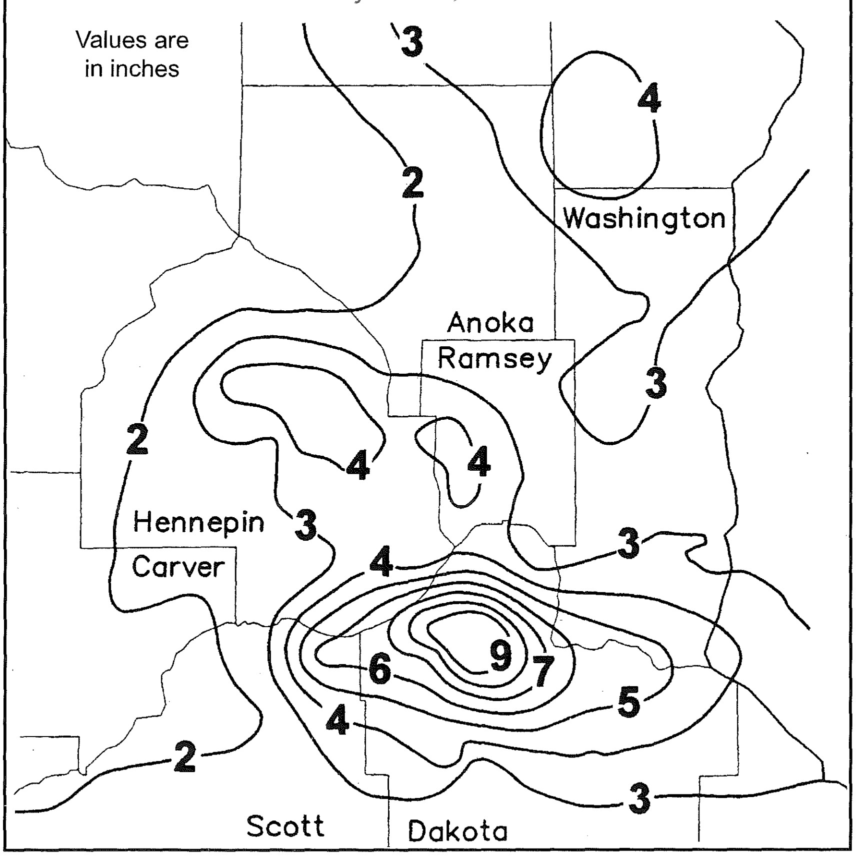
The wet weather of May continued into June, raising surface water levels that were lowered by precipitation shortfalls during the previous autumn, winter and early spring seasons. Rainfall totals in portions of southeastern, south central and northwestern Minnesota exceeded historical averages by more than ten inches for the season. Precipitation records for the month of June were set in Rochester (12.52 inches), Preston (11.86 inches) and Fargo/Moorhead (11.72 inches).

A major rainfall event soaked portions of Clay, Norman, Mahnomen and Becker Counties on June 19-20. Rain amounts exceeding six inches caused extensive urban flooding in Fargo/Moorhead, submerged large tracts of agricultural land and led to significant flooding on tributaries of the Red River. While most of the state received abundant to excessive spring and early summer precipitation, growing season totals for parts of central and east central Minnesota remained below normal. Scattered surface water levels remained below averages, still recovering from long term dryness.

June temperatures were generally below historical averages across Minnesota for the first time since October, 1999. Record cold temperatures were set on the morning of June 5, with many northern and eastern communities dropping below freezing. Three days later, 100-degree temperatures were observed in central and western Minnesota.

Precipitation patterns varied widely during the month of July. The northern third of the state was near to below normal for the month while the rest of Minnesota reported near to above normal precipitation. Some southern counties experienced heavy rainfalls during the first ten days of July. Heavy rains fell in the Twin Cities Metropolitan Area during the weekend of July 7-10. More than eight inches fell in three to five hours over a small area of northern Dakota County on July 7-8, with an additional two to three inches of rain later that weekend (Figure 11). South central and southeastern Minnesota received three to five inches of rain on July 9-10. During the afternoon of July 10, the Cedar River at Austin crested at a record level, affecting homes, businesses, bridges and streets. Nearly all of Minnesota experienced below normal precipitation during the second half of July. The City of Granite Falls was unfortunately in the path of a deadly and destructive tornado on July 25.

Figure 11 Precipitation Totals July 7 -10, 2000



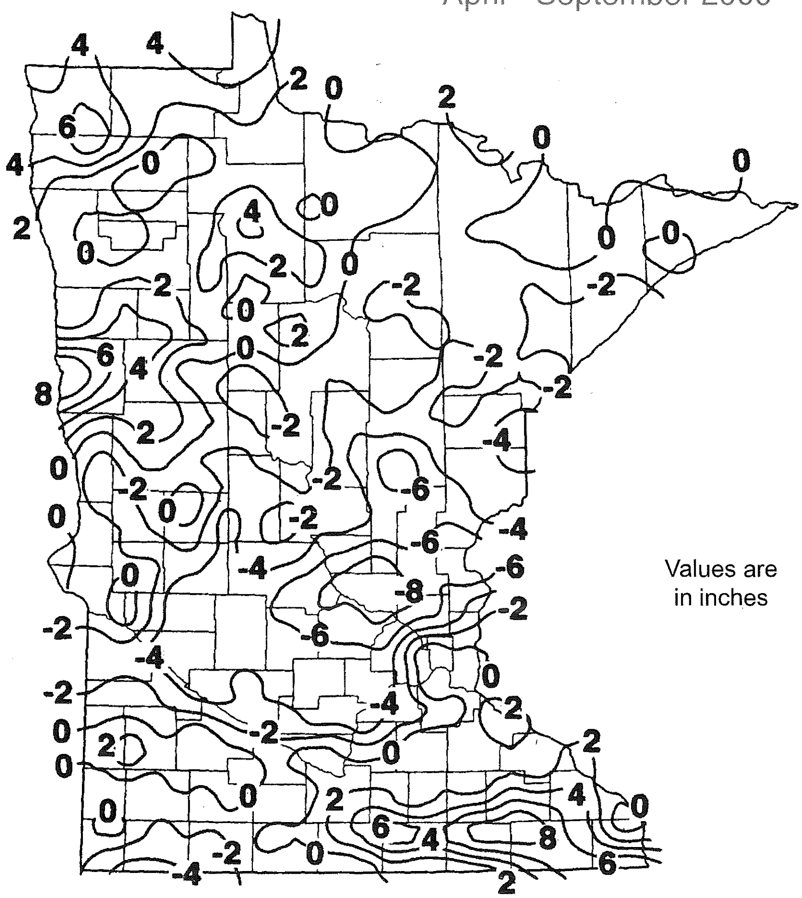
August precipitation was generally near to below normal, with a few exceptions. Some northwestern and north central counties reported rainfall amounts of an inch or more above normal, while isolated thunderstorms helped Rochester set a record for the four-month period of May through August (30.7 inches). In contrast, parts of central and east central Minnesota recorded growing season precipitation totals 30 percent below normal. Unlike the rest of the state, these areas did not recover from the precipitation deficits accrued during the previous autumn-winter-spring seasons. For example, the City of Santiago in Sherburne County was approximately nine inches of precipitation below normal for the year ending in August. Pockets of dryness also existed along the North Shore of Lake Superior, especially in Cook County. August temperatures were near average statewide, although dew point temperatures climbed into the 70's on six occasions during the month.

September precipitation was slightly above normal in some northwestern counties, but ranged from one to three inches below normal over the rest of the state. The dryness in central and east central Minnesota worsened as a result of the continued below-normal precipitation. Dry conditions could also be found in southwestern Minnesota and along the North Shore. Seasonal rainfall totals (April 1-September 30) in the dry areas were more than four inches below normal (Figure 12), ranking some communities in the lowest 10th percentile when compared with the historical climate record. Stream flows in these areas were very low, as were lake levels which had not been as low since the drought of the late 1980 s. Wildfire potential was also very high.

A significant rainfall event occurred during the evening of September 2 in east central Minnesota. Heavy thunderstorms produced three to four inches of rainfall in less than three hours in parts of the eastern Twin Cities Metropolitan Area. Thereafter, precipitation for the Twin Cities was negligible for the remainder of the month. Late summer and early autumn rains pushed seasonal totals in the far northwest to 25 percent or more above the historical average. September temperatures were close to the historical average statewide.

Figure 12

Precipitation
Departure from Normal
April - September 2000



Water Year 2000

The 2000 Water Year was highlighted by sharp geographical contrasts in precipitation across Minnesota. October 1999 through September 2000 precipitation totals were less than 18 inches in some western and central counties, while areas of the southeast reported total precipitation exceeding 36 inches (Figure 13). Water Year precipitation topped the historical average by more than six inches in some northwestern and southeastern communities, while a swath of central Minnesota fell short of the average by six inches or more (Figure 14).

Figure 13 Water Year Precipitation
October 1999 - September 2000

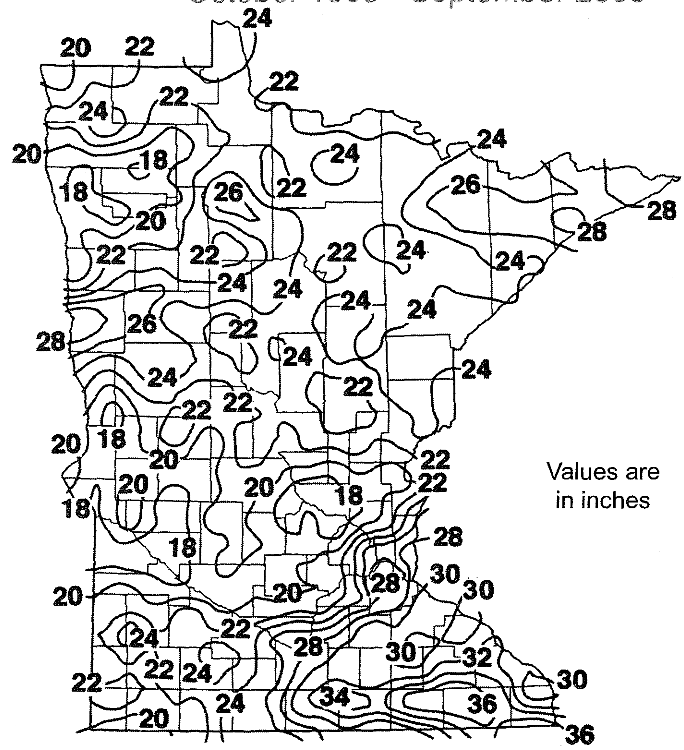
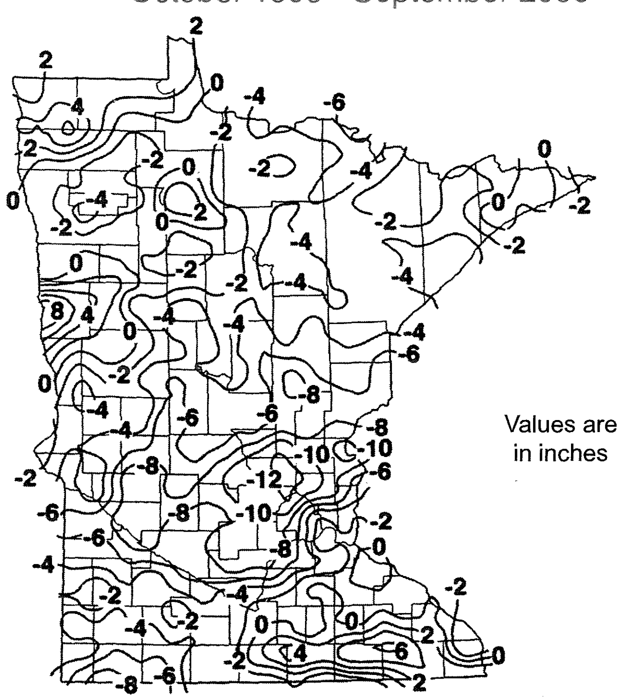
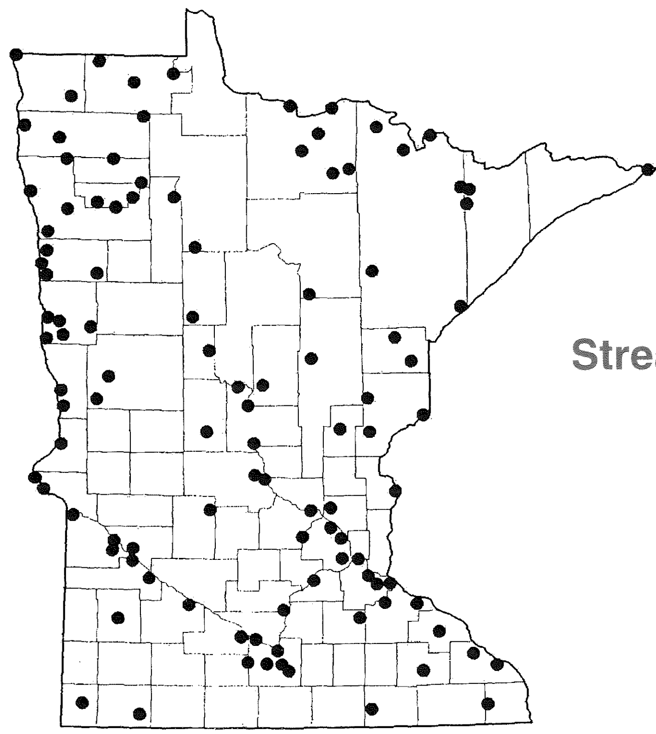


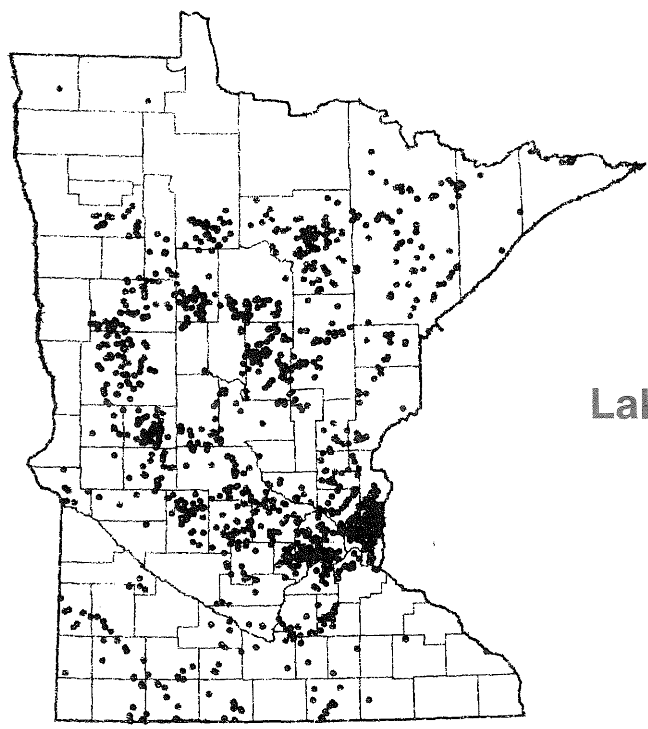
Figure 14 Water Year Precipitation
Departure from Normal
October 1999 - September 2000



Chapter Two SURFACE WATER



Stream Gage Network
2000
(97 Gages)



Lake Gage Network
2000
(962 Gages)

Stream Flow

Introduction

The Stream Hydrology Unit is responsible for collecting, distributing and analyzing flow data for rivers and streams in Minnesota. Data for these activities comes from a network of stream gages located throughout Minnesota. Figure 1 shows the 81 major watersheds of the state and the location of the continuous recording gages that the DNR uses to monitor statewide watershed stream flow conditions. These gages are used to gather data including historic high and low flows, and information for computing statistics such as flood frequencies and exceedence values (see box below).

Engineers use stream flow data to design the hydraulic capacity of bridges, culverts and control structures. Planners use stream flow data for land use development and to determine water availability for industrial, domestic and agricultural consumption. Biologists use stream flow data to assist in evaluating aquatic habitat potential in streams. Knowing how much water is flowing or available in a stream is very important for flood and drought planning.

Stream Drainage Systems

There are many types of rivers and streams in Minnesota. Along the North Shore of Lake Superior, and along the Mississippi River blufflands in the southeast, are high gradient streams that have scoured channels into bedrock. In the northwest are highly meandered streams that are situated in an ancient lake bed and are prone to flooding. In the southern third of the state, streams are often entrenched with well developed channels and are largely impacted by agricultural practices. North central streams can be impacted by both agricultural and forest land uses.

Minnesota is unique in that two of the three continental divides in North America pass through it. These two continental divides separate river flows into three major drainage basins: the Hudson Bay/Arctic Ocean, the Great Lakes/Atlantic Ocean and the Mississippi River/Gulf of Mexico. Within these three basins are nine major river basins: the Red River of the North, Rainy River, Lake Superior, Upper and Lower Mississippi River, St. Croix River, Minnesota River, Missouri River and the Des Moines - Cedar River (Figure 2).

EXCEEDENCE VALUE

An exceedence value is a statistical parameter, based upon historical discharge records, and is the probability of stream flow *exceeding* a certain value. A 50% exceedence value (Q50) indicates that the discharge at that reporting station has been *equalled* or *exceeded* 50% of the time during a specific period. Exceedence values can be calculated on a daily, monthly or annual basis.

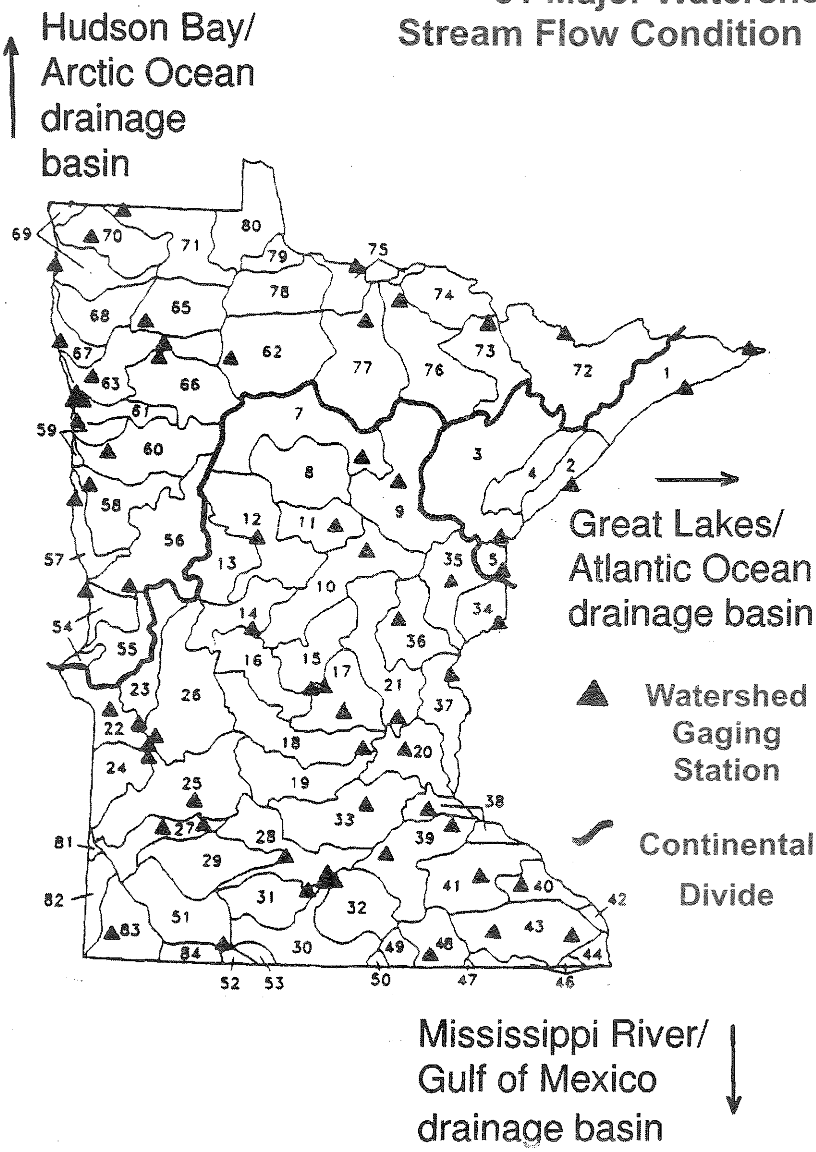
Stream flow reports are based upon the following exceedence values during the open water season.

Critical Flow = < annual Q90
Low Flow = < monthly Q75
Normal Flow = monthly Q75 to Q25
High Flow = > monthly Q25
Flood Flow = > NWS* flood stage (or highest monthly Q10)

*** National Weather Service**

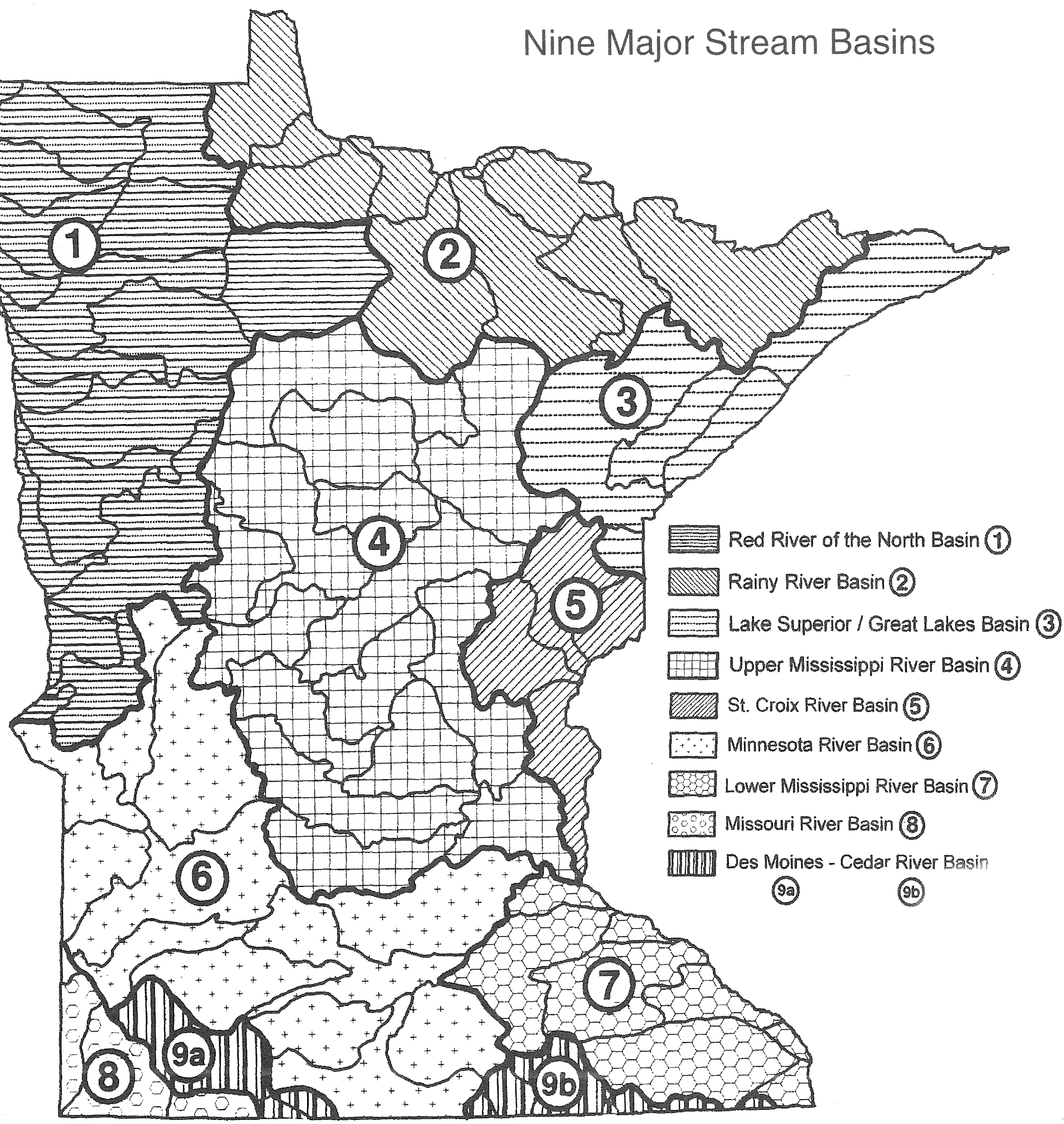
Figure 7

81 Major Watersheds
Stream Flow Condition Network



1 Lake Superior (north) ▲
2 Lake Superior (south) ▲
3 St. Louis River ▲
4 Cloquet River
5 Nemadji River ▲
*
7 Mississippi River (Headwaters, Lake Winnibigoshish) ▲
8 Leech Lake River
9 Mississippi River (Grand Rapids) ▲
10 Mississippi River (Brainerd) ▲
11 Pine River ▲
12 Crow Wing River ▲
13 Redeye River (Leaf River)
14 Long Prairie River ▲
15 Mississippi River (St. Cloud)
16 Sauk River ▲
17 Elk River (Elk River) ▲
18 North Fork Crow River ▲
19 South Fork Crow River
20 Mississippi River (Metro) ▲
21 Rum River ▲
22 Minnesota River (Headwaters)
23 Pomme de Terre River ▲
24 Lac qui Parle River ▲
25 Minnesota River (Montevideo) ▲
26 Chippewa River ▲
27 Redwood River ▲
28 Minnesota River (Mankato) ▲
29 Cottonwood River ▲
30 Blue Earth River ▲
31 Watonwan River ▲
32 Le Sueur River ▲
33 Minnesota River (Shakopee) ▲
34 St. Croix River (Upper)
35 Kettle River
36 Snake River
37 St. Croix River (St. Croix Falls) ▲
38 Vermillion River (Empire) ▲
39 Cannon River ▲
40 Mississippi River (Winona) ▲
41 Zumbro River ▲
42 Mississippi River (La Crescent)
43 Root River ▲
44 Mississippi River (Nevo)
*
46 Upper Iowa River
47 Wapsipinican River (Headwaters)
48 Cedar River ▲
49 Shell Rock River
50 Winnebago River (Lime Creek)
51 West Fork Des Moines River (Headwaters) ▲
52 West Fork Des Moines River (Lower)
53 East Fork Des Moines River
54 Bois de Sioux River ▲
55 Mustinka River
56 Otter Tail River ▲
57 Red River of the North (Headwaters) ▲
58 Buffalo River ▲
59 Marsh River ▲
60 Wild Rice River ▲
61 Sandhill River ▲
62 Upper and Lower Red Lake ▲
63 Red Lake River ▲
*
65 Thief River ▲
66 Clearwater River ▲
67 Grand Marais Creek (Red River of the North) ▲
68 Snake River
69 Tamarack River (Red River of the North) ▲
70 Two River ▲
71 Roseau River ▲
72 Rainy River (Headwaters) ▲
73 Vermillion River ▲
74 Rainy River (Rainy Lake)
75 Rainy River (Manitou) ▲
76 Little Fork River ▲
77 Big Fork River ▲
78 Rapid River
79 Rainy River (Baudette)
80 Lake of the Woods
81 Big Sioux River (Medary Creek)
82 Big Sioux River (Pipestone)
83 Rock River
84 Little Sioux River

Figure 2



Minnesota is further unique in that very little water flows into the state. Only two rivers receive out-of-state water: the headwaters of the Minnesota River from South Dakota and the Blue Earth River from Iowa. Minnesota exports large volumes of water via the Red, Rainy, Mississippi, (including the Minnesota and St. Croix Rivers), and through the numerous North Shore streams and rivers.

Stream Gaging in Minnesota

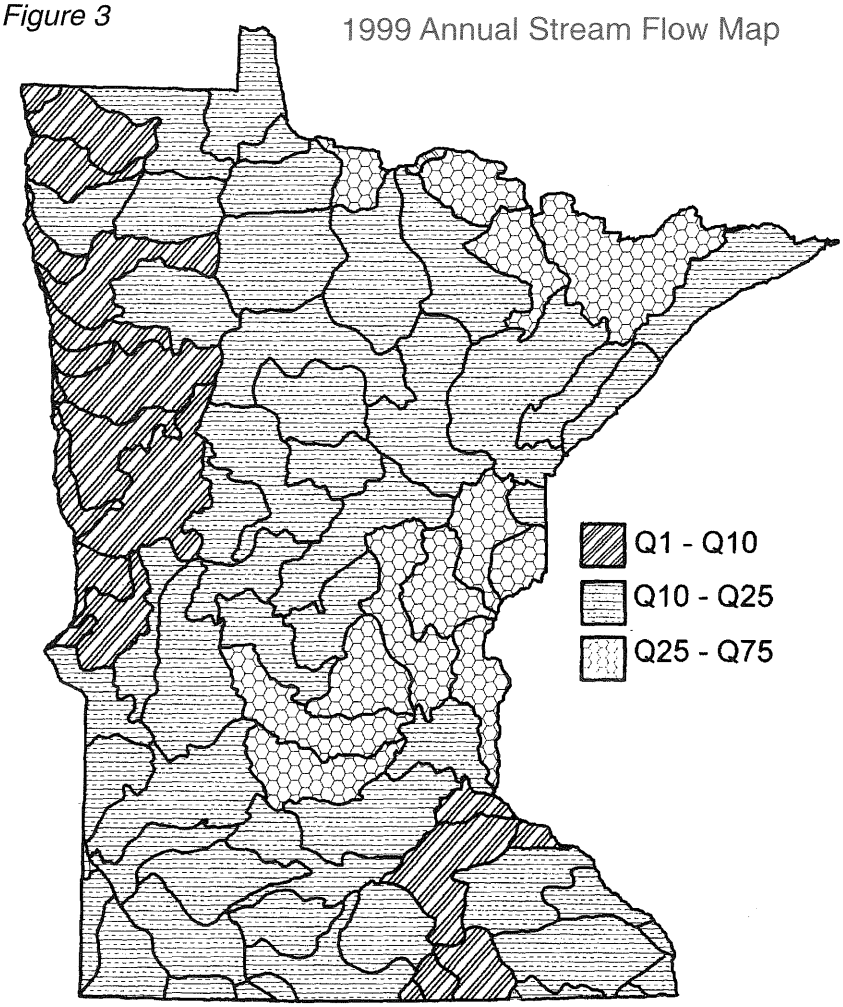
Gaging is an essential tool in analyzing stream flows in Minnesota. A stream gage is used to record the water elevation of a stream at a specific location. Measurements of stream discharge must be made periodically at the gage location to develop the relationship between stream elevation and the quantity of flow in the stream. If this relationship is developed, recorded stream elevations can be converted to discharge in cubic feet per second (cfs). State-of-the-art gages in Minnesota record stream elevations continuously and transmit the data to a central location for conversion to discharge and use in hydrologic analysis.

Most continuous recording stream gages in Minnesota are operated by the United States Geological Survey. DNR Waters supports about one third of these network gages through the USGS s Cooperative Water Resource Data program. In addition, the DNR maintains approximately forty flood warning gages. The USGS has been gaging Minnesota streams for over 100 years.

Currently, there are nearly 100 continuous recording stream gages maintained by the USGS. Additional stream gages are operated and maintained by the Corps of Engineers, the Department of Natural Resources, the Department of Transportation, the Pollution Control Agency, the Metropolitan Council and other state and local agencies, including watershed districts and lake associations.

Unfortunately, at least five stream gages were eliminated in 2000 due to budget constraints and another was destroyed by flooding. The loss of a stream gage can significantly impact flood prediction and low flow protection. The loss of a stream gage with a long-term record also can seriously degrade the historical record of the stream. It is this long-term record that is important in determining stream flow trends, drought and flood frequency calculations and other historical parameters.

Figure 3 1999 Annual Stream Flow Map



Water Year 1999

Water Year 1998 ended with normal to high stream flow conditions throughout most of the state, although low and below protected flow conditions could be found in parts of the Arrowhead and Upper Mississippi River Headwaters regions.

In the spring of 1999, low flow conditions occurred rarely, and then only in the St. Croix River watersheds. The central part of Minnesota experienced near normal flows throughout April while the southern third of the state remained high with an occasional flood flow. The north received heavy rains in early April, concurrent with the spring snowmelt peak. As a result, flooding occurred in parts of the Red River of the North, Rainy River and Mississippi River Headwaters watersheds.

Flows in the northern two-thirds of Minnesota were near normal in early May, although high flows continued in parts of the Red River watershed and in much of the southern third of the state. Heavy rains in mid-May produced flooding in the Upper Mississippi River basin, parts of the Red River and in the Twin Cities Metropolitan Area until early June.

Normal rains in early June maintained high flows throughout Minnesota, with a few exceptions in the Arrowhead, St. Croix and Upper Mississippi River basins. Heavy rains fell in the northwest in late June, however, little precipitation fell during the remainder of the month, and stream flow conditions receded to near normal over much of the state.

July rains pushed stream flows generally into the high range. A major thunderstorm event on July 4-5, 1999 (Figure 3 on page 4) in north central and northeast Minnesota caused flooding in parts of the Mississippi River Headwaters, Rainy River and Great Lakes basins. Many streams in these areas experienced a 10-year to 25-year flood event. Flows remained mostly in the high range throughout August and September, with occasional flood flows and sporadic normal flows occurring in the state.

The annual stream flow map for Water Year 1999 (Figure 3) shows that stream flows were above normal for most of the state and well above normal for much of the Red River. However, flow conditions in the Mississippi River Headwaters, Rainy River and Great Lakes basins would have been near normal for the year without the thunderstorm event in early July.

Water Year 2000

The autumn of 1999 and winter of 2000 featured below normal precipitation and above normal temperatures. Streams, which would normally be frozen, remained open and flowing. By the end of February, nearly all of Minnesota was snow free and, in early March, flows in the southern half of Minnesota were in the low range. Flows in the normal range could be found in the north due to higher ground water levels from prior years and due to a larger volume of water retained as ice over the winter.

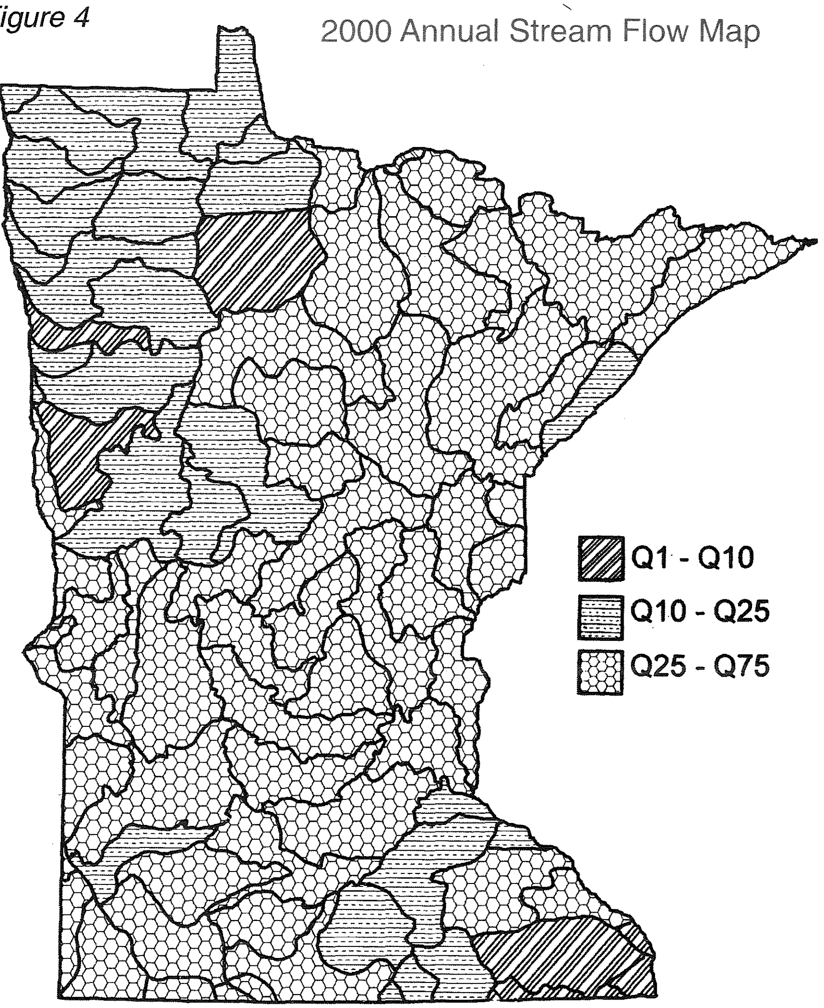
By early May, low flows were common in the southwest, east central and northeast watersheds, while the rest of Minnesota was near normal. A series of storms in late May pushed flows into the high range over the southern third of the state. Flows in the southeast would remain high into September in response to excess precipitation.

Low to near normal flows were experienced in the northern two-thirds of Minnesota throughout June. A series of storms over the northwest in late June brought many of the Red River watersheds into the high and flood flow categories. Flows remained high in the Red River valley for the remainder of summer.

Normal flows prevailed through July and early August, except in the extreme southeast and in the Red River valley. However, by mid-August, low and below critical flows were found in south-western and central Minnesota. At the end of the water year in late September, critical flow levels extended from the southwest corner to the northeast corner of Minnesota.

The annual stream flow map for Water Year 2000 (Figure 4) shows that much of the state was near normal. High and very high conditions for the year were observed in the Red River watersheds and in the southeast. However, the low and very low flows observed at the end of the water year are absorbed by the averaging used to produce the annual map.

Figure 4



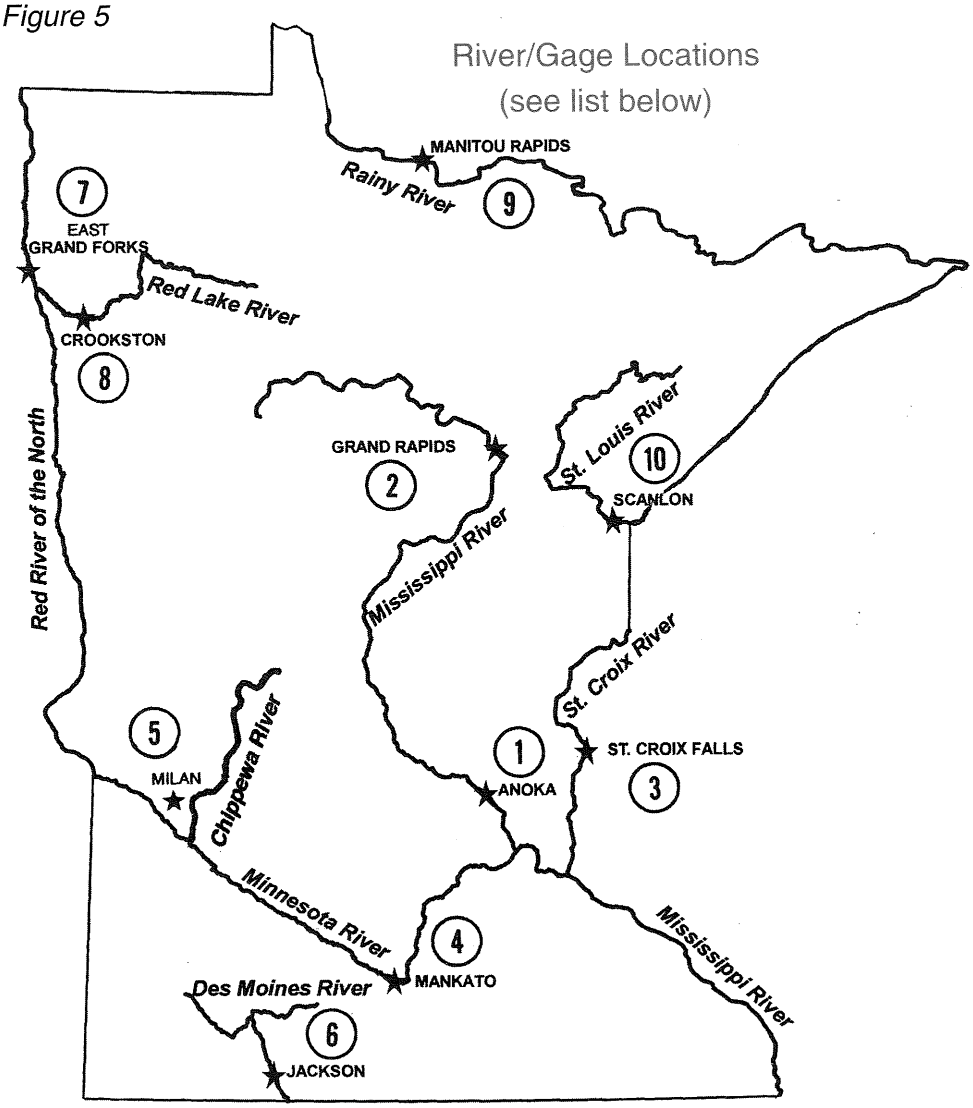
Hydrographs

Stream hydrographs show the volume of water discharged during a specific time period. Figure 5 shows the location of ten rivers and stream gaging stations where discharge hydrographs have been created.

Figures 6 and 8 show two-year hydrographs for the ten selected sites. In addition to the mean daily discharge, the daily Q25 and Q75 exceedence levels are shown.

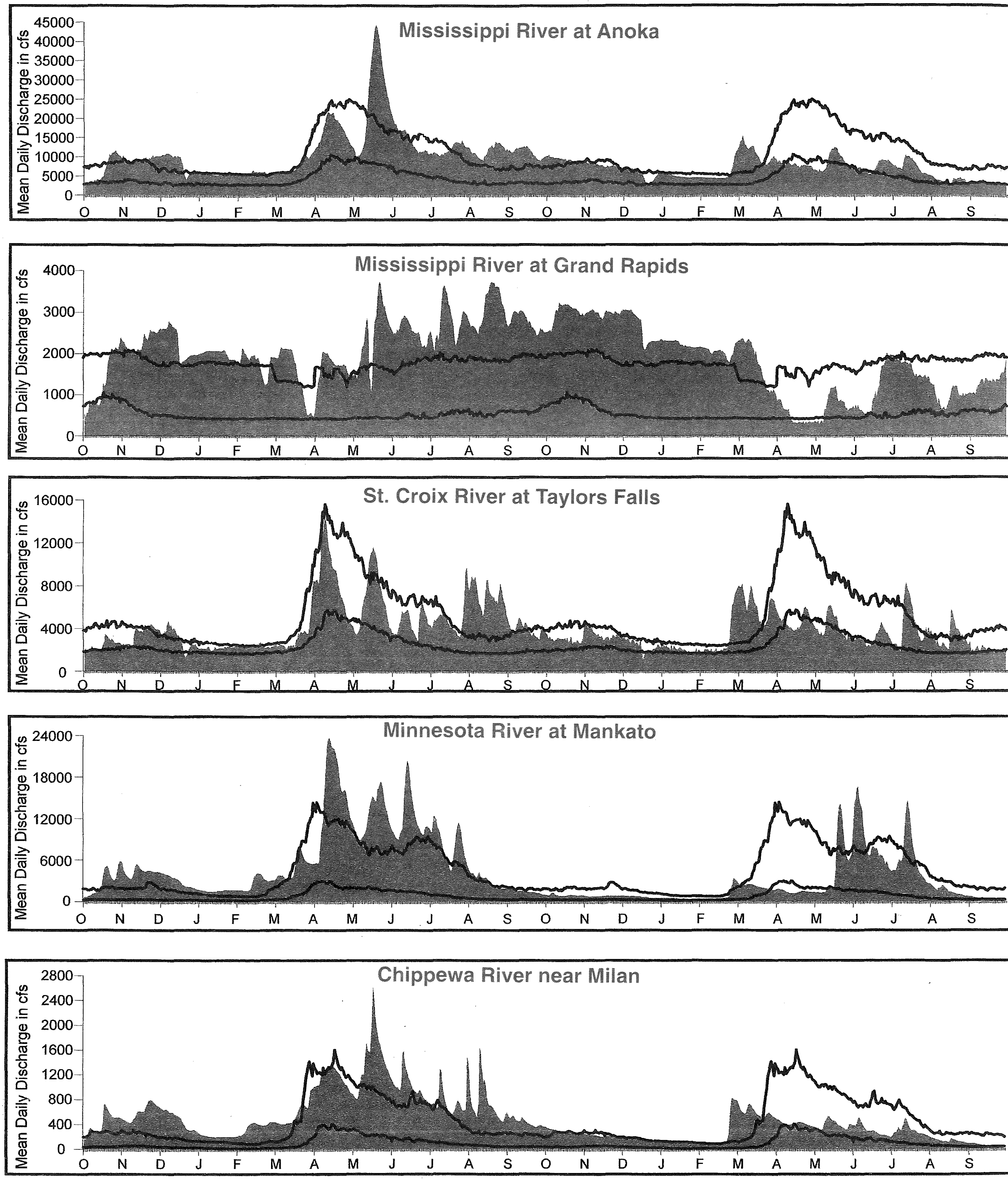
Figures 7 and 9 are period of record hydrographs for the same ten sites. The hydrographs show the average annual volume of water discharged during the water year, the annual Q25 and Q75 exceedence values and a 30-year moving average of the annual discharges. The 30-year moving average shows the trend in the volume of water flowing in a stream.

Figure 5



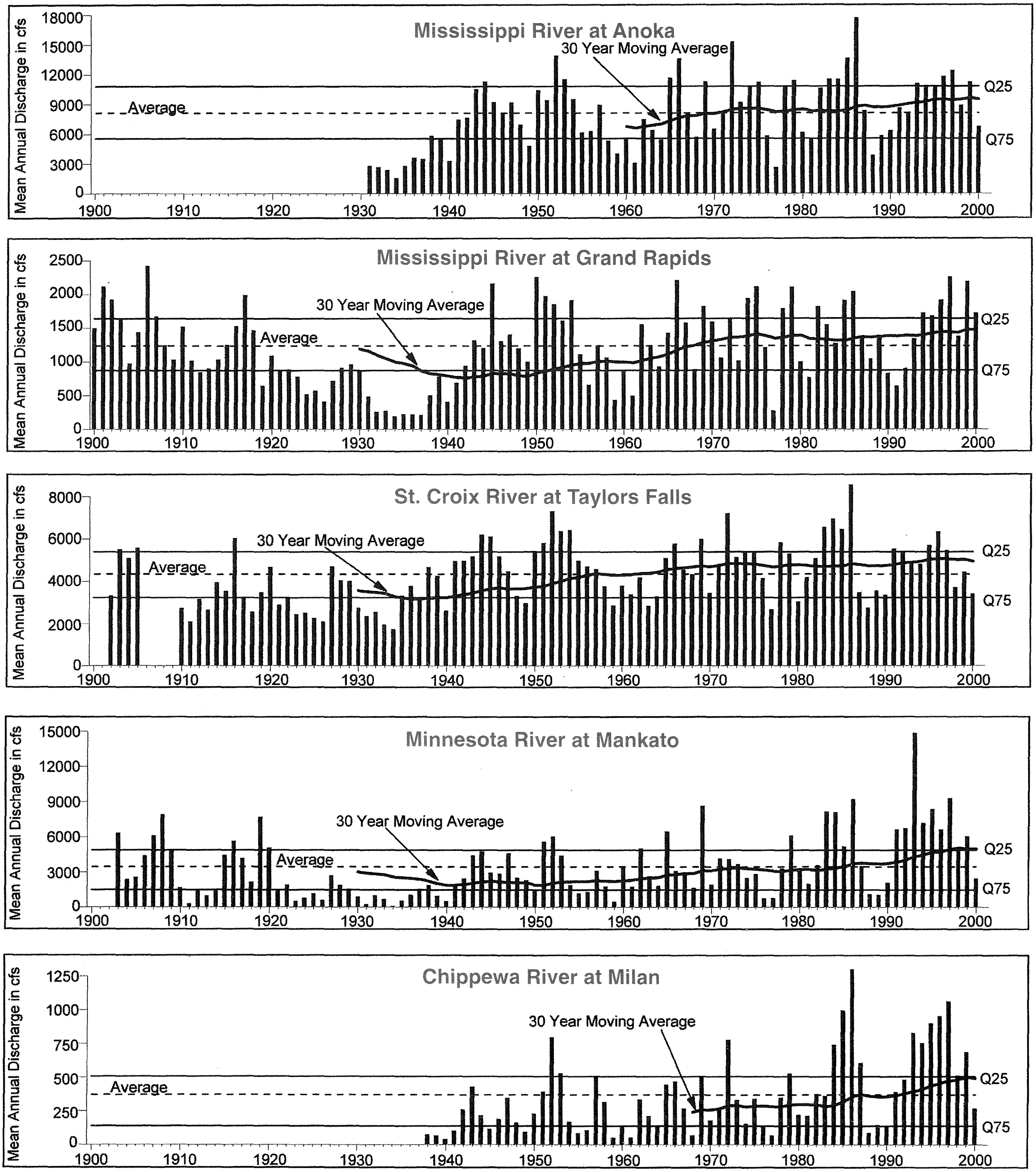
1) Mississippi River at Anoka
2) Mississippi River at Grand Rapids
3) St. Croix River at Taylors Falls
4) Minnesota River at Mankato
5) Chippewa River near Milan
6) Des Moines River at Jackson
7) Red River of the North at East Grand Forks
8) Red Lake River at Crookston
9) Rainy River at Manitou Rapids
10) St. Louis River at Scanlon

Figure 6



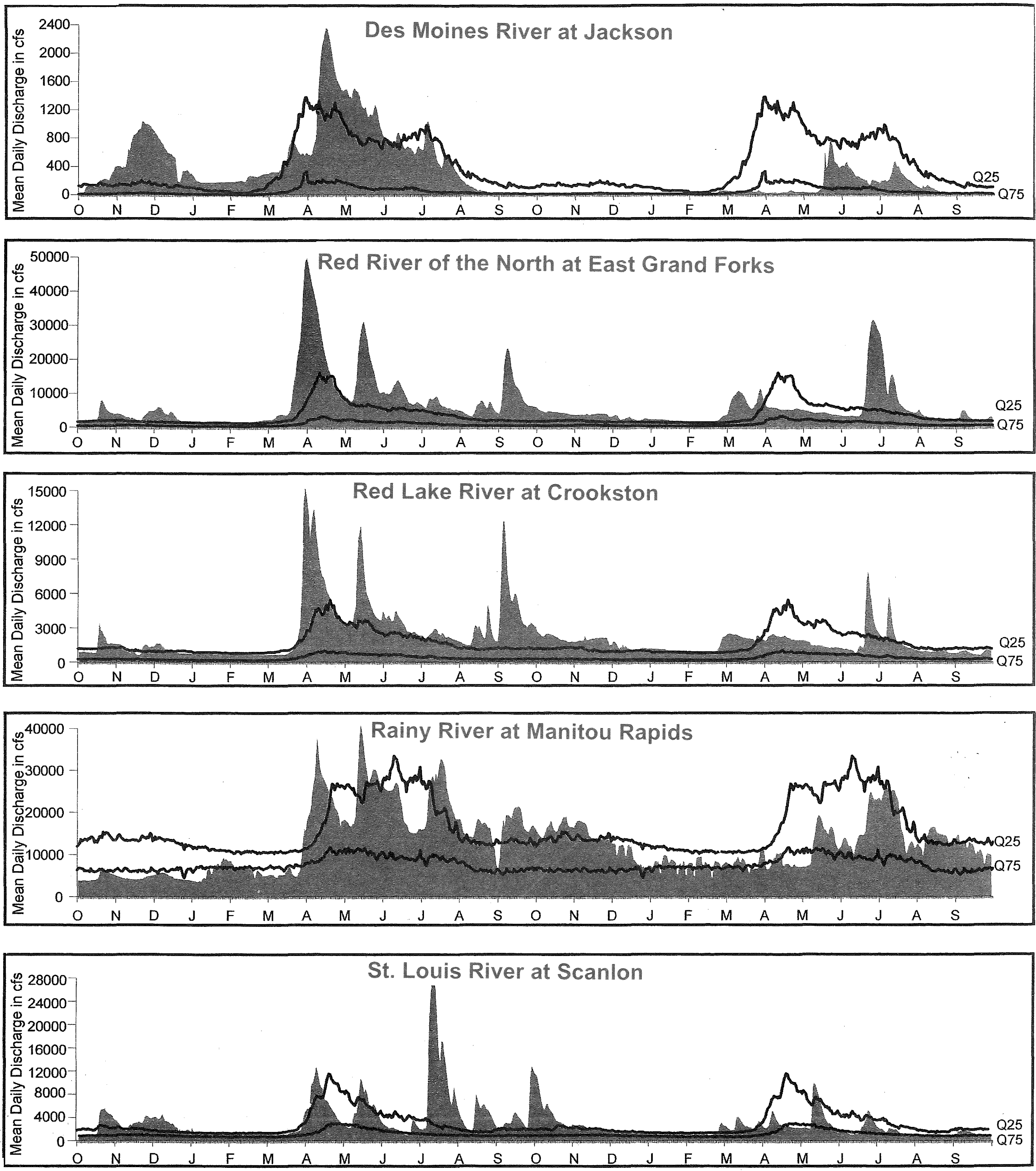
October 1, 1998 to September 30, 2000

Figure 7



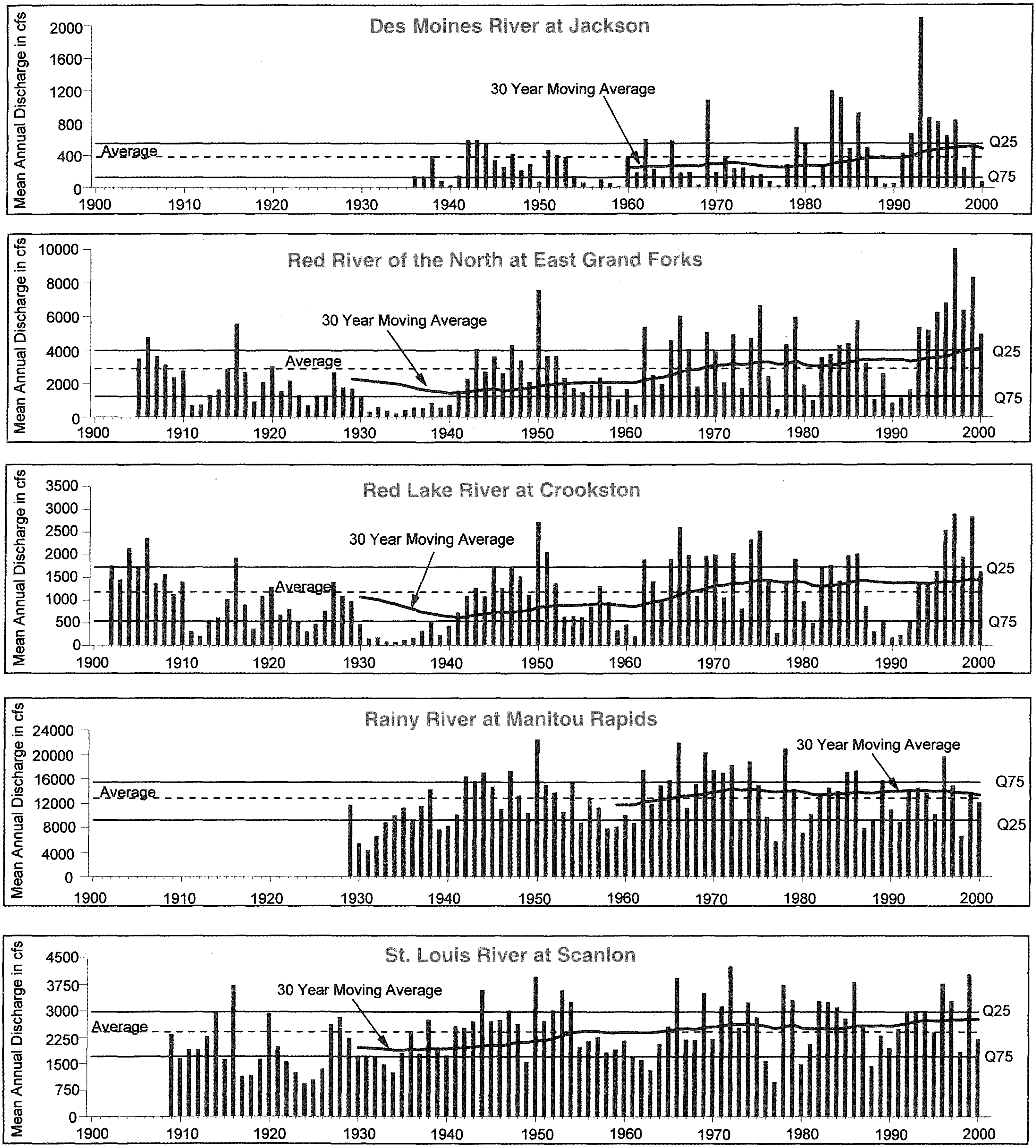
1900 to 2000

Figure 8



October 1, 1998, to September 30, 2000

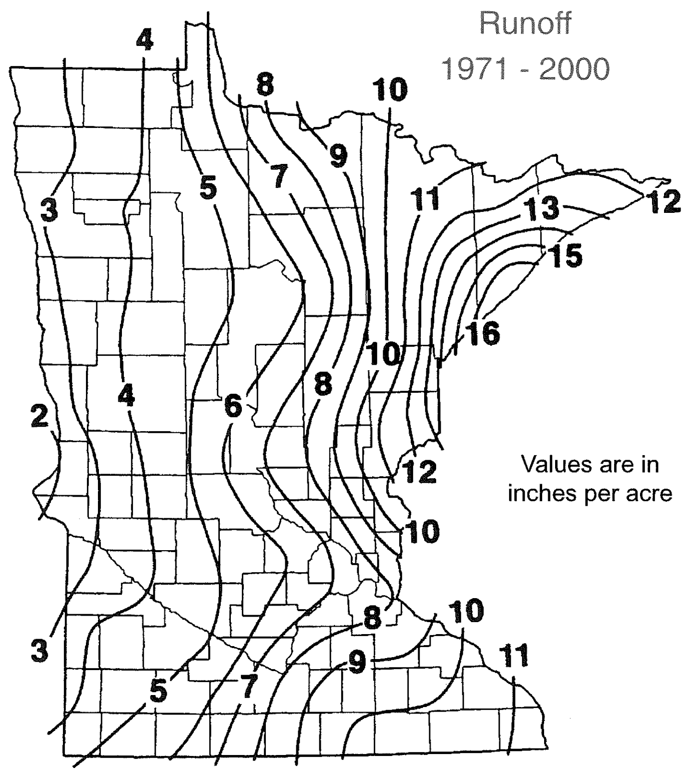
Figure 9



1900 to 2000

Average Annual Runoff

Figure 10



Runoff is the volume of water that, after falling as precipitation (rain and snow), flows off land to lakes, streams, rivers and other drainage features. Nearly all of the water entering major rivers in Minnesota will ultimately flow out of the state.

The amount of runoff is a result of several factors including climatology, surficial and bedrock geology, soil type and land use. Areas of steep slope and shallow soils tend to produce more runoff than areas of deep soil and flat surfaces. Developed areas that contain impermeable features such as roads and buildings tend to have very high runoff. Temperature can also significantly alter runoff by either increasing or decreasing evaporation and transpiration. Spring snowmelt is a major source of runoff in Minnesota.

Figure 10 is a map showing the average annual runoff for the 30-year period 1971-2000. The map was developed by averaging the annual discharge for each of 80 stream gages over the 30-year period. Each value, in cubic feet per second, was then converted to inches per acre for the drainage area of the gage.

To identify changes in average annual runoff, values for the 30-year period 1951-1980 were calculated. A comparison of the difference between the 1951-1980 period and the 1971-2000 period (Figure 11) shows that there has not been a notable change in runoff for much of the northerly two-thirds of Minnesota during the last 50 years. However, the southerly third of the state has experienced a significant increase in the volume of runoff. A primary reason for the increased runoff is that average annual precipitation has increased by approximately two inches in the south during the 50-year period. Precipitation in the north has increased by an average of approximately one inch, with some parts of the Arrowhead approaching a two-inch increase.

Figure 11

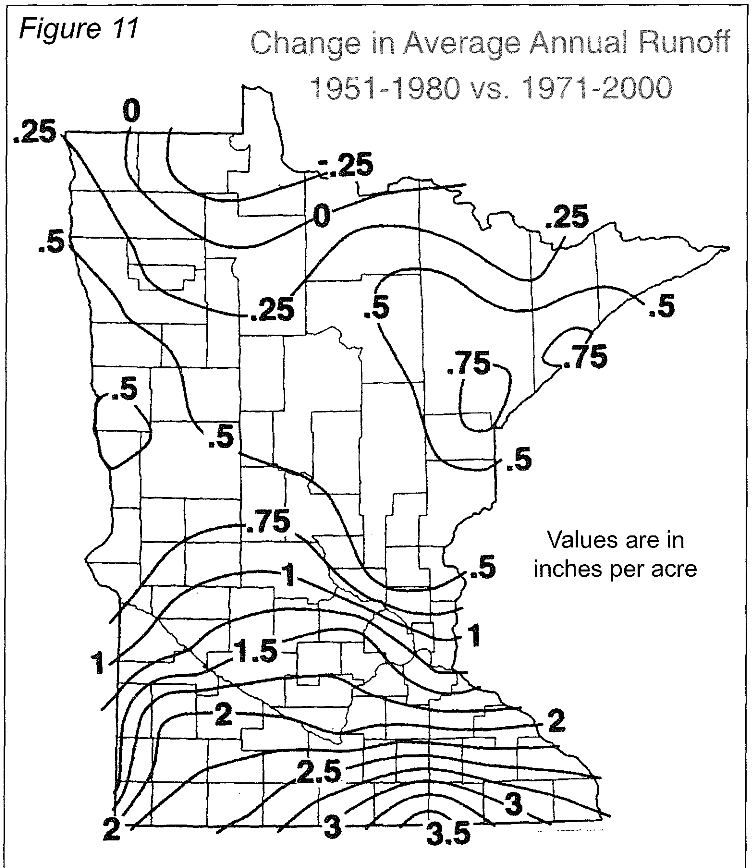
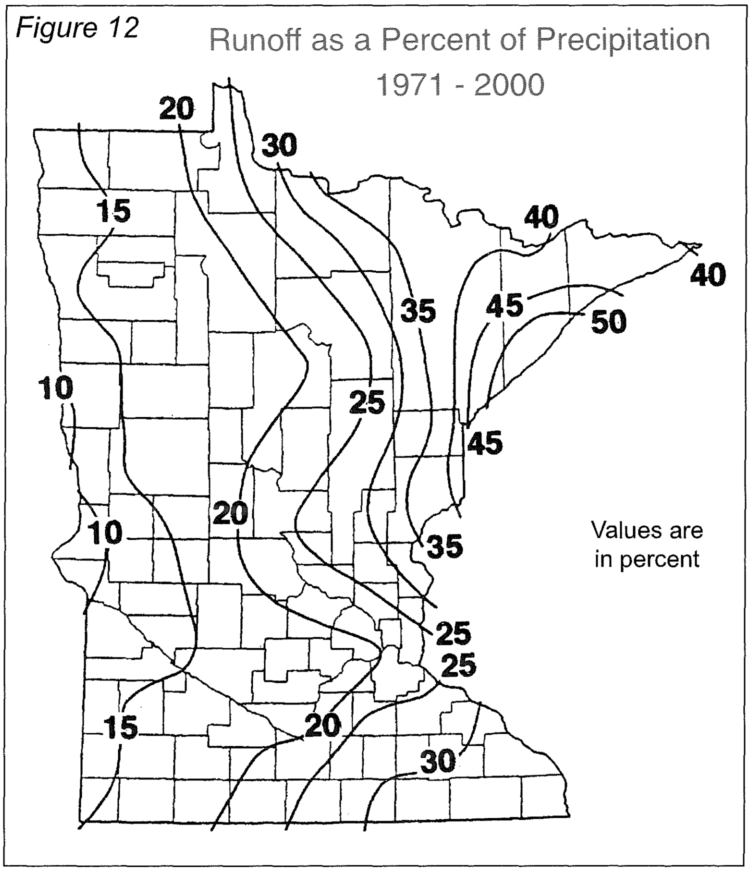


Figure 12 shows the volume of water running off the land as a percent of precipitation. The volume of precipitation that becomes runoff varied from 15 percent to 40 percent during the 30-year period of 1971-2000. However, it is possible for runoff to be less than 10 percent of precipitation in dry years or greater than 50 percent in wet years.

The very high values of runoff (50 percent or greater) along the north shore of Lake Superior are due to several factors including steep slopes, shallow soils with bedrock outcrops and heavier amounts of precipitation.

One of the consequences of a greater volume of runoff is that rivers must handle the additional water. Figures 7 and 9 on pages 21 and 23 clearly show that the annual hydrographs for the Minnesota River at Mankato, the Chippewa River near Milan and the Des Moines River at Jackson are now noticeably higher than they were in the mid-twentieth century.

Figure 12



Lake Levels

The water levels of all lakes fluctuate, some more than others. The primary factor that affects water level changes is the quantity and distribution of precipitation (rain & snow). Other factors that contribute to water level changes are outlet conditions, beaver dams, ground water movement and watershed characteristics (Figure 1). Knowing and understanding the history of water level fluctuations can help lake users deal with problems associated with the changing levels.

Historical water level data are useful in calibrating hydrologic and hydraulic computer models. These data also benefit watershed management authorities and other governmental units in preparing local water management plans and to locate building and sewage treatment sites.

The success of monitoring water levels is greatly dependent on citizen volunteers and cooperating organizations who participate in the DNR Waters Lake Level Minnesota (LLM) program. Lake levels were actively monitored at nearly 1000 sites in 2000 by citizen volunteers and cooperative organizations (Figure 2). Volunteer observers usually live on or near a lake, which makes it convenient to obtain weekly or more frequent readings. There is no cost to the volunteers to be in this program as the gage and installation are provided by DNR Waters. Each year the volunteer receives an updated water level graph and summary sheet that contains the information they provided.

Figure 1 Factors That Cause Lake Levels to Fluctuate

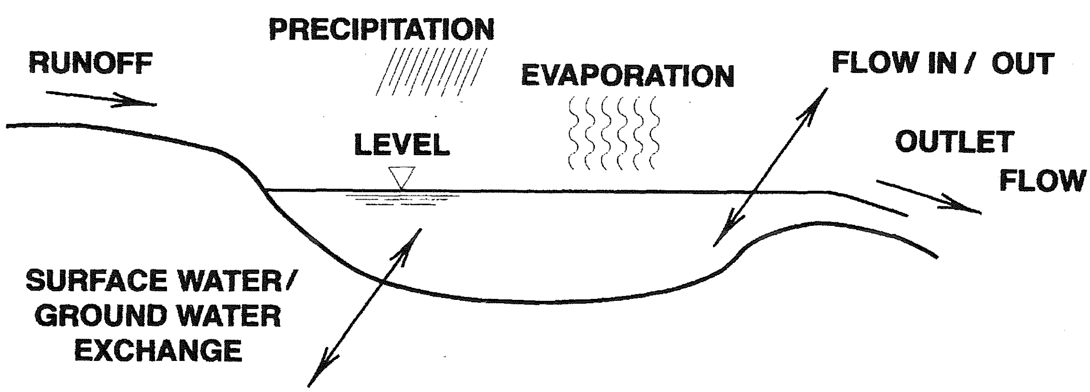
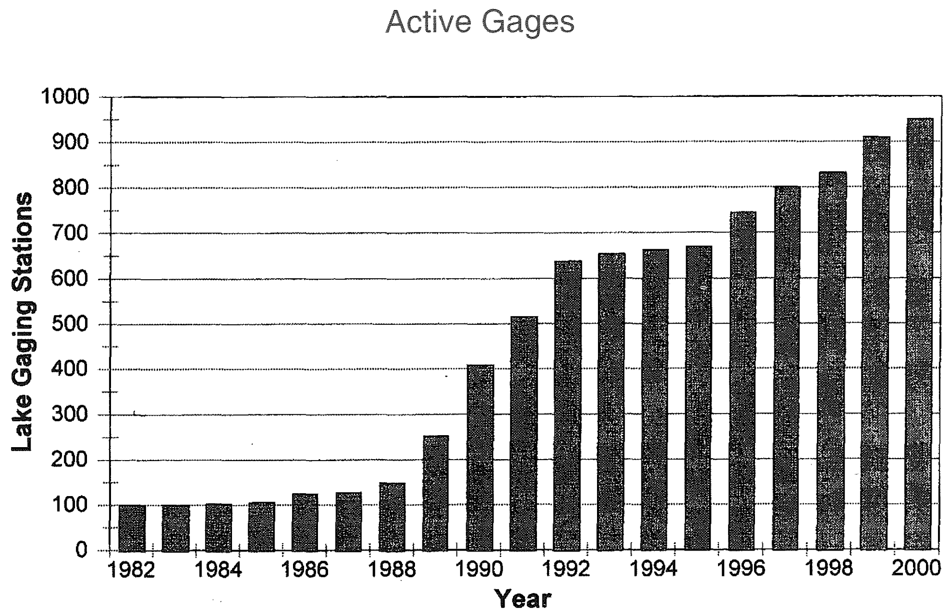


Figure 2



Lake level monitoring has also been accomplished in cooperation with various public and private organizations including:

- Federal (USGS, COE, NRCS)
- State (DNR)
- Counties
- Cities
- Soil & Water Conservation Districts
- Watershed Districts
- Consulting Land Surveyors and Engineers
- Power and Mining Companies

In order to improve geographic coverage, pull together all available data and eliminate possible dublication of efforts, DNR Waters has initiated cooperative programs with these organizations. This component of LLM accounts for approximately 290 lakes, up 20 percent from WY1998.

All lake level readings received are entered into Lakes-db©, a database program for easy management and access of recorded lake levels and other useful information. This information is now available on the internet (see "Lake Finder" sidebar on page 28).

Annual Lake Level Fluctuation

Minnesota lakes typically fluctuate one to two vertical feet in a given year., but historical fluctuations have been recorded in excess of ten feet. Water Year 1999 saw a statewide average fluctuation of 1.24 feet, which corresponds to the above-normal precipitation received during the year. Water Year 2000 had an average fluctuation of 1.05 feet (averages for six years are shown in Figure 3). The tables on pages 34 to 40 display fluctuations for Water Year 1999, Water Year 2000, an average fluctuation for the indicated period of record and the range between the historical high and low.

Figure 3

Water Year	Average Fluctuation Statewide (ft)
1995	1.03
1996	1.24
1997	1.55
1998	1.04
1999	1.24
2000	1.05

Lake Level Data on the DNR Website

"Lake Finder" is a feature of both the DNR website (www.dnr.state.mn.us) and the DNR Waters website (www.dnr.state.mn.us/waters). Lake Finder provides access to DNR Fisheries lake surveys and lake maps, Pollution Control Agency water quality and clarity data and the Health Department fish consumption advisory.

In 2000, DNR Waters added a new option titled "lake water levels". A single click on the checkmark below "lake water levels" will display a concise summary of recorded lake levels for the indicated period of record, a lake level graph for the last ten years (if enough data points are available), the ordinary high water (OHW) elevation, datum adjustment and reference benchmark (see Figure 4).

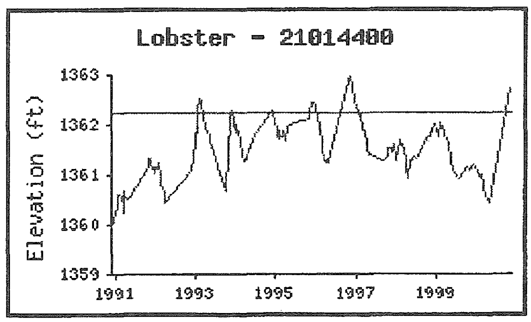
Most of the recorded water levels for each lake are collected by volunteers involved with the Lake Level Minnesota program. DNR Waters presently has water level information for approximately 3300 lakes.

Figure 4

Lake name: Lobster **County: Douglas**

Water Level Data

Period of record: 10/23/1936 to 04/25/2001
# of readings: 1137
Highest recorded: 1362.93 ft (05/01/1997)
Highest known: 1364.2 ft
Lowest recorded: 1351.73 ft (10/23/1936)
Recorded range: 11.2 ft
Average water level: 1357.02 ft
Last reading: 1362.68 ft (04/25/2001)
OHW elevation: 1362.2 ft
Datum: 1929 (ft)



Last 10 years of data, click to enlarge.

Download lake level data as: [dBase] [ASCII] (If you have trouble try right clicking on the download link and choosing the "Save ... As" option.)

Benchmarks

Elevation: 1364.92 ft **Date Set:** 02/06/1979
Datum: 1929 (ft)

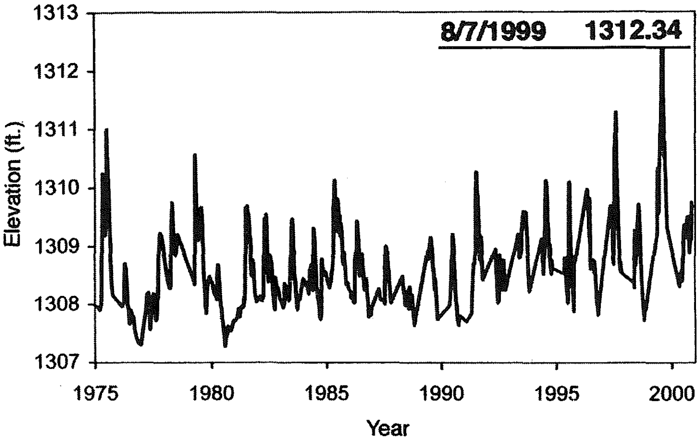
Benchmark Location
Township: 128 **Range:** 38 **Section:** 19

Description: Brass disk in right upstream abutment of Lobster Lk outlet dam.

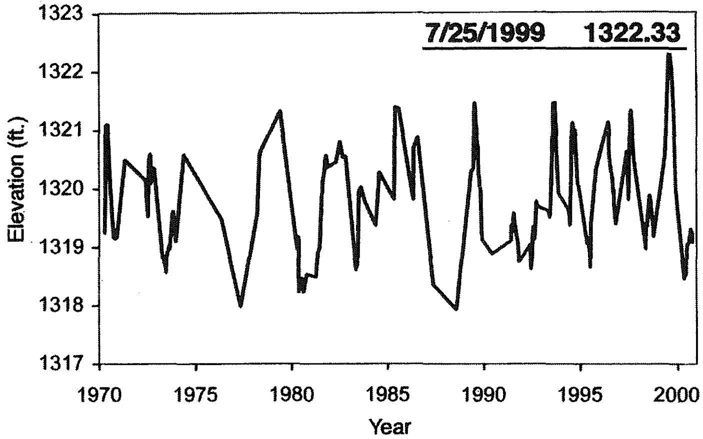
Lake Level Trends

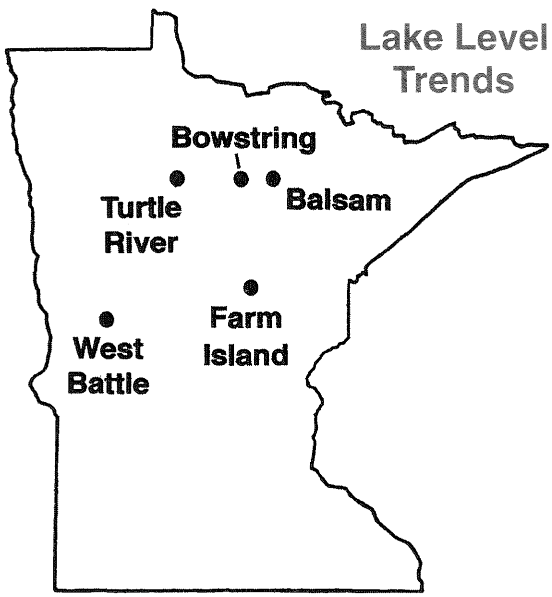
Many lakes, primarily located in the northern half of the state, experienced their highest recorded levels during 1999. Lake level hydrographs for five representative lakes are shown on page 29, with their peak levels and corresponding dates highlighted.

Turtle River Lake (4-111) Beltrami County

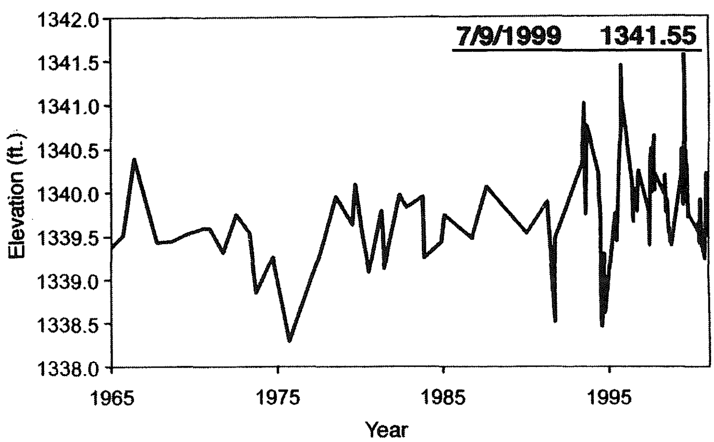


Bowstring Lake (31-813) Itasca County

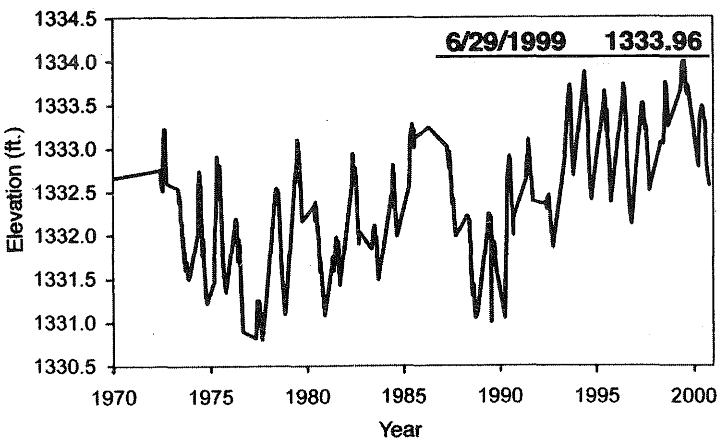




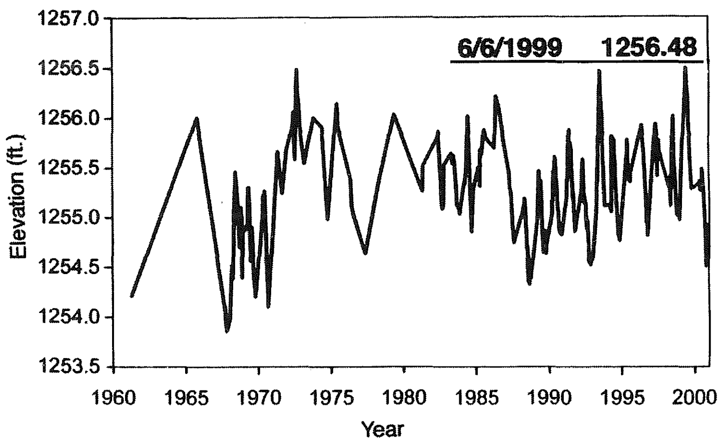
Balsam Lake (31-813) Itasca County



West Battle Lake (56-239) Otter Tail County



Farm Island Lake (1-159) Aitkin County



Landlocked Basins

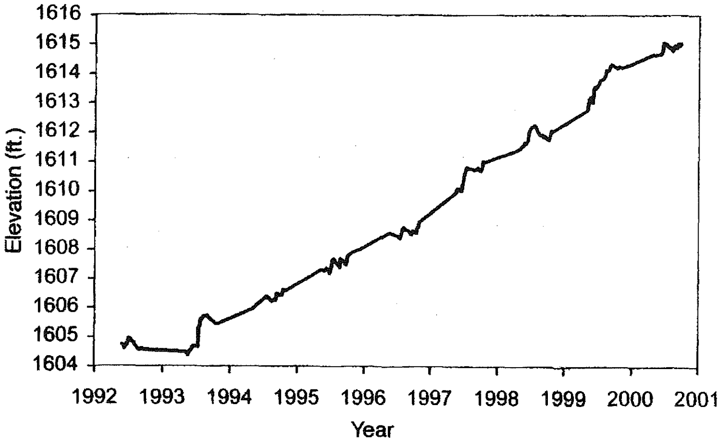
A landlocked lake has no regularly-functioning surface outlet channel, a small watershed, and typically experiences large, long-term water level fluctuations. The importance of ground water contributions to landlocked lakes can make them a good indicator of local ground water levels and movement.

The graphs on page 31 represent water levels for five landlocked basins that experienced their highest levels during 1999.

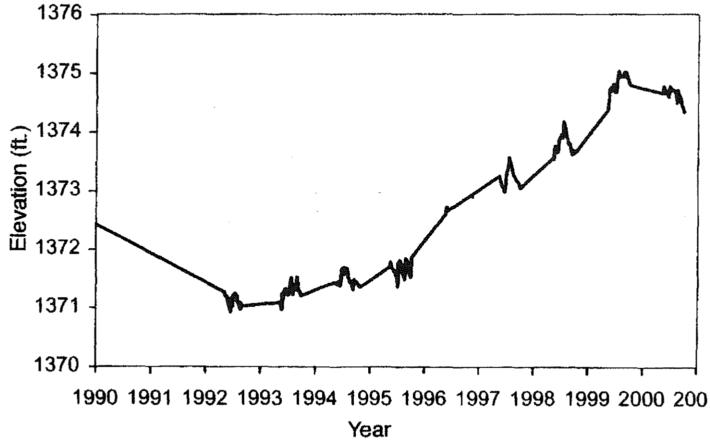
Ten-Year Trends

For many lakes that are presently monitored, reliable information has been collected for more than ten years. A ten-year average is used as a reference mark when comparing water year data to a longer-term average, and is useful in locating trends in a particular basin. Lakes graphed on pages 32 and 33 show above average levels in WY1999 in response to above average precipitation (see Figure 5 on page 5). With sharp geographical differences in precipitation in WY2000 (see Figure 14 on page 12), lakes in the northern half of the state continued to be above their ten-year average while lakes in central and southwestern Minnesota were below average.

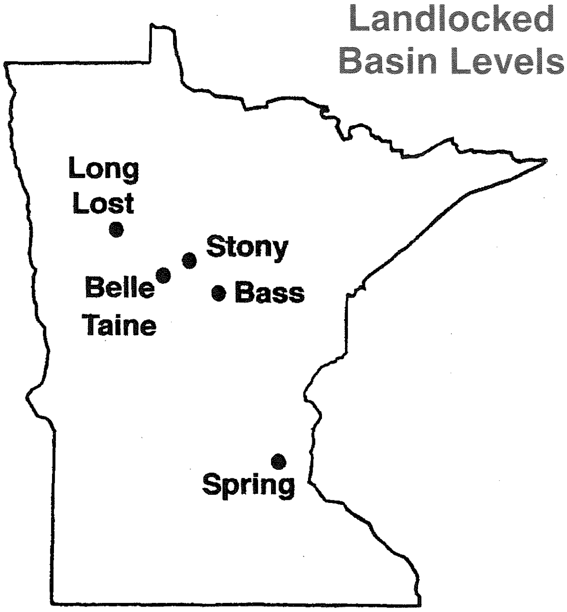
Long Lost Lake (15-68) Clearwater County



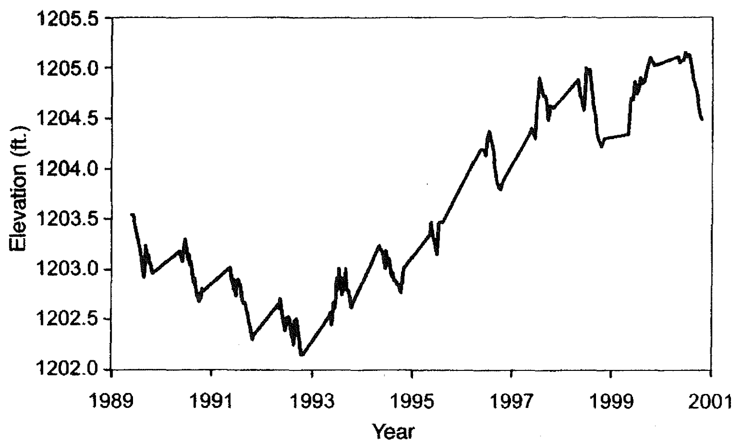
Stoney Lake (11-371) Cass County



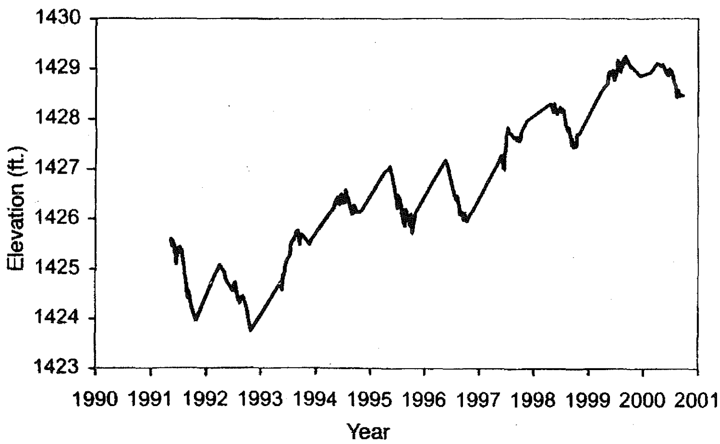
Landlocked Basin Levels



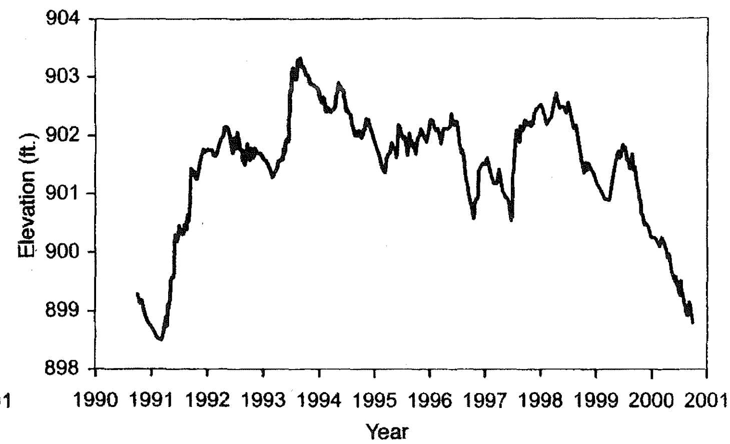
Bass Lake (18-256) Crow Wing County



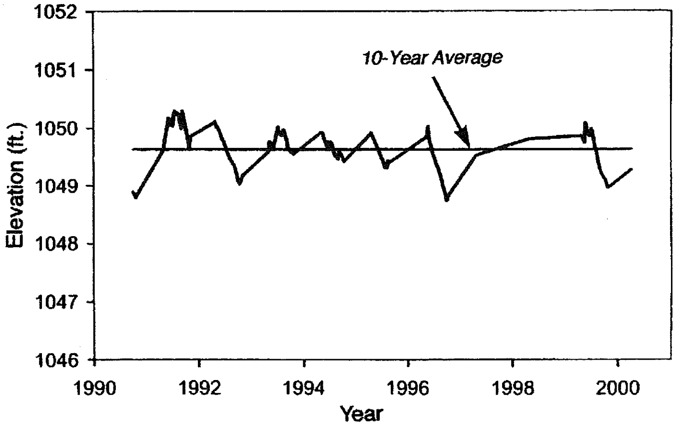
Belle Taine Lake (29-146) Hubbard County



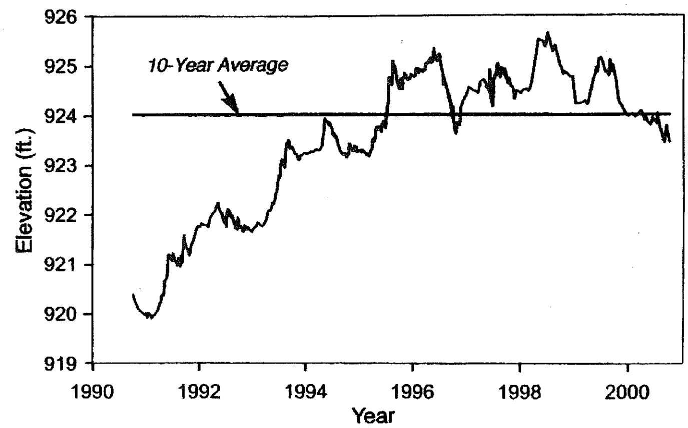
Spring Lake (2-71) Anoka County



Lake Sylvia (86-289) Wright County

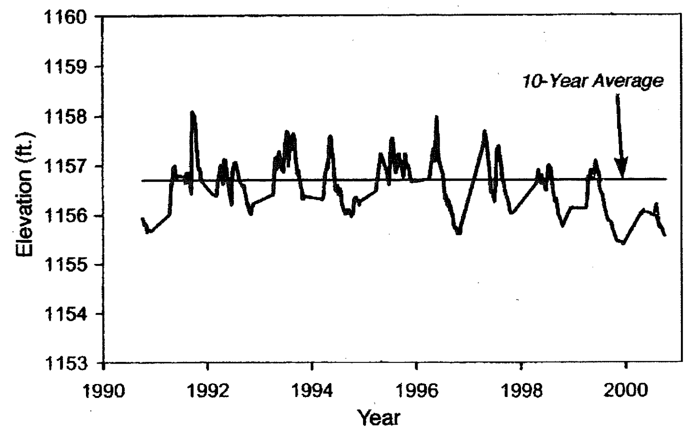


White Bear Lake (2-167) Washington County

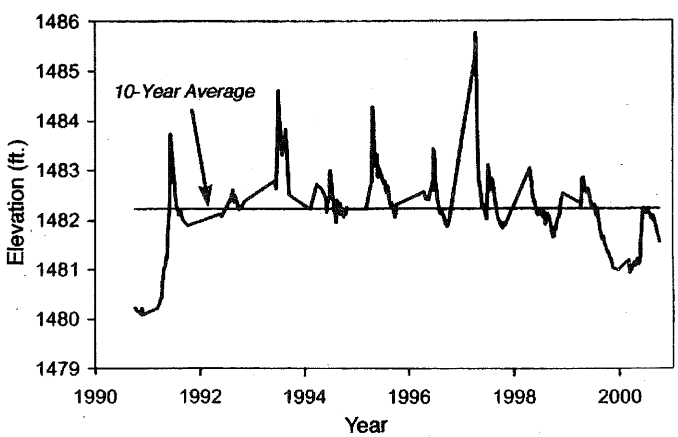


Ten-Year Trends

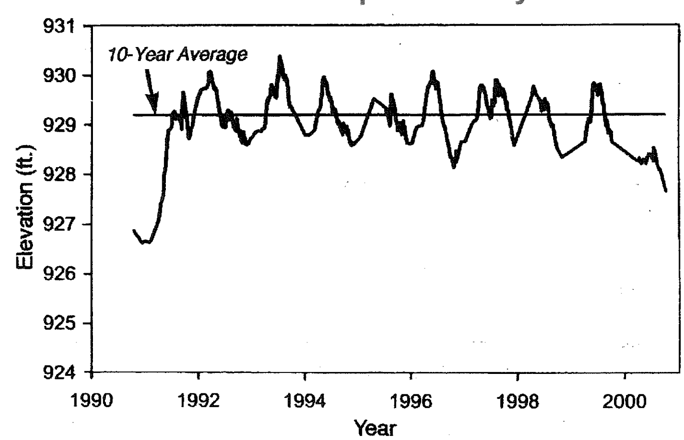
Green Lake (34-79) Kandiyohi County



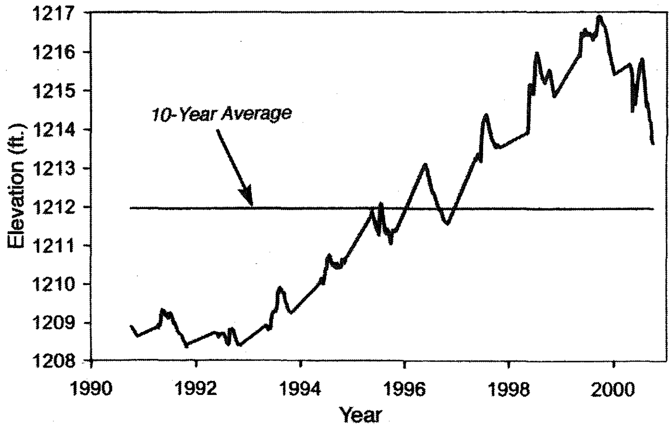
Lake Shetek (51-46) Murray County



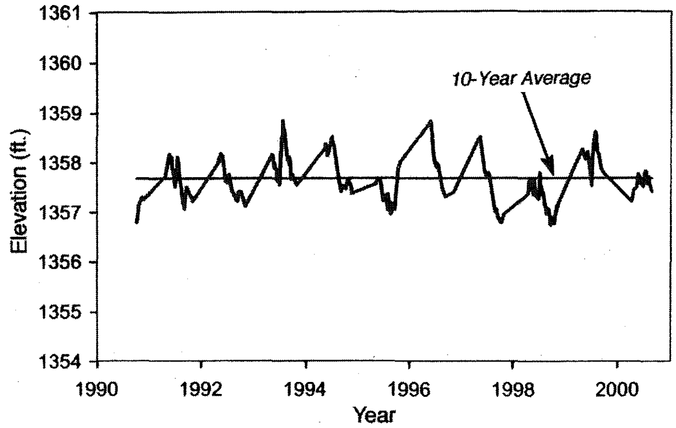
Lake Minnetonka (27-133) Hennepin County



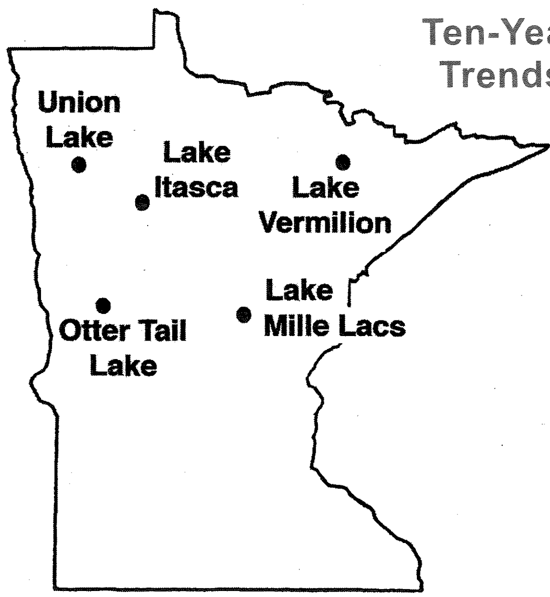
Union Lake (60-217) Polk County



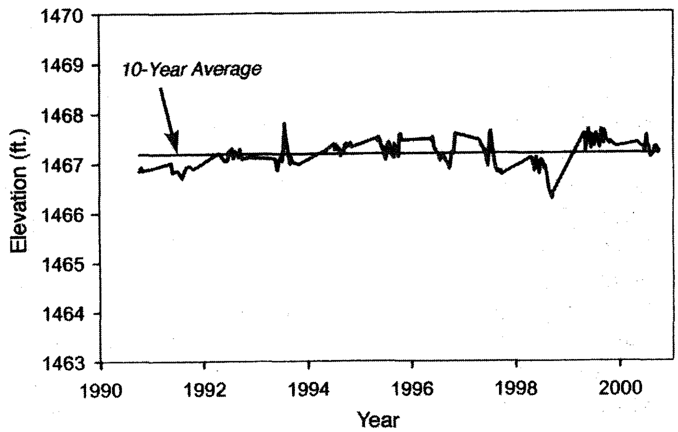
Lake Vermillion (69-37) St. Louis County



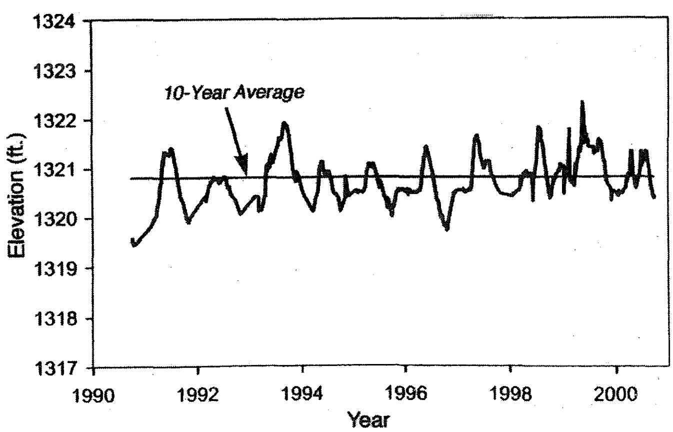
Ten-Year Trends



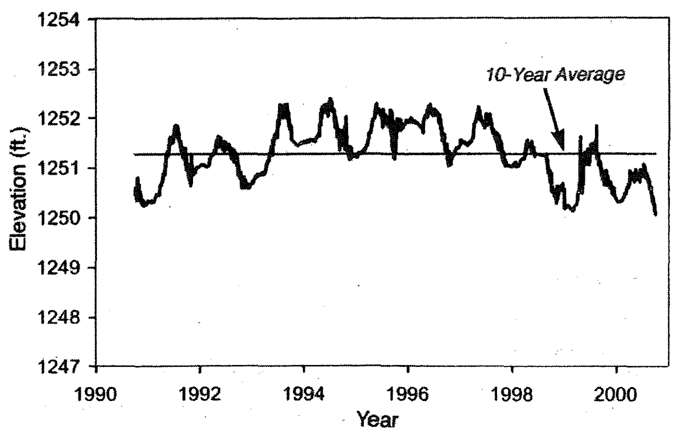
Lake Itasca (15-16) Clearwater County



Otter Tail Lake (56-242) Otter Tail County



Lake Mille Lacs (48-02) Mille Lacs County



Annual Lake Level Fluctuation (feet)

Lake Name	WY99	WY00	WYAv.	# Yrs.	Range
AITKIN COUNTY					
Big Sandy (1-62)	3.36	2.40	5.31	(102)	16.83
Blackface (1-45)	0.80	0.79	0.75	(9)	1.25
Cedar (1-209)	2.06	0.74	1.61	(50)	3.87
Clear (1-93)	0.75	0.43	0.85	(30)	4.39
Dam (1-96)	1.42	0.97	1.23	(17)	2.66
Elm Island (1-123)	1.46	1.12	1.33	(7)	3.23
Farm Island (1-159)	1.51	0.82	1.01	(23)	3.28
Fleming (1-105)	0.50	0.84	0.73	(9)	1.90
Gun (1-99)	0.99	0.77	0.71	(11)	1.68
Hanging Kettle (1-170)	1.43	0.40	1.47	(15)	3.75
Horseshoe (1-34)	0.50	0.59	0.70	(6)	1.10
Lone (1-125)	0.22	0.74	0.64	(10)	4.65
Long (1-101)	0.52	0.32	0.52	(8)	1.40
Minnewawa (1-33)	1.52	0.67	0.83	(18)	1.82
Rat (1-77)	1.12	0.57	1.09	(8)	3.95
Rock (1-72)	0.68	0.94	0.76	(7)	1.68
Round (1-23)	0.58	0.57	0.64	(8)	1.43
Round (1-204)	1.33	0.80	0.94	(10)	2.20
Spirit (1-178)	0.47	0.25	0.53	(20)	3.03
Sugar (1-87)	0.77	0.62	0.73	(30)	2.65
Waukenabo (1-136)	1.38	1.50	1.36	(19)	4.34
ANOKA COUNTY					
Baldwin (2-13)	3.14	1.34	2.97	(26)	6.86
Bunker (2-90)	0.94	3.38	1.69	(15)	7.87
Coon (2-42)	0.73	1.29	1.07	(32)	4.84
Crooked (2-84)	1.01	1.77	0.94	(16)	3.40
Fawn (2-35)	0.56	1.06	1.00	(12)	4.64
Golden (2-45)	1.14	0.84	0.87	(12)	2.44
Ham (2-53)	0.82	1.98	1.08	(16)	4.78
Howard (2-16)	0.83	0.69	0.95	(11)	2.46
Itasca (2-110)	0.71	3.45	1.57	(11)	8.25
Laddie (2-72)	0.83	2.20	1.03	(9)	4.19
Martin (2-34)	0.84	0.60	1.14	(22)	4.08
Moore (2-75)	0.79	0.75	0.93	(12)	1.76
Netta (2-52)	0.68	1.85	1.11	(17)	5.56
Otter (2-3)	1.12	1.04	1.63	(78)	6.72
Reshanau (2-9)	1.92	0.66	1.88	(11)	4.54
Rice (2-8)	3.14	1.34	3.08	(12)	6.64
Rogers (2-104)	1.39	2.35	1.43	(12)	5.35
Rondeau (2-15)	0.60	0.70	0.86	(9)	1.94
Round (2-89)	0.82	2.54	1.22	(16)	5.93
Sand Shore (2-102)	0.96	1.12	0.91	(9)	2.32
Sandy (2-80)	0.80	0.89	1.36	(9)	2.98
Spring (2-71)	0.95	2.25	1.59	(46)	6.60
BECKER COUNTY					
Bad Medicine (3-85)	1.31	0.71	0.90	(14)	6.21
Big Cormorant (3-576)	0.48	0.98	1.09	(35)	10.30
Cotton (3-286)	0.60	0.82	0.98	(34)	5.15
Detroit (3-381)	0.70	1.01	0.96	(22)	2.44

Lake Name	WY99	WY00	WYAv.	# Yrs.	Range
BECKER COUNTY (cont):					
Elbow (3-159)	0.88	0.87	1.23	(9)	3.33
Eunice (3-503)	0.34	0.26	0.58	(10)	1.87
Height of Land (3-195)	1.68	0.98	1.53	(43)	4.45
Ice Cracking (3-156)	0.85	0.98	1.11	(11)	4.64
Ida (3-582)	1.11	0.68	0.97	(13)	4.50
Juggler (3-136)	0.56	0.54	0.78	(8)	4.93
Little Bemidji (3-234)	0.68	0.70	0.97	(6)	2.74
Little Toad (3-189)	0.95	0.62	0.69	(7)	1.79
Long (3-383)	0.38	0.44	0.53	(14)	1.64
Maud (3-500)	0.66	0.30	0.74	(9)	1.86
Melissa (3-475)	1.05	1.63	1.09	(25)	6.30
Muskrat (3-360)	0.53	0.64	0.88	(28)	2.81
Pickerel (3-287)	1.40	0.72	1.00	(9)	5.83
Rock (3-293)	1.76	1.10	1.26	(6)	2.01
Round (3-155)	0.84	2.66	1.19	(18)	2.97
Sallie (3-359)	1.08	0.84	1.24	(33)	5.58
Straight (3-10)	0.48	0.35	0.52	(15)	6.16
Talac (3-619)	0.59	0.98	1.29	(8)	9.72
Toad (3-107)	0.98	1.14	1.21	(20)	5.20
Two Inlets (3-17)	0.95	1.21	1.24	(19)	3.91
Upper Cormorant (3-588)	0.48	0.90	1.06	(25)	3.89
White Earth (3-328)	1.02	1.52	1.01	(20)	3.34
BELTRAMI COUNTY					
Bemidji (4-130)	2.04	1.43	1.77	(17)	4.25
Big Bass (east basin) (4-132)	2.67	2.81	1.18	(6)	4.25
Big Bass (west basin) (4-132)	0.70	1.49	0.59	(6)	2.05
Cass (4-30)	2.51	2.15	1.91	(54)	4.83
Gallagher (Rhoda)(4-92)	1.13	1.21	0.80	(28)	2.39
Long (4-76)	1.06	0.42	0.76	(14)	2.85
Red (4-35)	3.03	1.70	1.63	(55)	6.93
Stump (4-130)	1.74	1.60	2.24	(17)	5.70
Turtle River (4-111)	4.62	1.20	1.83	(28)	5.06
BENTON COUNTY					
Little Rock (5-13)	0.38	0.56	0.63	(7)	1.17
BIG STONE COUNTY					
Big Stone (6-152)	1.30	1.20	2.37	(31)	10.83
East Toqua (6-138)	0.89	0.95	1.56	(10)	4.90
BLUE EARTH COUNTY					
Duck (7-53)	1.18	0.96	1.08	(10)	3.17
BROWN COUNTY					
Sleepy Eye (8-45)	0.80	0.70	1.49	(13)	5.54
Somsen (8-18)	1.19	1.56	3.09	(10)	8.88

Annual Lake Level Fluctuation (feet)

Lake Name	WY99	WY00	WYAv.	# Yrs.	Range
CARLTON COUNTY					
Big (9-32)	0.76	0.63	0.59	(8)	1.52
Chub (9-8)	0.69	1.09	0.96	(14)	3.47
Eagle (9-57)	1.35	0.93	0.79	(8)	1.88
Eddy (9-39)	2.57	1.78	2.58	(7)	4.17
Little Hanging Horn (9-35)	3.02	1.61	2.20	(10)	3.53
Park (9-29)	0.90	0.79	0.69	(10)	1.65
Torch Light (9-25)	1.46	0.77	0.93	(8)	1.86
CARVER COUNTY					
Berliner (10-103)	1.46	1.20	1.19	(10)	3.95
Hydes (10-88)	1.16	1.03	0.76	(7)	3.83
Lotus (10-6)	1.22	0.56	1.38	(30)	3.90
Minnewashta (10-9)	1.44	0.80	1.30	(15)	3.40
Oak (10-93)	0.77	1.49	1.09	(6)	3.26
Patterson (10-86)	1.50	0.76	1.23	(11)	3.40
Riley (10-2)	1.29	0.70	1.41	(30)	4.74
Waconia (10-59)	1.34	0.87	1.13	(32)	5.90
CASS COUNTY					
Ada (11-250)	0.65	0.66	0.78	(11)	2.36
Agate (11-216)	0.85	0.50	0.67	(10)	3.05
Barnum (11-281)	0.99	0.62	0.68	(7)	2.12
Big Rice (11-73)	2.80	1.90	2.17	(33)	5.00
Birch (11-412)	0.56	0.79	0.93	(10)	2.00
Blackwater (11-274)	1.38	0.31	0.57	(6)	3.93
Child (11-263)	1.24	0.82	0.92	(11)	1.98
Hay (11-199)	0.85	0.64	0.88	(10)	3.32
Horseshoe (11-358)	0.95	0.84	0.54	(10)	3.09
Inguadona (11-120)	1.68	1.69	1.43	(9)	2.90
Laura (11-104)	1.10	1.00	0.72	(15)	1.85
Leech (11-203)	1.92	1.73	1.40	(36)	3.35
Little Boy (11-167)	1.24	0.48	1.10	(8)	2.50
Long (11-142)	1.50	0.71	0.96	(10)	4.79
Lower Trelipe (11-129)	1.46	1.19	1.11	(21)	4.63
Mud (11-100)	5.40	4.20	2.61	(26)	6.70
Paquet (11-381)	0.33	1.23	1.08	(8)	2.26
Portage (11-476)	1.96	0.80	0.96	(10)	4.44
Stony (11-371)	0.66	0.44	0.55	(9)	4.11
Sylvan (11-304)	0.88	0.60	0.84	(19)	3.21
Ten Mile (11-413)	0.62	0.47	0.78	(26)	2.72
Vermillion (11-29)	2.46	1.10	1.97	(7)	5.25
Winnibigoshish (11-147)	2.44	1.90	2.00	(41)	3.90
Woman (11-201)	1.02	0.70	0.83	(11)	1.72
CHISAGO COUNTY					
Goose (13-83)	1.70	0.50	1.55	(13)	3.17
Green (13-41)	0.72	0.68	1.05	(23)	9.10
North Center (13-32)	0.70	1.10	1.58	(28)	7.26
Rush (13-69)	1.32	0.91	1.39	(34)	3.28
Sunrise (13-31)	0.70	0.77	0.96	(13)	13.07

Lake Name	WY99	WY00	WYAv.	# Yrs.	Range
CLEARWATER COUNTY					
Itasca (15-16)	0.44	0.44	0.71	(33)	2.21
Long Lost (15-68)	2.58	0.87	1.38	(9)	10.76
COOK COUNTY					
Clearwater (16-139)	1.55	0.90	1.11	(6)	1.55
Flour (16-147)	0.74	0.54	0.64	(11)	1.88
Gunflint (16-356)	1.25	1.33	1.68	(10)	3.33
Poplar (16-239)	1.33	0.27	1.12	(12)	3.70
Saganaga (16-633)	1.02	1.24	1.80	(10)	5.15
Sea Gull (16-629)	1.19	0.97	1.72	(9)	3.44
COTTONWOOD COUNTY					
Cottonwood (17-22)	1.77	2.27	1.94	(13)	9.90
CROW WING COUNTY					
Bass (18-256)	0.80	0.54	0.67	(12)	3.00
Bonnie (18-259)	0.83	0.58	0.65	(11)	2.90
Clark (18-374)	0.94	0.30	0.82	(12)	1.73
Crooked (18-41)	0.87	1.28	0.77	(11)	2.38
Crow Wing (18-155)	2.07	0.52	1.43	(9)	3.85
East Twin (18-407)	0.70	0.50	0.62	(10)	2.57
Edward (18-305)	1.15	0.71	0.89	(33)	7.13
Garden (18-329)	0.78	0.32	0.48	(12)	1.29
Gilbert (18-320)	2.10	0.64	1.13	(11)	4.71
Gladstone (18-338)	0.84	0.46	0.65	(12)	1.21
Goodrich (18-226)	0.47	0.54	0.52	(8)	1.30
Hamlet (18-70)	1.90	0.88	1.03	(37)	6.70
Hartley (18-392)	0.52	0.65	0.68	(12)	3.28
Horseshoe (18-251)	1.01	0.76	0.69	(12)	2.49
Hubert (18-375)	1.03	0.70	0.97	(20)	3.50
Island (18-183)	1.95	0.94	1.45	(12)	2.98
Little Hubert (18-340)	1.61	1.14	0.96	(12)	3.29
Little Pelican (18-351)	0.91	0.79	0.68	(12)	1.94
Lougee (18-342)	1.16	0.67	0.72	(12)	2.40
Lower Mission (18-243)	0.61	0.42	0.67	(24)	2.20
Mollie (18-335)	1.21	0.70	0.75	(12)	2.94
North Long (18-372)	1.09	0.95	0.90	(30)	2.88
O'Brien (18-227)	0.38	0.31	0.55	(9)	1.89
Olander (18-91)	1.37	1.02	1.14	(39)	7.25
Ossawinnamakee (18-352)	0.72	0.40	0.78	(17)	1.81
Pelican (18-308)	0.97	0.56	0.87	(44)	4.51
Perch (18-304)	0.80	0.62	0.74	(12)	2.86
Portage (18-50)	0.80	1.51	0.90	(10)	3.11
Rabbit (18-93)	0.55	0.35	0.95	(43)	3.24
Roger (18-184)	1.14	0.77	0.81	(13)	2.30
Ross (18-165)	1.70	1.36	1.42	(17)	3.05
Ruth (18-212)	0.30	0.82	0.86	(34)	6.31
Shaffer (18-348)	1.16	0.97	0.74	(13)	2.84
Sorenson (18-323)	1.25	0.64	0.95	(12)	2.98
South Long (18-136)	2.20	0.94	1.13	(35)	3.24

Annual Lake Level Fluctuation (feet)

Lake Name	WY99	WY00	WYAv.	# Yrs.	Range
CROW WING COUNTY (cont):					
Upper South Long (18-96)	2.14	0.60	1.11	(31)	3.42
West Twin (18-409)	0.82	0.71	0.61	(10)	2.28
Whitefish (18-1)	0.85	1.24	1.16	(9)	2.91
Young (18-252)	1.14	0.98	0.78	(12)	2.36
DAKOTA COUNTY					
Marion (19-26)	1.40	1.94	2.09	(42)	13.22
Orchard (19-31)	3.40	0.58	1.05	(9)	3.58
Sunfish (19-50)	0.92	0.71	1.00	(10)	3.42
DOUGLAS COUNTY					
Aaron (21-242)	0.40	0.62	0.77	(7)	2.34
Andrew (21-85)	0.64	0.74	0.94	(9)	3.79
Chippewa (21-145)	1.54	1.36	1.20	(17)	3.30
Christina (21-375)	1.05	0.54	0.94	(28)	2.97
Geneva (21-52)	1.11	0.45	0.94	(7)	2.32
Ida (21-123)	0.46	0.76	1.08	(18)	7.94
Irene (21-76)	0.68	0.61	0.69	(11)	1.33
Latoka (21-106)	0.25	0.20	0.50	(8)	5.98
Le Homme Dieu (21-56)	0.74	0.48	0.94	(10)	1.80
Lobster (21-144)	0.75	1.15	1.18	(28)	11.20
Louise (21-94)	2.47	1.56	1.49	(14)	5.71
Maple (21-79)	0.77	0.43	0.76	(7)	2.90
Mary (21-92)	0.38	0.70	1.32	(10)	5.31
Mill (21-180)	1.15	0.36	1.14	(8)	3.37
Miltona (21-83)	1.28	0.54	1.08	(25)	4.60
Moon (21-226)	1.40	0.66	1.28	(16)	10.59
Moses (21-245)	0.80	0.38	1.52	(16)	13.24
Red Rock (21-291)	1.98	1.30	1.46	(10)	4.21
Victoria (21-54)	1.45	0.54	1.16	(19)	3.45
Winona (21-81)	0.74	0.38	0.69	(7)	1.66
FREEBORN COUNTY					
Albert Lea (24-14)	1.10	2.25	2.09	(19)	5.52
Bear (24-28)	0.95	1.74	1.18	(17)	5.58
Fountain (24-18)	1.32	4.14	1.93	(6)	5.27
Geneva (24-15)	3.95	3.18	1.50	(8)	4.58
Lower Twin (24-27)	0.80	1.48	1.14	(8)	2.66
Upper Twin (24-31)	0.90	1.10	1.33	(8)	3.06
GRANT COUNTY					
Elk (26-40)	0.64	0.78	0.75	(6)	1.76
Pelican (26-2)	0.58	0.41	1.00	(12)	7.64
HENNEPIN COUNTY					
Calhoun (27-31)	1.26	1.78	1.86	(73)	6.36
Cedar Island (27-119)	1.04	0.74	1.13	(14)	6.50
Eagle/Pike (27-111)	0.79	0.44	1.01	(14)	3.27
Edward (27-121)	0.63	0.64	0.99	(13)	3.69

Lake Name	WY99	WY00	WYAv.	# Yrs.	Range
HENNEPIN COUNTY (cont):					
Fish (27-118)	1.78	1.94	1.47	(13)	2.87
Harriet (27-16)	0.97	1.32	1.22	(70)	4.57
Hiawatha (27-18)	2.18	2.41	2.78	(34)	12.00
Independence (27-176)	1.90	0.86	1.64	(20)	7.81
Indianhead (27-44)	1.12	1.28	1.24	(8)	3.19
Langdon (27-182)	1.31	0.84	1.30	(9)	3.38
Long (27-160)	1.72	1.07	1.36	(15)	3.35
Loring (27-655)	0.95	0.62	0.92	(18)	3.57
Medicine (27-104)	1.40	1.52	1.56	(28)	5.08
Minnetoga (27-88)	0.70	0.46	0.98	(27)	2.94
Minnetonka (27-133)	1.50	0.87	1.39	(95)	8.73
Nesbitt Pond (27-1018)	1.72	1.19	1.00	(7)	1.85
Nokomis (27-19)	0.56	2.13	2.07	(51)	8.76
Parkers (27-107)	3.63	1.54	2.58	(28)	11.65
Powderhorn (27-14)	1.38	3.55	3.10	(16)	10.84
Rice (27-116)	1.31	0.64	1.84	(13)	10.88
Sarah (27-191)	2.41	0.60	1.69	(7)	3.38
Twin (27-42)	2.21	0.99	1.35	(10)	3.98
Weaver (27-117)	0.66	0.51	0.94	(13)	3.19
Wirth (27-37)	0.25	2.60	1.59	(46)	5.86
HUBBARD COUNTY					
Belle Taine (29-146)	1.80	0.68	1.36	(47)	13.84
Big Sand (29-185)	1.39	0.52	0.84	(10)	2.50
Big Stony (29-143)	0.90	0.88	0.69	(7)	1.52
Blue (29-184)	0.71	0.85	0.58	(6)	1.07
Eagle (29-256)	2.08	1.72	1.55	(10)	2.78
East Crooked (29-101)	0.89	0.41	0.84	(7)	3.54
Fifth Crow Wing (29-92)	0.68	0.56	0.73	(7)	1.26
Fish Hook (29-242)	1.88	1.64	1.12	(10)	2.12
Gilmore (29-188)	0.46	0.32	0.49	(7)	0.89
Grace (29-71)	0.49	0.44	0.70	(10)	2.75
Island (29-254)	1.68	2.34	2.15	(10)	3.92
Little Sand (29-150)	0.48	0.52	0.71	(27)	3.08
Long (29-161)	0.53	0.67	0.51	(14)	1.18
Middle Crooked (29-101)	0.88	0.41	0.69	(6)	2.03
Palmer (29-87)	1.39	0.70	0.84	(10)	2.91
Plantagenet (29-156)	2.32	1.02	1.40	(19)	3.47
Stocking (29-172)	0.56	0.48	0.51	(6)	1.08
West Crooked (29-101)	1.37	0.77	0.68	(7)	2.01
ISANTI COUNTY					
Green (30-136)	1.60	0.60	1.42	(18)	7.04
Skogman (30-22)	0.72	1.02	1.22	(22)	4.29
Spectacle (30-135)	0.38	1.10	0.65	(8)	2.68
Typo (30-9)	0.76	0.52	1.54	(12)	3.57

Annual Lake Level Fluctuation (feet)

Lake Name	WY99	WY00	WYAv.	# Yrs.	Range
ITASCA COUNTY					
Ball Club (31-812)	2.34	5.84	3.13	(10)	6.93
Balsam (31-259)	2.16	0.66	1.13	(18)	3.26
Bass (31-576)	1.24	0.60	0.82	(21)	2.47
Beatrice (31-58)	1.52	0.90	0.85	(9)	1.92
Bello (31-726)	1.56	0.39	0.76	(6)	1.87
Bowstring (31-813)	3.16	3.17	1.62	(22)	4.40
Buck (31-69)	1.06	0.46	0.52	(16)	1.33
Burrows (31-413)	1.15	0.80	0.71	(11)	2.18
Caribou (31-620)	0.50	0.60	0.60	(12)	2.28
Carlson (31-366)	1.45	1.22	0.85	(6)	1.62
Crooked (31-193)	9.40	4.28	6.02	(8)	9.40
Deer (31-719)	0.28	0.70	0.52	(7)	1.20
Dixon (31-921)	3.78	2.06	2.78	(7)	4.41
Dora (31-882)	3.49	3.14	1.98	(20)	4.35
Forest (31-374)	0.68	0.22	0.69	(35)	2.94
Grave (31-624)	1.10	0.27	0.58	(8)	1.27
Hale (31-361)	0.46	1.04	1.03	(8)	2.36
Hale (31-373)	1.15	0.49	0.83	(42)	3.16
Jessie (31-786)	3.44	0.55	1.16	(11)	3.44
Johnson (31-586)	1.33	1.02	0.91	(11)	3.01
Lawrence (31-231)	10.98	2.64	4.74	(6)	10.98
Little Bowstring (31-758)	1.59	1.00	1.17	(7)	2.08
Little Long (31-266)	1.70	0.35	1.01	(9)	2.32
Little Long (31-613)	1.45	1.07	0.76	(10)	5.68
Little Winnibigoshish (31-850)	6.05	4.55	5.42	(12)	7.92
Long (31-570)	1.19	0.82	0.92	(35)	3.39
Loon (31-571)	1.59	0.88	1.05	(36)	3.62
McGuire (31-78)	2.60	2.29	2.64	(9)	4.80
Moose (31-722)	1.65	0.44	0.76	(12)	1.77
North Star (31-653)	1.10	0.40	0.61	(12)	1.40
Owen (31-292)	1.06	0.63	0.72	(11)	2.28
Pigeon Dam (31-894)	1.65	1.50	1.25	(13)	3.30
Pokegama (31-532)	4.51	3.28	3.06	(47)	8.89
Ruby (31-422)	0.80	0.65	0.59	(11)	2.21
Sand (31-438)	1.06	0.80	0.82	(9)	3.14
Sand (31-826)	3.56	3.56	1.65	(18)	4.40
Shallow (31-84)	0.41	0.53	0.61	(9)	1.12
Shoal (31-141)	1.20	0.58	1.00	(7)	1.85
Siseebakwet (31-554)	0.82	0.48	0.74	(52)	2.19
Smith (31-650)	1.67	1.12	0.80	(11)	3.17
Snaptail (31-255)	1.59	0.84	1.01	(9)	1.91
South Sturgeon (31-3)	2.51	1.37	1.36	(7)	3.40
Spider (31-538)	1.32	0.82	0.79	(11)	2.40
Split Hand (31-353)	2.12	1.98	1.55	(19)	3.65
Swan (31-67)	0.86	0.68	1.51	(52)	4.65
Trout (31-216)	1.56	1.10	1.16	(40)	6.09
White Swan (31-260)	0.80	0.50	0.58	(11)	2.25

Lake Name	WY99	WY00	WYAv.	# Yrs.	Range
JACKSON COUNTY					
Fish (32-18)	0.75	0.67	1.26	(12)	7.45
Heron (Duck) (32-57)	1.40	1.28	1.51	(10)	5.58
KANABEC COUNTY					
Fish (33-36)	2.84	0.82	1.82	(9)	4.82
Knife (33-28)	1.80	0.30	2.12	(33)	11.99
KANDIYOHI COUNTY					
Andrew (34-206)	0.91	0.84	1.48	(33)	13.60
Calhoun (34-62)	1.22	0.80	1.35	(29)	6.83
Diamond (34-44)	0.89	0.42	0.99	(19)	3.95
Eagle (34-171)	0.41	0.74	1.15	(31)	5.22
Elizabeth (34-22)	1.05	0.91	1.13	(20)	3.11
Elkhorn (34-119)	0.33	0.54	0.88	(19)	4.11
Florida (34-217)	0.74	0.94	1.37	(20)	5.22
Florida Slough (34-204)	0.18	0.32	1.41	(14)	4.95
Foot (34-181)	0.66	0.92	1.18	(18)	3.93
George (34-142)	0.52	0.92	1.02	(25)	3.88
Green (34-79)	1.34	0.82	1.53	(45)	4.91
Henderson (34-116)	0.81	0.92	0.91	(15)	5.24
Long (34-66)	0.45	0.71	0.50	(18)	1.61
Long (34-192)	0.72	0.80	1.13	(19)	5.07
Mud (34-158)	0.61	0.94	1.30	(33)	3.64
Nest (34-154)	1.21	1.58	1.31	(32)	5.20
Norway (34-251)	0.91	0.78	1.24	(18)	4.29
Skataas (34-196)	0.87	0.78	1.19	(13)	4.81
Sunburg (34-359)	0.41	0.86	1.02	(6)	3.00
Swenson (34-321)	0.53	1.02	1.14	(13)	5.63
Unnamed (Golden Pond) (34-355)	1.03	1.44	0.97	(6)	2.54
Wagonga (34-169)	0.68	0.80	1.49	(16)	4.40
LAKE COUNTY					
Farm (38-779)	0.44	0.28	0.44	(8)	0.78
Garden (38-782)	0.63	0.44	1.31	(9)	3.67
LE SUEUR COUNTY					
Emily (40-124)	1.28	1.00	1.35	(23)	7.34
Frances (40-57)	1.07	0.78	0.85	(9)	13.14
Volney (40-33)	1.24	0.98	1.28	(10)	3.60
Washington (40-117)	1.82	1.26	1.48	(22)	5.35
West Jefferson (40-92)	1.53	1.15	1.39	(26)	6.92
MCLEOD COUNTY					
Marion (43-84)	0.72	0.90	1.02	(11)	3.05
Winsted (43-12)	1.97	0.44	1.58	(10)	3.31
MAHNOMEN COUNTY					
Tulaby (44-3)	0.68	0.80	1.10	(8)	2.44

Annual Lake Level Fluctuation (feet)

Lake Name	WY99	WY00	WYAv.	# Yrs.	Range
MARTIN COUNTY					
Amber (46-34)	2.20	1.38	1.40	(8)	3.89
Budd (46-30)	2.56	2.16	1.48	(7)	5.32
George (46-24)	1.82	1.32	1.31	(8)	8.84
MEEKER COUNTY					
Belle (47-49)	0.80	1.26	1.19	(9)	11.84
Clear (47-95)	0.90	0.82	1.27	(11)	4.21
Francis (47-2)	0.86	0.88	0.87	(18)	4.31
Jennie (47-15)	0.75	0.92	0.91	(9)	9.04
Long (47-26)	0.65	0.55	0.50	(6)	1.08
Manuella (47-50)	0.85	0.69	1.40	(12)	4.47
Minnie-Belle (47-119)	0.71	1.06	1.30	(12)	5.92
Ripley (47-134)	0.85	0.80	0.91	(8)	9.61
Stella (47-68)	0.70	0.90	0.99	(12)	2.48
Thompson (47-159)	0.86	0.90	1.35	(11)	6.61
Washington (47-46)	0.52	0.66	0.65	(12)	2.03
MILLE LACS COUNTY					
Mille Lacs (48-2)	1.70	1.01	1.33	(70)	7.69
Onamia (48-9)	1.72	0.92	1.63	(35)	6.12
MORRISON COUNTY					
Alexander (49-79)	1.20	0.89	0.99	(19)	3.82
Round (49-56)	1.07	0.62	0.78	(6)	1.46
Shamineau (49-127)	0.81	0.77	0.83	(7)	4.51
Sullivan (49-16)	2.00	0.74	1.35	(22)	3.79
MOWER COUNTY					
East Side (50-2)	0.80	1.56	0.96	(7)	1.73
MURRAY COUNTY					
Currant (51-82)	1.50	0.65	1.36	(7)	4.56
Sarah (51-63)	0.46	0.64	1.12	(6)	4.25
Shetek (51-46)	1.46	1.32	2.00	(51)	7.67
NOBLES COUNTY					
Indian (53-7)	1.42	1.80	1.72	(13)	4.48
Ocheda (53-24)	1.59	1.51	1.38	(33)	5.42
OLMSTED COUNTY					
Shady (55-5)	0.74	1.88	2.10	(7)	6.30
OTTER TAIL COUNTY					
Beers (56-724)	1.15	0.58	1.01	(7)	3.78
Big McDonald (56-386)	0.85	1.00	0.93	(6)	1.60
Big McDonald,West (56-386)	1.86	0.80	1.05	(7)	8.66
Big Pine (56-130)	1.19	1.13	1.53	(51)	4.73
Blanche (56-240)	0.60	0.47	0.56	(8)	1.56

Lake Name	WY99	WY00	WYAv.	# Yrs.	Range
OTTER TAIL COUNTY (cont):					
East Leaf (56-116)	2.52	1.48	2.10	(6)	3.22
East Lost (56-378)	2.01	1.38	2.00	(8)	3.38
Jewett (56-877)	0.70	0.66	0.64	(6)	3.37
Lida (56-747)	0.52	0.41	0.89	(7)	2.10
Little McDonald (56-328)	1.04	1.02	1.05	(9)	4.26
Little Pine (56-142)	1.09	0.64	1.07	(36)	3.30
Lizzie (56-760)	0.58	1.08	1.19	(53)	4.56
Long (56-388)	0.86	0.66	0.77	(17)	6.20
Middle Leaf (56-116)	1.79	1.30	1.83	(6)	3.61
Otter Tail (56-242)	1.95	1.00	1.43	(71)	4.63
Pelican (56-786)	0.79	0.64	1.29	(27)	4.94
Pickerel (56-204)	1.65	0.94	1.16	(7)	2.66
Pickerel (56-475)	0.51	0.54	0.69	(22)	3.03
Prairie (56-915)	1.06	0.34	0.82	(20)	4.70
Rush (56-141)	1.40	1.50	1.55	(61)	3.87
Rush (TW) (56-141)	1.88	1.10	1.83	(16)	5.08
Star (56-385)	0.95	0.76	1.04	(24)	3.79
Swan (56-781)	0.91	0.79	1.02	(9)	3.63
Twenty-one (56-728)	1.12	0.58	0.95	(6)	3.73
Wall (56-658)	0.50	0.32	0.39	(9)	0.75
West Battle (56-239)	0.35	0.70	1.07	(28)	7.22
West Lost (56-481)	0.92	1.67	1.76	(6)	4.61
West McDonald (56-386)	1.64	1.32	1.03	(7)	2.00
PINE COUNTY					
Grindstone (58-123)	0.50	1.02	1.06	(24)	2.72
Pokegama (58-142)	3.70	1.76	3.71	(21)	8.20
Sand (58-81)	1.81	1.17	1.41	(26)	5.99
Sturgeon (58-67)	0.60	0.43	0.92	(25)	4.04
Upper Pine (58-130)	0.65	0.46	0.63	(8)	1.18
POLK COUNTY					
Breeze (60-144)	1.37	0.85	0.95	(8)	3.65
Cable (60-293)	0.56	0.86	0.88	(9)	7.90
Cameron (60-189)	0.54	0.58	0.73	(8)	3.08
Cross (60-27)	1.59	0.94	1.45	(12)	3.46
Hill River (60-142)	1.02	0.46	0.99	(9)	1.94
Maple (60-305)	1.17	0.90	1.16	(24)	11.22
Poplar (60-6)	1.69	1.19	1.66	(9)	3.30
Sarah (60-202)	3.46	3.57	2.93	(12)	14.89
Spring (60-12)	0.64	0.82	0.86	(9)	2.35
Turtle (60-32)	1.77	0.90	1.31	(13)	4.18
Union (60-217)	2.07	3.11	1.53	(15)	8.55
POPE COUNTY					
Gilchrist (61-72)	2.38	1.30	2.15	(10)	4.44
Leven (61-66)	2.02	1.00	1.58	(7)	2.86
Linka (61-37)	0.60	0.76	0.86	(7)	1.61
Marlu (61-60)	0.92	0.60	0.95	(7)	1.75

Annual Lake Level Fluctuation (feet)

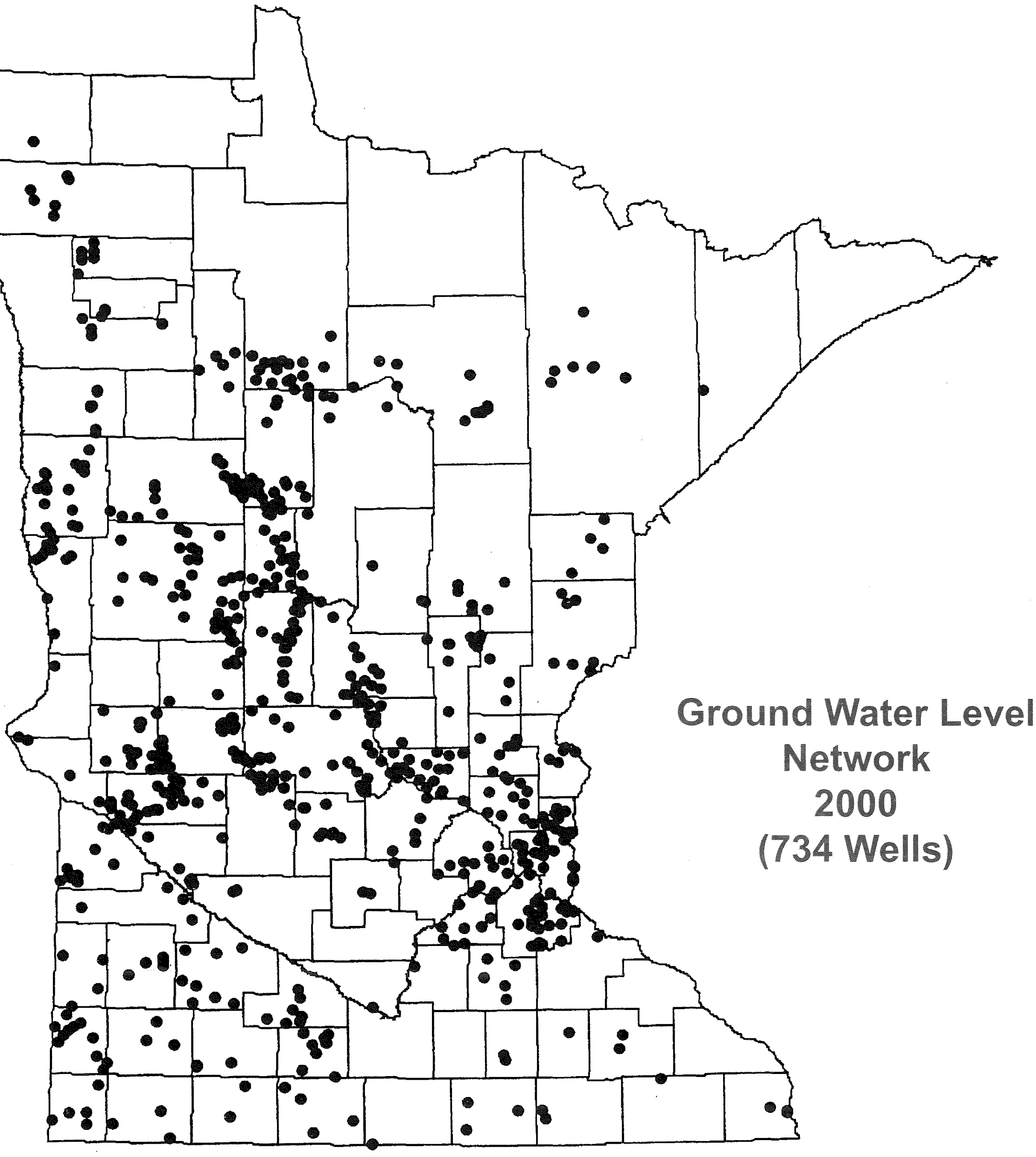
Lake Name	WY99	WY00	WYAv.	# Yrs.	Range
POPE COUNTY (cont):					
Minnewaska (61-130)	0.66	1.58	1.17	(56)	10.01
Villard (61-67)	1.73	0.80	1.57	(7)	3.33
RAMSEY COUNTY					
Bald Eagle (62-2)	0.88	0.59	1.27	(78)	6.88
Beaver (62-16)	0.98	1.28	1.95	(46)	7.10
Bennett (62-48)	1.83	3.17	2.85	(14)	6.60
RAMSEY COUNTY					
Birch (62-24)	0.87	1.23	1.32	(71)	7.13
Como (62-55)	1.14	2.40	1.67	(23)	4.19
Gervais (62-7)	1.08	1.40	2.15	(77)	7.20
Grass (62-74)	3.86	2.96	3.26	(19)	9.63
Island (62-75)	0.96	0.73	1.40	(55)	9.32
Johanna (62-78)	0.96	1.62	1.98	(78)	13.91
Josephine (62-57)	0.78	0.90	1.17	(77)	4.20
Long (62-67)	1.54	1.48	1.72	(77)	5.20
McCarron (62-54)	0.74	0.89	1.15	(77)	4.45
Owasso (62-56)	1.12	0.98	1.15	(77)	6.83
Phalen (62-13)	1.91	3.20	3.49	(77)	12.32
Pike (62-69)	0.94	1.75	1.38	(32)	4.57
Round (62-9)	1.84	2.32	2.00	(67)	11.67
Silver (East) (62-1)	1.05	0.99	1.71	(76)	10.05
Silver (West) (62-83)	1.01	1.43	1.72	(67)	13.25
Snail (62-73)	1.39	1.42	1.60	(77)	9.96
Turtle (62-61)	0.72	0.88	0.98	(78)	5.68
Valentine (62-71)	1.11	1.75	1.82	(76)	6.95
Wabasso (62-82)	1.33	1.10	1.40	(63)	5.53
Wakefield (62-11)	1.18	1.71	2.30	(48)	10.53
Willow (62-40)	0.62	0.92	1.00	(14)	2.01
RENVILLE COUNTY					
Allie (65-6)	1.05	0.94	1.25	(11)	8.28
Preston (65-2)	0.86	0.78	1.28	(8)	3.70
RICE COUNTY					
Cannon (66-8)	1.32	0.40	1.04	(7)	6.16
Cedar (66-52)	0.91	0.96	1.07	(13)	2.44
Circle (66-27)	0.73	1.98	1.64	(18)	8.92
Fox (66-29)	0.85	2.00	1.47	(19)	5.05
French (66-38)	1.32	1.42	1.10	(10)	5.05
Rice (66-48)	0.78	0.83	1.58	(15)	3.72
ST. LOUIS COUNTY					
Beaver (69-501)	0.99	0.56	0.83	(12)	2.88
Big Rice (69-669)	1.71	1.22	1.11	(11)	2.43
Birch (69-3)	1.66	1.58	3.09	(18)	5.57
Burntside (69-118)	1.12	0.70	0.98	(10)	4.76
Colby (69-249)	3.34	2.79	2.53	(35)	7.02
Comstock (69-412)	2.04	1.58	1.56	(7)	2.47

Lake Name	WY99	WY00	WYAv.	# Yrs.	Range
ST. LOUIS COUNTY (cont):					
Eagles Nest #1 (69-285)	2.00	1.24	0.81	(8)	3.10
Eagles Nest #2 (69-285)	2.00	1.24	0.81	(8)	3.10
Eagles Nest #3 (69-285)	1.18	0.89	0.82	(9)	1.41
Eagles Nest #4 (69-218)	0.35	0.20	0.42	(8)	0.97
Ely (69-660)	0.68	1.32	0.84	(47)	2.80
Island Lake Reservoir (69-372)	1.70	10.26	18.87	(25)	32.25
Jacobs (69-231)	1.66	1.04	0.77	(10)	2.31
Janette (69-887)	0.73	0.48	0.66	(8)	1.49
Little Stone (69-28)	0.30	0.70	0.77	(8)	2.99
Long (69-509)	0.70	1.54	0.98	(11)	2.24
Long (69-653)	1.02	0.61	0.78	(9)	1.47
Maple Leaf (69-700)	0.67	0.52	0.81	(10)	1.64
ST. LOUIS COUNTY					
Merrill (69-891)	0.58	0.53	0.67	(8)	1.38
Nichols (69-627)	0.47	0.80	0.66	(12)	1.71
Perch (69-932)	0.58	0.75	0.55	(10)	2.23
Prairie (69-848)	1.13	1.22	1.23	(17)	2.85
Sand (69-736)	0.68	0.42	0.66	(9)	1.55
Schubert (69-546)	1.00	0.41	1.00	(6)	2.13
St. Mary's (69-651)	2.15	0.92	1.22	(43)	4.57
Stone (69-27)	0.81	0.62	0.80	(11)	1.64
Stone (69-686)	2.36	1.28	1.17	(8)	3.01
Sturgeon (69-939)	2.60	1.57	1.52	(17)	3.00
Vermilion (69-378)	1.85	0.60	1.61	(50)	3.15
Wild Rice (69-371)	1.38	1.35	1.64	(6)	2.81
SCOTT COUNTY					
Cedar (70-91)	1.00	0.56	0.92	(7)	2.42
O'Dowd (70-95)	1.04	1.08	1.12	(8)	5.08
Spring (70-54)	2.16	1.44	1.58	(10)	2.86
Upper Prior (70-72)	2.74	1.27	2.31	(29)	12.20
SHERBURNE COUNTY					
Elk (71-141)	2.50	1.20	1.57	(6)	4.87
Long (71-159)	0.63	1.86	1.15	(9)	9.04
Rush (71-147)	1.49	0.52	1.54	(11)	5.37
STEARNS COUNTY					
Big (73-159)	1.16	0.76	1.29	(11)	5.20
Big Fish (73-106)	1.25	0.84	0.98	(24)	4.06
Big Watab (73-102)	0.82	0.60	0.73	(16)	1.90
Carnelian (73-38)	0.70	0.92	1.53	(9)	10.56
Eden (73-150)	2.68	0.82	2.41	(13)	10.38
Grand (73-55)	0.82	0.82	1.06	(20)	3.21
Horseshoe (73-157)	2.10	0.80	1.71	(15)	5.28
Koronis (73-200)	1.72	0.81	2.05	(20)	6.00
Long (73-4)	1.45	1.36	1.24	(8)	3.38
Pearl (73-37)	0.46	0.32	0.69	(15)	3.70
Rice (73-196)	2.79	1.33	3.03	(15)	6.94

Annual Lake Level Fluctuation (feet)

Lake Name	WY99	WY00	WYAv.	# Yrs.	Range
STEVENS COUNTY					
Long (75-24)	0.60	0.71	1.34	(21)	7.48
Page (75-19)	0.88	1.01	1.43	(21)	8.08
Perkins (75-75)	0.26	1.13	1.27	(18)	4.86
SWIFT COUNTY					
Camp (76-72)	1.44	2.28	1.78	(6)	4.42
Oliver (76-146)	1.41	4.05	1.32	(6)	18.91
TODD COUNTY					
Beauty (77-35)	0.84	0.73	0.75	(7)	2.40
Big (77-63)	1.22	0.72	0.89	(8)	1.61
Big Birch (77-84)	0.92	0.90	1.01	(24)	3.03
Big Birch,HW (77-84)	0.80	0.68	0.68	(10)	1.48
Fairy (77-154)	0.83	1.64	1.22	(12)	9.91
Little Birch (77-89)	0.75	0.48	1.01	(21)	3.39
Long (77-27)	0.70	0.40	0.73	(8)	1.80
Maple (77-181)	1.44	0.60	1.29	(12)	2.61
Mound (77-7)	0.39	0.54	0.58	(8)	0.94
Osakis (77-215)	0.42	0.70	1.51	(40)	7.39
Sauk (77-150)	1.88	0.72	1.74	(18)	5.20
WADENA COUNTY					
Hazel (80-5)	0.94	1.01	0.92	(21)	3.33
Stocking (80-37)	0.50	0.47	0.55	(13)	1.52
WASHINGTON COUNTY					
Bass (82-35)	2.61	1.42	1.48	(6)	3.75
Battle Creek (82-91)	1.46	0.85	1.36	(11)	3.02
Big Carnelian (82-49)	0.66	0.47	1.28	(24)	14.26
Big Marine (82-52)	1.10	0.61	1.00	(27)	7.10
Bone (82-54)	1.20	0.78	1.25	(20)	4.27
Carver (82-166)	1.47	0.75	1.43	(10)	3.21
Clear (82-163)	1.18	0.71	1.14	(27)	3.54
Cloverdale (82-9)	1.52	1.42	2.21	(7)	9.21
DeMontreville (82-101)	1.00	0.73	1.47	(33)	6.40
Downs (82-110)	1.21	1.81	2.52	(19)	7.73
WASHINGTON COUNTY (cont):					
Eagle Point (82-109)	1.28	0.81	2.16	(26)	7.40
Egg (82-147)	0.34	0.26	0.79	(11)	3.41
Elmo (82-106)	0.64	0.43	1.23	(26)	9.58
Forest (82-159)	0.38	0.62	0.74	(26)	2.78
Goose (82-59)	0.92	1.75	1.38	(7)	6.00
Halfbreed (82-80)	0.86	0.72	0.95	(11)	2.92
Horseshoe (82-74)	0.39	0.36	1.72	(23)	15.74
Jane (82-104)	0.54	0.27	1.63	(33)	8.99
Lily (82-23)	1.53	2.13	1.43	(6)	11.98
Little Carnelian(82-14)	1.49	1.72	3.75	(9)	35.17
Long (82-118)	3.64	1.78	3.25	(27)	10.34
McDonald (82-10)	0.62	0.96	1.03	(7)	3.92
Mud (82-26)	0.50	0.35	0.67	(6)	1.80
Oneka (82-140)	0.27	1.19	0.95	(22)	4.13
Square (82-46)	0.47	0.22	0.72	(24)	5.34
Sunfish (82-107)	0.62	1.43	1.59	(26)	18.15
Sunnybrook (82-133)	1.62	1.24	1.90	(8)	3.40
Sunset (82-153)	1.28	1.11	1.13	(7)	2.70
Tanners (82-115)	0.66	1.25	1.27	(10)	2.80
Turtle (82-36)	0.76	0.64	1.04	(7)	3.41
West Boot (82-44)	0.59	0.53	0.73	(6)	2.78
White Bear (82-167)	0.94	1.24	1.17	(84)	7.07
WATONWAN COUNTY					
Fedji (83-21)	0.52	2.28	1.04	(10)	4.19
WRIGHT COUNTY					
Augusta (86-284)	1.06	0.56	0.99	(7)	2.85
Birch (86-66)	1.01	1.34	1.15	(8)	6.19
Charlotte (86-11)	0.50	1.47	1.39	(16)	8.68
Collinwood (86-293)	0.90	0.90	0.93	(6)	3.88
Indian (86-223)	0.52	1.12	1.49	(15)	9.76
Maple (86-134)	1.44	1.22	1.20	(15)	5.34
Pelican (86-31)	0.69	0.47	0.57	(6)	8.00
Sugar (86-233)	1.20	0.86	0.77	(24)	4.34
Sylvia (86-289)	0.96	0.32	0.87	(22)	3.65

Chapter Three GROUND WATER



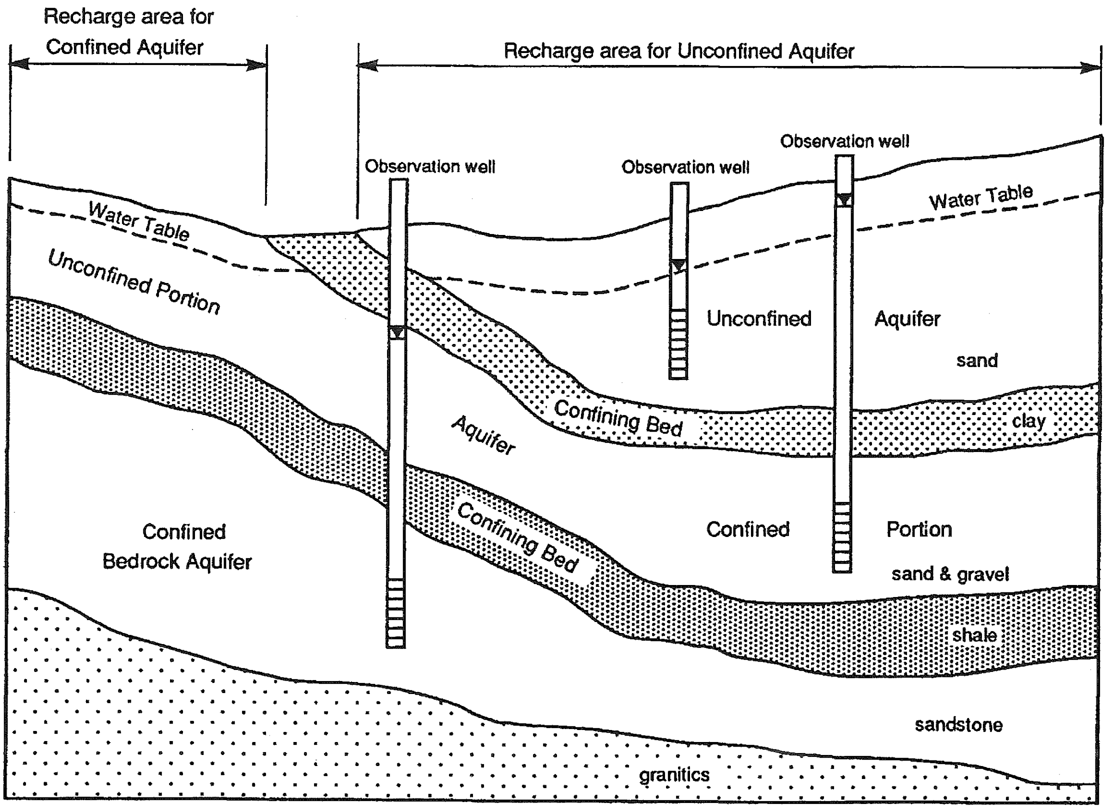
Introduction

Monitoring of ground water levels in Minnesota began in 1942 and, starting in 1947, was expanded by a cooperative program between the DNR and the United States Geological Survey (USGS). In Water Year 1999, the participation of the USGS ended.

The number of observation wells (obwells) has remained constant at about 700 obwells over the last few water years. Data from these wells are used to assess ground water resources, determine long term trends, interpret impacts of pumping and climate, plan for water conservation, evaluate water conflicts and otherwise manage the water resource. Soil and Water Conservation Districts (SWCD) under contract with DNR Waters measure the wells monthly and report the readings to DNR Waters. Readings are also obtained from volunteers at other locations.

Figure 1

Hypothetical Unconfined and Confined Aquifer Systems



Aquifers

An aquifer is a water-saturated geologic formation which is sufficiently permeable to transmit economic quantities of water to wells and springs. Aquifers may exist under unconfined or confined conditions (Figure 1).

UNCONFINED AQUIFERS - In an unconfined aquifer, the ground water surface that separates the unsaturated and saturated zones is called the water table. The water table is exposed to the atmosphere through openings in the overlying unsaturated geologic materials. The water level inside the casing of a well placed in an unconfined aquifer will be at the same level as the water table. Unconfined aquifers may also be called water table or surficial aquifers.

For most of Minnesota, these aquifers are composed of glacial sand and gravel. Their areal extent is not always well defined nor is their hydraulic connection documented. They are often locally isolated pockets of glacial outwash deposited over an area of acres to square miles. Recharge to these units may be limited to rainfall over the area of the aquifer or augmented by ground water inflow. Consequently, care must be taken in extrapolating water table conditions based upon the measurements of a single water table well.

CONFINED AQUIFERS - When an aquifer is separated from the ground surface and atmosphere by a material of low permeability, the aquifer is confined. The water in a confined aquifer is under pressure, and therefore, when a well is installed in a confined aquifer, the water level in the well casing rises above the top of the aquifer. This aquifer type includes buried drift aquifers and most bedrock aquifers.

Buried drift aquifers are composed of glacially deposited sands and gravels, over which a confining layer of clay or clay till was deposited. Their areal extent and hydraulic connections beneath the ground surface are often unknown; therefore, an obwell placed in one of these units may be representing an isolated system. Ground water investigations involving buried drift aquifers require considerable effort to evaluate the local interconnection between these aquifer units.

Bedrock aquifers are, as the name implies, geologic bedrock units which have porosity and permeability such that they meet the definition of an aquifer. Water in these units is either located in the spaces between the rock grains (such as sand grains) or in fractures within the more solid rock. While these aquifers can be unconfined, the ones measured in the obwell network are generally bounded above and below by low-permeability confining units. Unlike buried drift aquifers, bedrock aquifers are fairly well defined in terms of their areal extent and the units are considered to be connected hydrologically throughout their occurrence.

Seasonal climatic changes affect the water levels in aquifer systems. Recharge, which is characterized by rising water levels, results as snow melt and precipitation infiltrate the soil and percolate to the saturated zone. Drawdown, characterized by the lowering of water levels, results as plants transpire soil water, ground water discharges into lakes, springs and streams, and/or well pumping withdraws water from the aquifer. An unconfined aquifer generally responds more quickly to these changes than a confined aquifer since the water table is in more direct contact with the surface. However, the magnitude of change in water levels will usually be more pronounced in a confined aquifer.

The remainder of this chapter discusses the ground water levels in unconfined and confined aquifers during Water Years 1999 (WY99) and 2000 (WY00). This discussion focuses on a comparison of water levels in WY99 and WY00 to the water levels over the period of record for the observation wells analyzed in this report. The water levels for these two water years are presented for each month in the context of the median reading, highest and lowest reading and quartiles of all previous readings in each month. (See sidebar on page 44 for expanded explanation.) To achieve meaningful comparisons, representative obwells were chosen from the network based on their length of record and their geographical location. Such periods of record are generally from 15 to 30 years, with the shortest being 10 years and a few as long as 38 years.

During WY99 and WY00, the DNR monitored water levels in approximately 700 wells throughout the state. Water levels are usually recorded monthly except for January and February. Figures 2, 3 and 4 show the locations of these wells, identifying those that were placed in unconfined (water table) aquifers, in buried drift aquifers and in bedrock aquifers.

Figure 2 Water Table Observation Wells

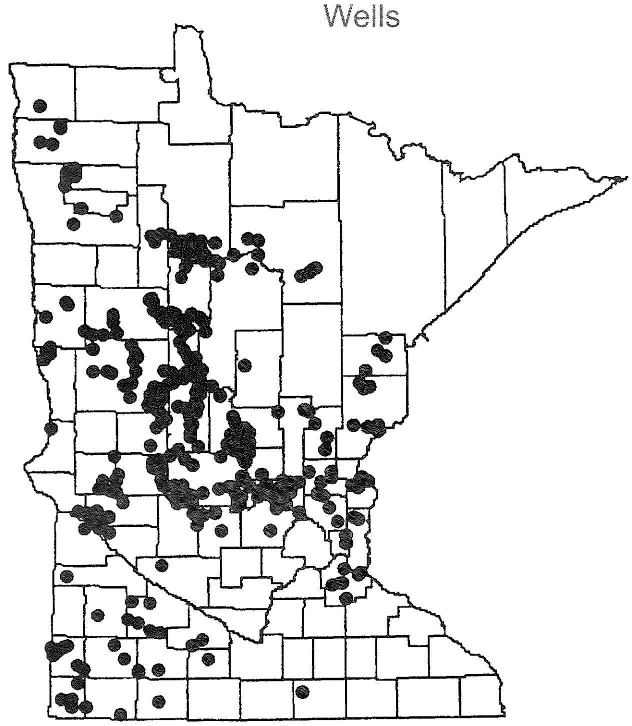


Figure 3 Buried Drift Observation Wells

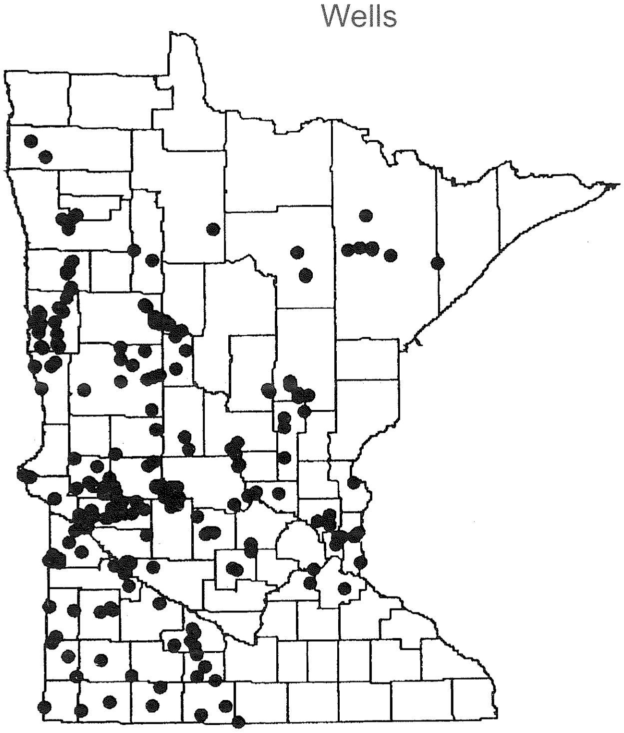
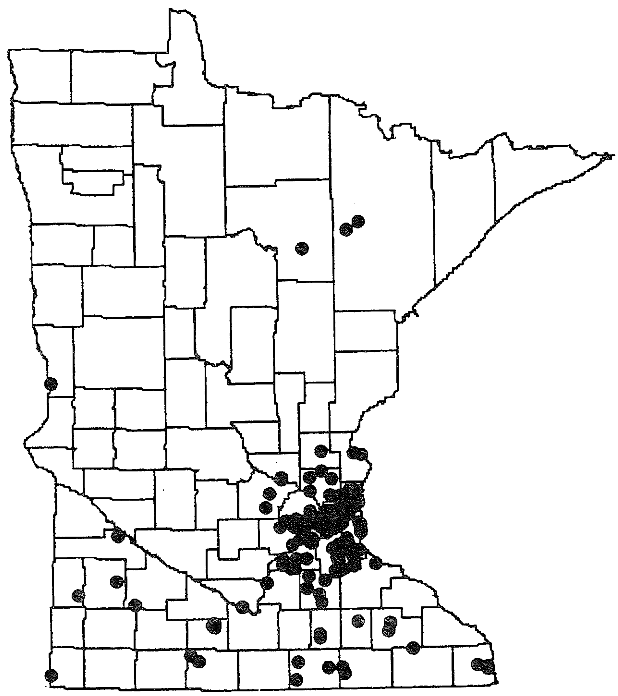


Figure 4 Bedrock Observation Wells

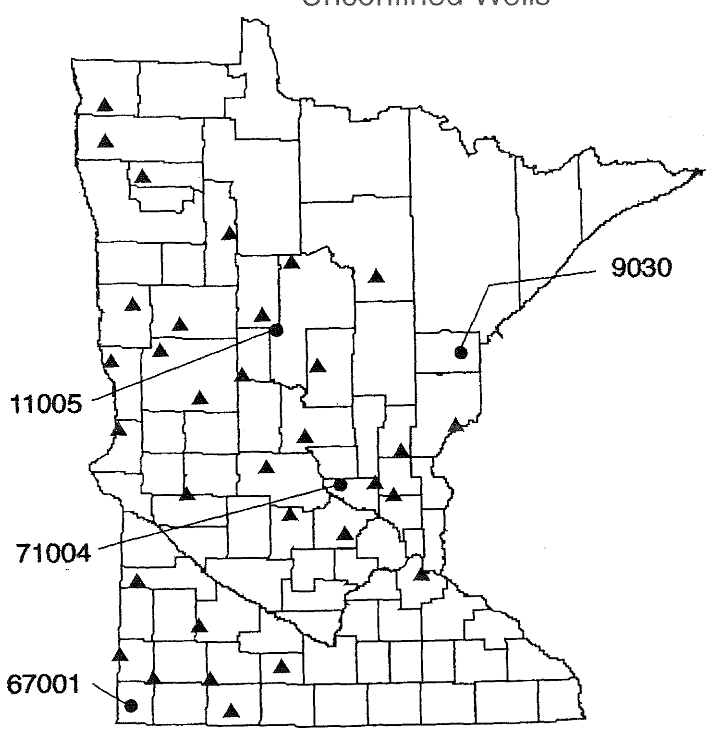


Statistical Analyses

Water levels are presented, for selected observation wells, as hydrographs superimposed over a set of descriptive statistics. Statistics used in these comparisons are computed for the appropriate month using data over the period of record preceding WY99. For each well, all existing data prior to this summary's period were statistically processed to provide, for each month, the median water level value, the 25th and 75th percentile water level, and the maximum and minimum recorded water level. The spread of values between the 25th and 75th percentile represent the range of water levels in which 50% of the previously measured water levels would be found. Median water levels were used instead of mean (average) water levels, because, for these data, the median provides a better estimate of the central tendency of the data.

The accompanying hydrographs indicate the measured and statistical depth to water from the ground surface. When plotted as they are with negative values, these depths reflect water levels and behave accordingly. As water levels rise in a well, points on the graph also rise toward the surface datum. On the statistical hydrographs, quartiles are plotted and identified as Q1 and Q3. In a statistical interpretation relative to water levels, Q1 represents the 75th percentile water level (a high level) and Q3, the 25th percentile water level (a low level). One fourth of all measured water levels were below Q3 and one-fourth were above Q1.

Figure 5 Location of Representative Unconfined Wells



Unconfined Aquifers (Water Table)

While drainage from an unconfined aquifer continues throughout the winter, recharge is restricted. In general, winter precipitation is stored as snowpack and frozen soil prevents or slows the infiltration and percolation of spring snow melt. By the end of winter, water tables would be expected to be at a low point. As the soil thaws and spring rains occur, the water table aquifers are recharged, resulting in the higher water tables.

The approximate location of the water table wells used in this report are shown in Figure 5. The wells identified by number are also the subject wells in Figures 6A and 6B. Figure 6A on page 46 illustrates hydrographs for several obwells showing water levels in WY99 and WY00 compared to analyses of data over the preceding period of record. Figure 6B on page 47 shows the standard hydrographs for the same wells over the entire period of record.

The representative unconfined obwells are roughly grouped according to precipitation patterns observed during WY99 and WY00. These precipitation patterns are shown in Figures 5 and 14 (pages 5 and 12) of the Climatology Chapter. The wet area stretched from the northwest corner of the state south to Lac Qui Parle County. Portions of those western counties from Clay and Becker to Lac Qui Parle were very wet. In WY99 there was also a wet area from the central and southern Twin Cities metro area into northern Rice and Goodhue Counties, which became dryer in WY00. Dry encompasses much of the state from the middle of Itasca and St. Louis Counties extending southwest in a wide band to the southwestern corner of the state.

"Wet" area — Unconfined water table wells in this area reflect the precipitation excess throughout this period, especially in WY99. In some instances water levels were the highest on record, although normal seasonal fluctuations were observed. Water levels remained high in WY00, but showed some decline toward the end of the year.

Comparison of the WY99 water levels to the analyzed historical record shows that water levels in the west and northwest were above the median and often in the upper quartile. In the center of the state, there was no discernable trend except that water levels declined from above the median in mid-WY99 to below median at the end of WY00.

"Dry" area — Unconfined water table wells in this area reflect the precipitation deficit throughout this period. Water levels in the dry area were generally elevated during the winter of WY00, but dropped during the following summer. Water levels in the center of the dry area were similar to those of the very dry period from WY89 to WY91.

When compared with analyzed water levels for the period of record preceding WY99, water levels in the summer of WY00 often fall below the 25th percentile and, in some instances, near the lowest levels recorded. During the earlier portions of this period, water levels were generally within the 25% to 75% range, but most often below the median.

Figure 6A. Unconfined (Water Table) Obwells: Historical monthly statistics compared to WY 1999 and WY 2000 readings.

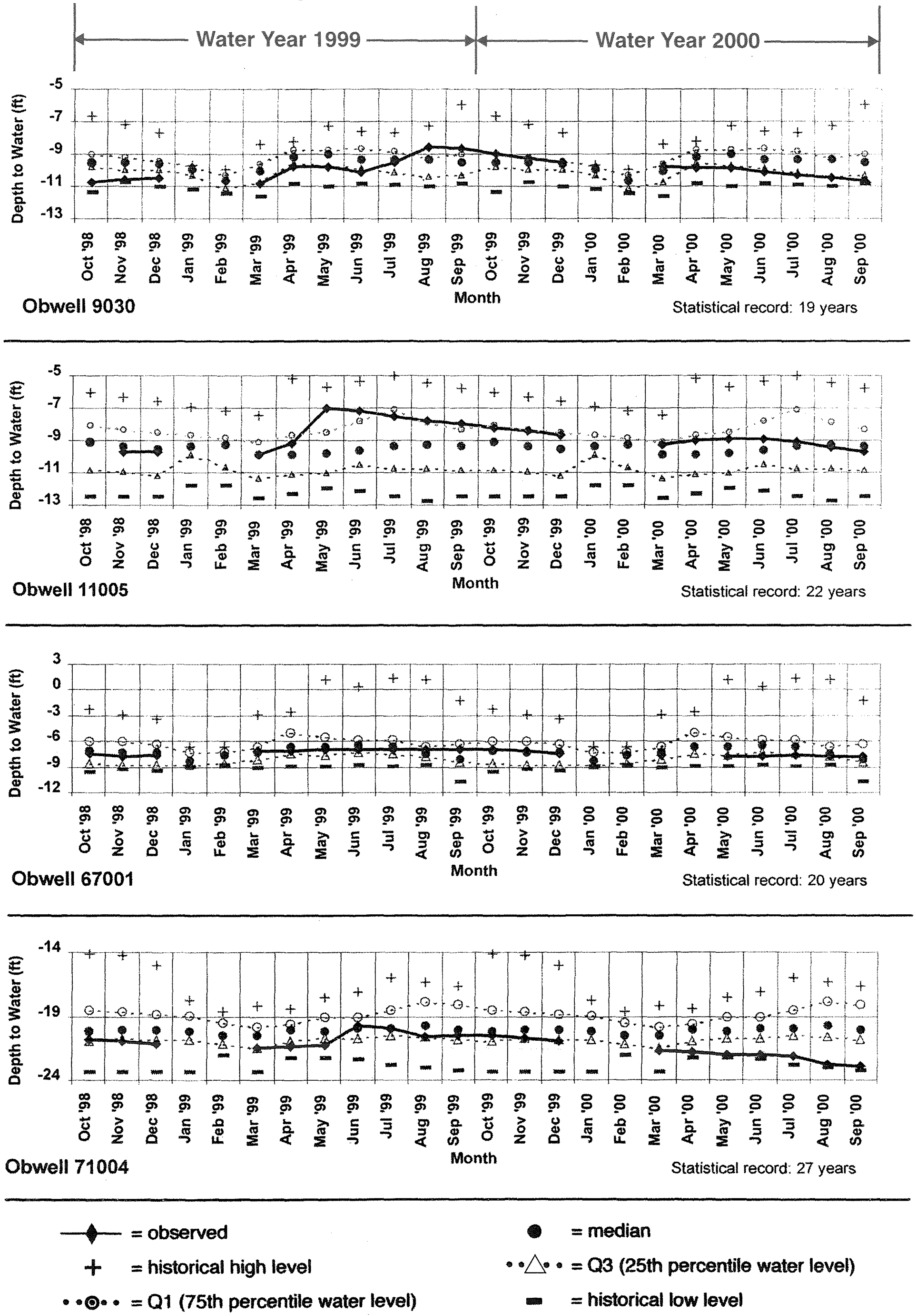
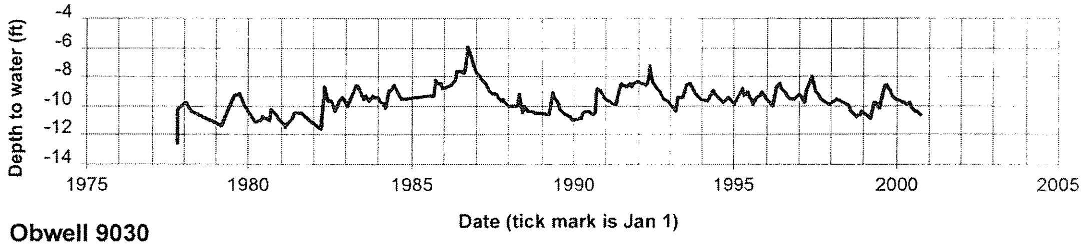
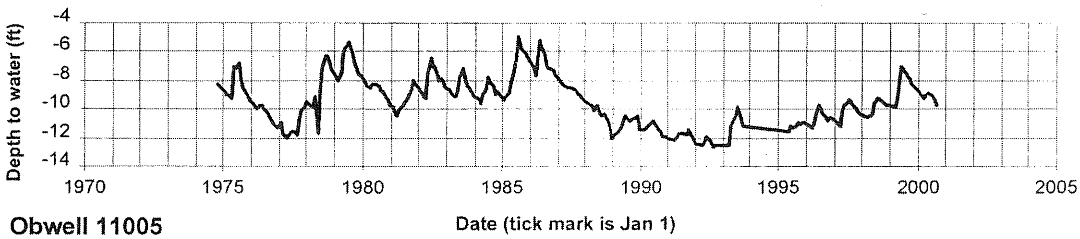


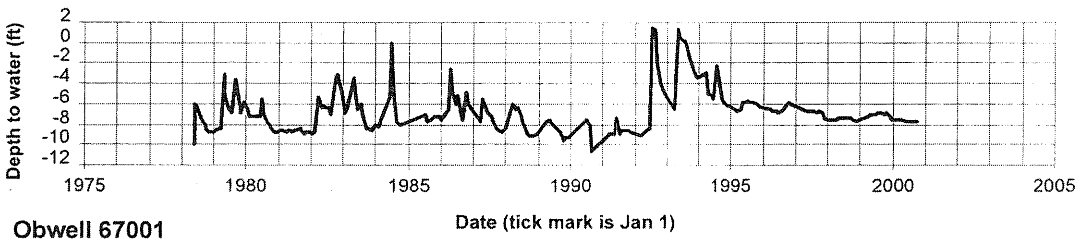
Figure 6B. Unconfined (Water Table) Obwells: Water levels for the entire period of record.



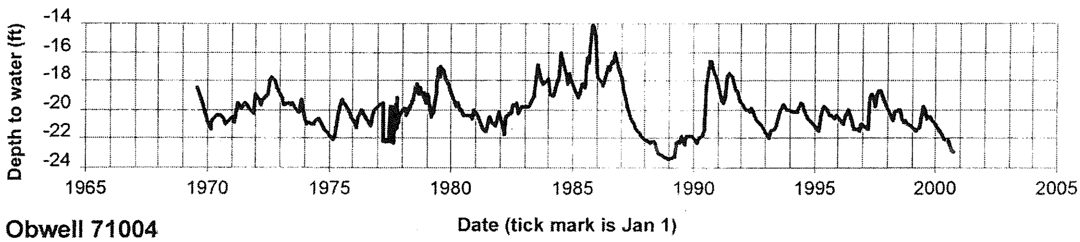
Obwell 9030



Obwell 11005



Obwell 67001



Obwell 71004

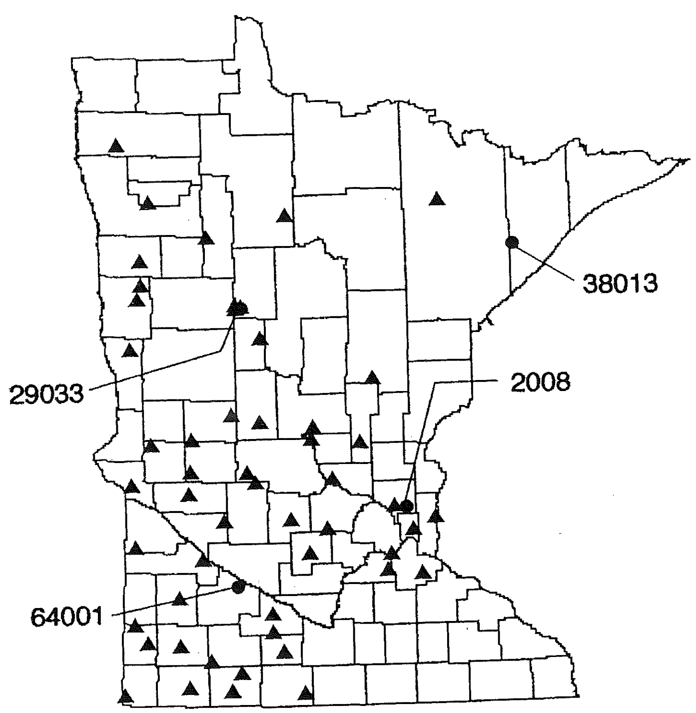
Confined Aquifers

Confined buried drift and bedrock aquifers are not separated according to precipitation patterns in this summary. Usually, changes in precipitation patterns are not reflected in confined aquifers until after the extreme (dry or wet) precipitation pattern has been in existence for an extended period or has ended. This is due primarily to the presence of an overlying confining bed which inhibits a direct response to the precipitation pattern.

Buried Drift Aquifers

Under confined conditions, these aquifers generally respond more slowly to seasonal inputs from snowmelt and precipitation than water table aquifers. However, buried drift aquifers can be near the surface with their extent poorly defined and with some connection to adjacent unconfined aquifers. As a result, response of buried drift aquifers to recharge is determined by individual characteristics. The response is therefore difficult to predict.

Figure 7 Location of Representative Buried Drift Wells



The approximate location of the buried drift wells used in this summary are shown in Figure 7. The wells identified by number are also the subject wells in Figures 9A and 9B. Figure 9A on page 50 illustrates hydrographs for several obwells showing water levels in WY99 and WY00 compared to analyses of data over the preceding period of record. Figure 9B on page 51 shows the standard hydrographs of these same wells over the entire period of record.

For the state as a whole, a downward trend in buried drift water levels is evident toward the end of WY00.

In the northeast, buried drift aquifer water levels were higher in WY00 than WY99. In WY99, these levels were below the 25th percentile but rose to near the median between the 25th and 75th percentile by WY00.

Buried drift levels in the Twin Cities Metro area responded similarly to those of the water table aquifers in the same area. In the southeast, Dakota County buried drift levels in WY 99 were well above the median and, in a few instances, were the highest recorded in a particular month. These levels show a downward trend in WY00. In Anoka County on the northern edge of this area, buried drift water levels were well below the median, dropping into the first quartile. These water levels dropped throughout both water years and ended near the lowest levels on record.

In northwestern Minnesota, buried drift water levels were generally above the median and occasionally above the 75th percentile. In areas which experienced very wet conditions, buried drift water levels were near or above the highest recorded level. Even at these high levels, a slight downward trend is discernable from WY99 to WY00.

From central Minnesota to the southwestern corner of the state, buried drift water levels generally were below the median. Toward the end of WY00 these levels had an apparent downward trend and had dropped into the lowest percentile.

Bedrock - Prairie du Chien-Jordan Aquifer

The Prairie du Chien-Jordan aquifer is usually considered to be in a confined condition, however, locally it may respond as an unconfined aquifer. Examples of this would include situations where the aquifer is adjacent to unconfined materials, where buried glacial valleys intersect the aquifer or where the aquifer is the first bedrock under surficial unconfined sands.

Locations of the Prairie du Chien-Jordan wells used in this report are shown in Figure 8. Wells identified by number are those wells for which hydrographs are shown in the figures that follow. Prairie du Chien-Jordan water levels tended to decline slightly through WY99 and WY00. However, no aquifer-wide trend can be discerned when the WY99 and WY00 water levels are compared to the analyzed historical records, except that levels in these years seem to be at the extremes, either below the 25th or above the 75th percentiles. Figure 10A on page 52 includes a comparison of the analyzed historical records with the actual readings for WY99 and WY00 for selected wells. Figure 10B on page 53 shows hydrographs over the period of record for selected wells.

Bedrock - Mt. Simon Aquifer

With some exceptions, the Mt. Simon is a confined aquifer. It may respond as an unconfined aquifer in the atypical instances where the aquifer is adjacent to unconfined materials, such as along deeply incised buried glacial valleys.

Locations of the Mt. Simon wells used for this summary are shown in Figure 8. The wells identified by number are also the subject wells in the hydrographs that follow. Figure 11A on page 54 presents a comparison of WY99 and WY00 readings with the analyzed historical record for several Mt. Simon aquifer wells in this report. Figure 11B on page 55 shows the standard hydrographs for these selected wells over their entire period of record. Water levels in the west and southwest were below the median for these wells; in the southeast were above the median and, in several months, were the highest on record; and in the north, water levels were above the median in some months. Obwell 70002, located near Savage, MN has been experiencing a decline in water levels since 1980. Several readings in Obwell 70002 for WY99 and WY00 established new record low levels and most were below the 25th percentile, however, these readings appear to have a very slight upward trend over the two water years.

Figure 8 Location of Representative Mt. Simon and Prairie du Chien-Jordan Wells

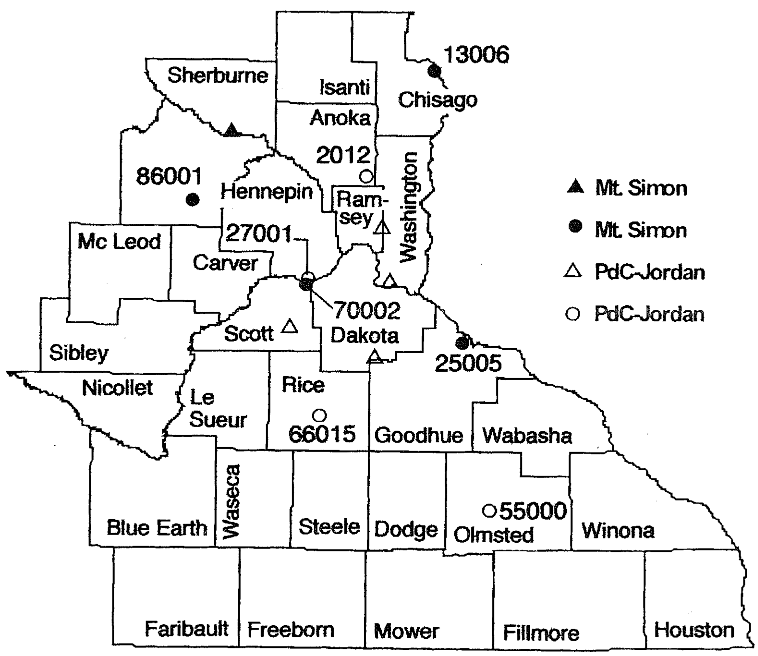


Figure 9A. Buried Drift Obwells: Historical monthly statistics compared to WY 1999 and WY 2000 readings.

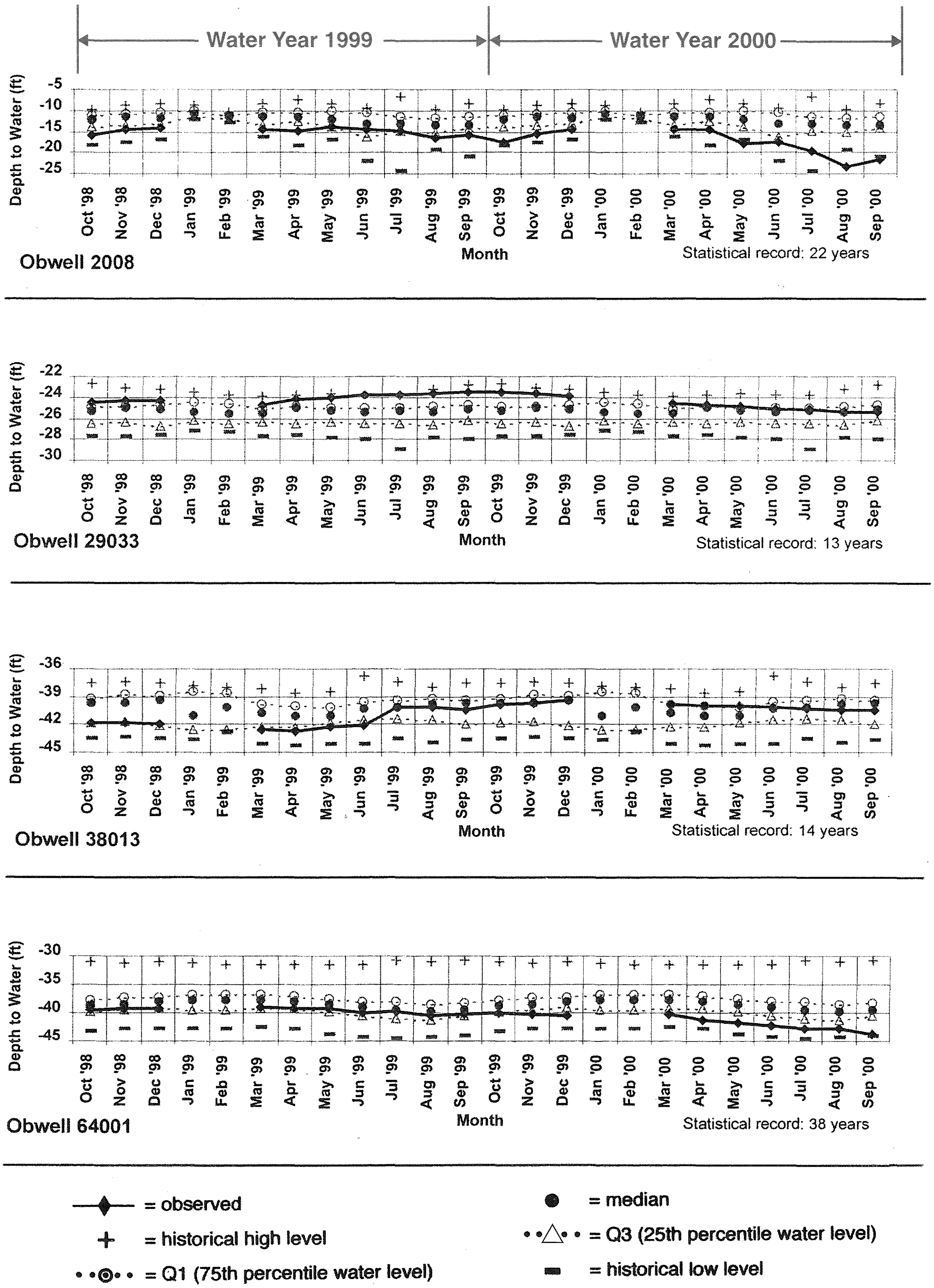
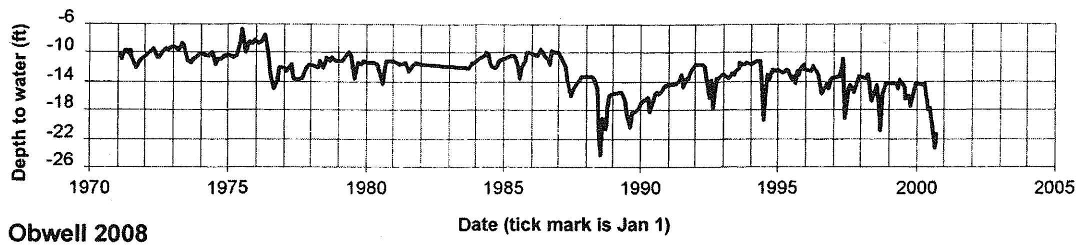
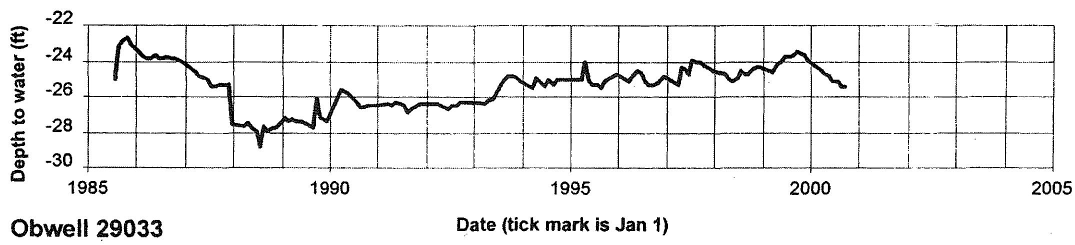
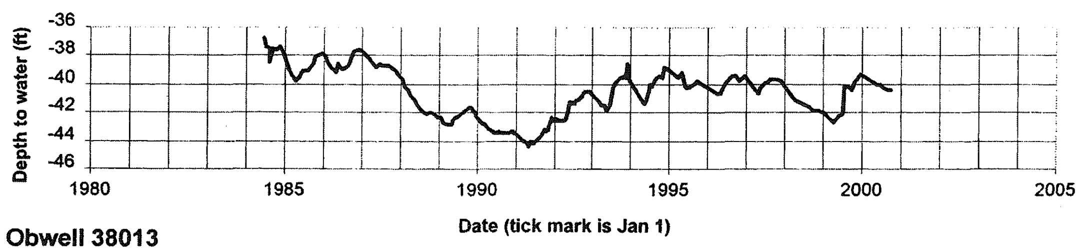


Figure 9B. Buried Drift Obwells: Water levels for the entire period of record.







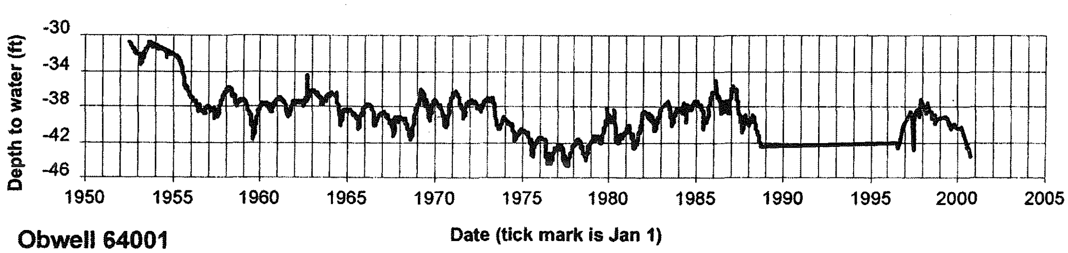


Figure 10A. Prairie du Chien- Jordan Bedrock Obwells: Historical monthly statistics compared to WY 1999 and WY 2000 readings.

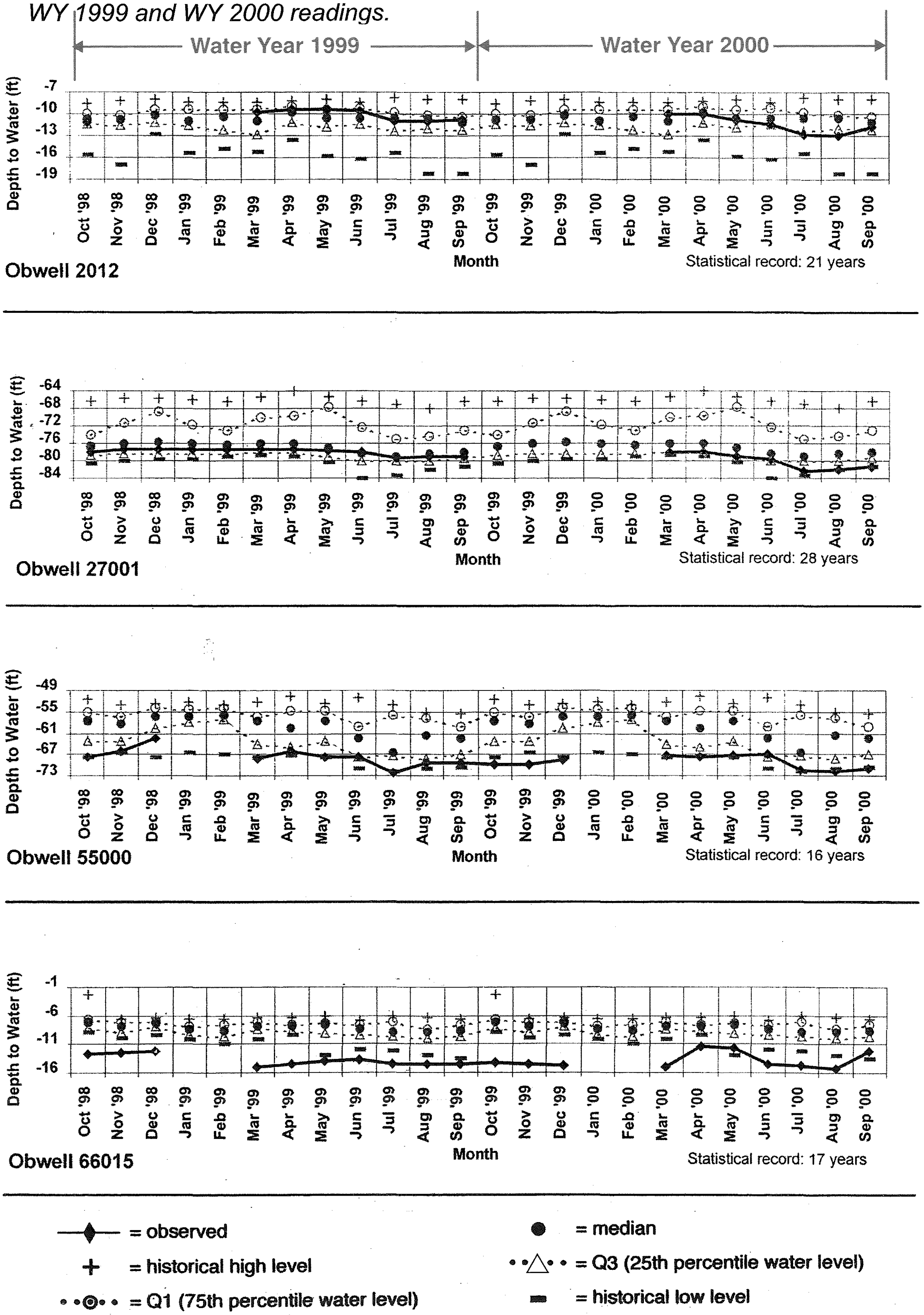
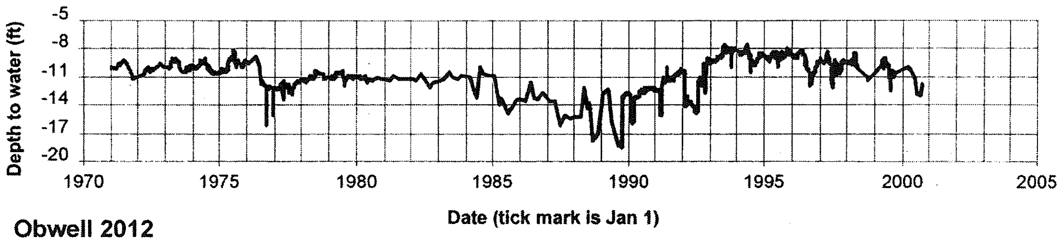
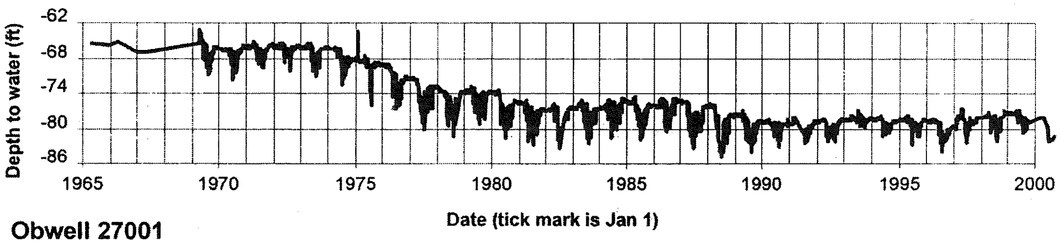
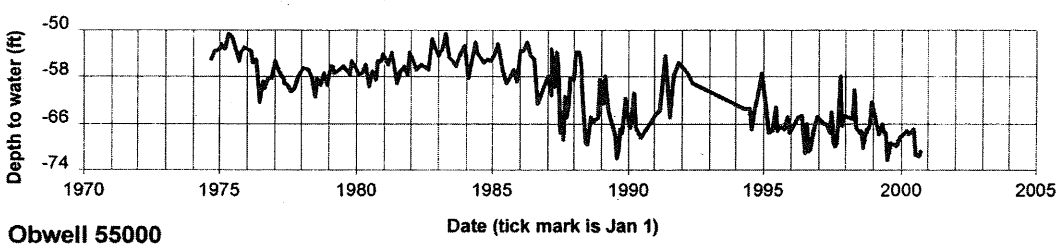


Figure 10B. Prairie du Chien- Jordan Bedrock Obwells: Water levels for the entire period of record.







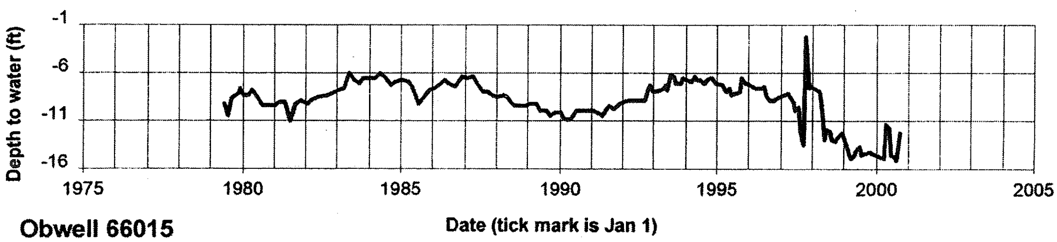


Figure 11A. Mt. Simon Bedrock Obwells: Historical monthly statistics compared to WY 1999 and WY 2000 readings.

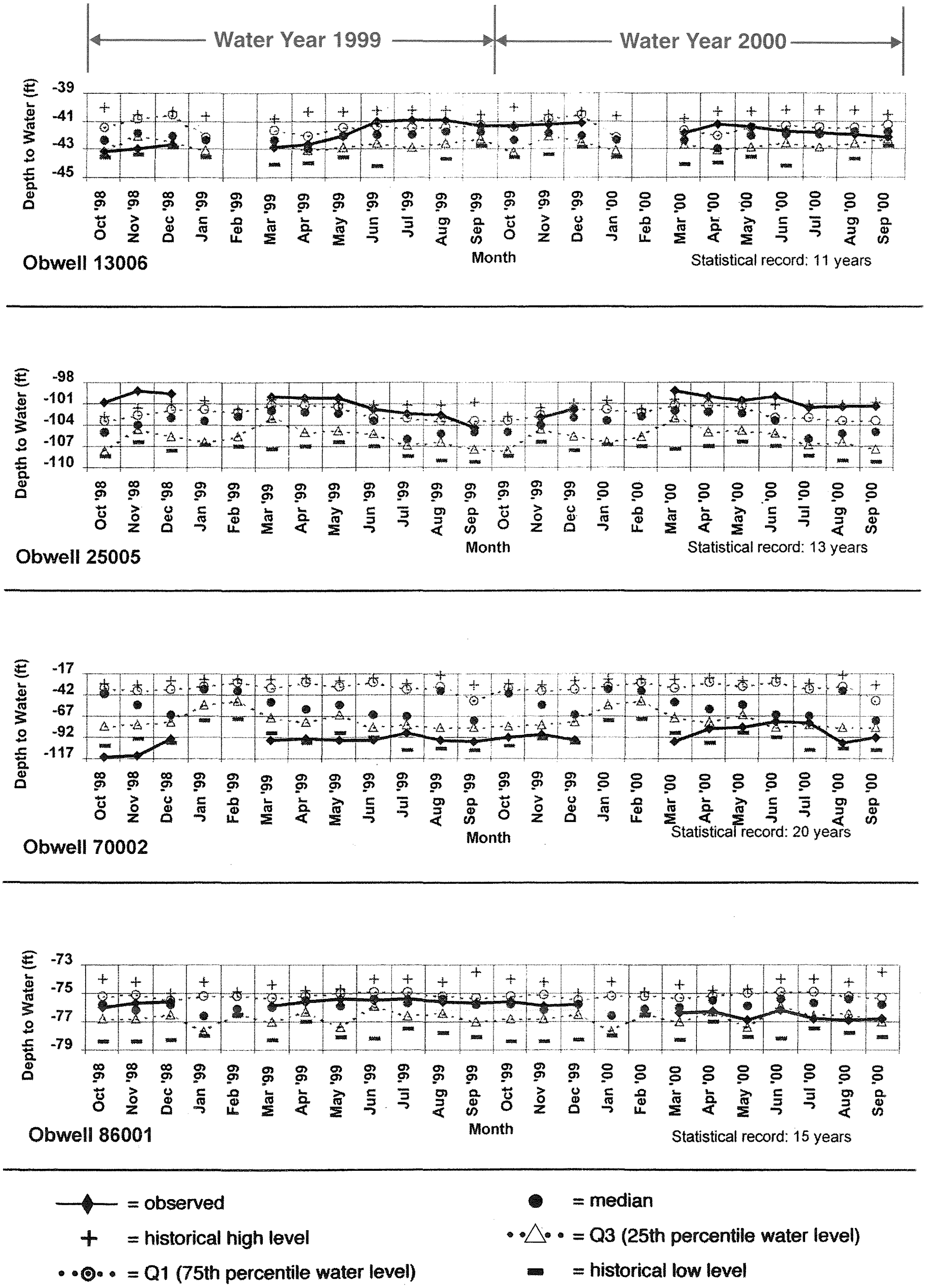
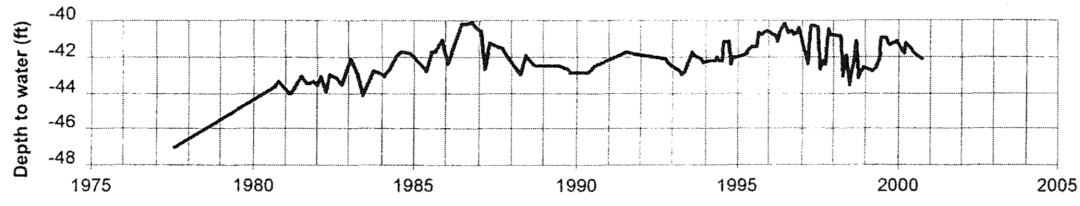
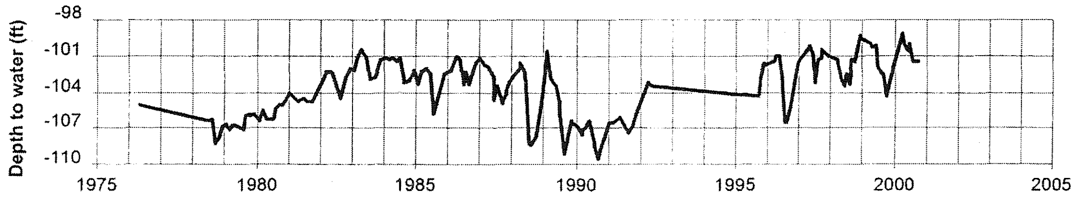


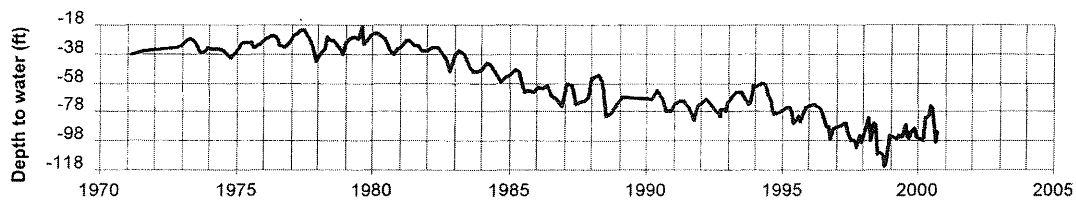
Figure 11B. Mt. Simon Bedrock Obwells: Water levels for the entire period of record.



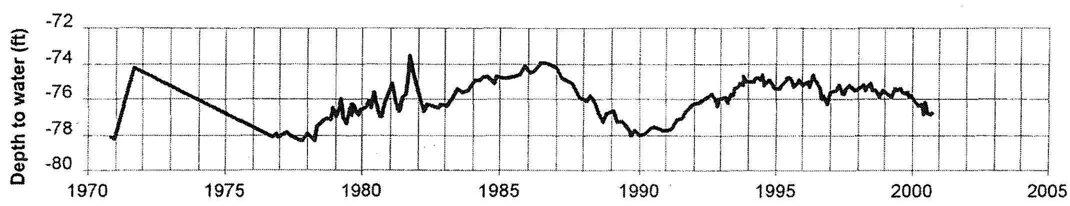
Obwell 13006



Obwell 25005



Obwell 70002



Obwell 86001

Ground Water Level Network Improvement

A systematic review of each obwell has been implemented and will involve a visit to each site by DNR hydrogeologists. When feasible, physical tests such as slug tests and gamma logging will be performed in order to confirm the quality and usefulness of the obwell within the network. Although around 700 obwells are actively monitored, the database contains some information for nearly twice that many sites. The fate of inactive obwells will be determined so that appropriate management actions can occur. The review of each county or aquifer will include an analysis of the coverage and water levels, which could result in a change of monitoring frequency or obwell distribution. This review will take several years to complete.

The DNR Waters program of exploratory drilling and observation well installation continued in the southwest and west central regions, with several test holes and a few obwells being installed. In anticipation of continued industrial growth, two obwells were installed near the City of Renville in Renville County. Test holes were drilled in Yellow Medicine and Chippewa Counties, while two obwells were added in Washington County to monitor the effect of development on ground water levels around the City of Stillwater. DNR Waters, in cooperation with the Minnesota Pollution Control Agency, replaced a number of shallow (less than 50 deep) wells which were lost due to a variety of circumstances such as inadvertent sealing, road construction and land owner decisions to eliminate wells from their property.

The vibrating wire piezometer, a technology used in civil engineering, has been adapted to monitor ground water levels. Basically, a transducer is placed at the desired depth in a borehole or well and is sealed in place. Measurements are then taken at the ground surface using a computer and a data logger. This technique was first used by DNR Waters in WY99 to continue the record of a Mt. Simon aquifer obwell which was sealed due to development. This technique has also been used for a Franconia/Ironton/Galesville well, sealed by the property owner, so that a new monitoring point has been added to the network. The technology holds great promise for enhancement of ground water level monitoring.

all ground water monitoring is not the same...

What is a ground water level observation well?

Ground water levels may be obtained from wells that are drilled for the exclusive purpose of measuring ground water levels. They are just as likely though to be obtained from other types of wells or piezometers, which are or were used for some other purpose. For instance, some ground water level observation wells (obwells) are large diameter municipal water supply or irrigation supply wells. Others are or were smaller diameter domestic supply wells. And yet other wells were installed as part of an aquifer study or a ground water quality study of an area of specific interest. Instead of drilling new wells, existing wells are incorporated into the ground water level network whenever possible if the existing well meets the specifications for well construction and if the existing well is in a location where ground water levels are needed.

Minnesota Statutes and Rules contain the well code that the Minnesota Department of Health uses to determine the type of well construction needed for a particular well use. For at least the last eleven years, wells for the ground water level network were installed by DNR Waters to higher construction standards than the well code requires so that these wells may also be used by other agencies for water quality monitoring (water withdrawn).

Why isn't all ground water monitoring for both water quality and water levels completed at the same well at the same time?

Many differences in the location, construction, measurement technique and purpose exist between ground water quality monitoring wells and ground water level observation wells. A water level taken at a water quality monitoring well may not be useful for the study of ground water levels and the requirements for obtaining useable water quality samples are often not compatible with the needs for ground water level data. Why? There are several reasons...

• Location - Obwells are usually located away from points of pumping influence in order to monitor the general water level of the aquifers although obwells may also be placed near points of appropriation for compliance monitoring. Much water quality monitoring is done in relation to a point of contamination or at a statistically based location for background water quality monitoring (that is wells to be sampled are selected on a location grid regardless of the aquifer). If an obwell happens to match the statistical location, that obwell may be used for water quality sampling. Most often though, the location where ground water level data is needed is seldom where water quality data is wanted. DNR Waters avoids using contaminated wells for ground water level measurement in order to avoid health risks.

• Quality control - Although DNR Waters assembles ground water level data collected by many sources, obwell data collected by the SWCDs is separated from water level data collected by others because we cannot be certain of the measurement method used by others. Water quality sampling is even more exacting. Persons taking water quality samples must be trained in the quality control methods that are applicable and must be trained about the health risks associated with contaminated water.

• Well construction -

- materials: Water quality is affected by well construction. PVC, which is used for most new obwells, can t be monitored for some chemicals because of interference from the PVC or the glue used. On the other hand, steel may be inappropriate for other water quality parameters.
- diameter: Many shallower obwells are 2" or less in diameter. It can be difficult to obtain water quality samples from many such small diameter wells. The deeper obwells that DNR Waters drills are usually constructed of 4" steel. Because DNR Waters ground water level wells are constructed to a higher standard than is required, other agencies may use these wells for water quality monitoring; however, those wells may not be at a location where water quality monitoring is needed.
- screen: The screen of ground water level wells is usually placed as deep into an aquifer as feasible in order to always have a water level if the ground water level of the aquifer drops. However, for some water quality monitoring, such as for nitrates, the screen is set right at the existing water level in order to detect the substance of interest as it reaches the water table.

• Frequency and trip saving- Water level readings are generally taken once per month and sometimes more frequently. Water quality samples are collected much less frequently, perhaps once or twice per year. Fifteen to twenty or more water levels can be taken in one day depending on distance between the wells, but the number of wells from which water quality samples can be taken in a day is considerably less so several days would be needed instead of one in order to visit each well for both reasons.

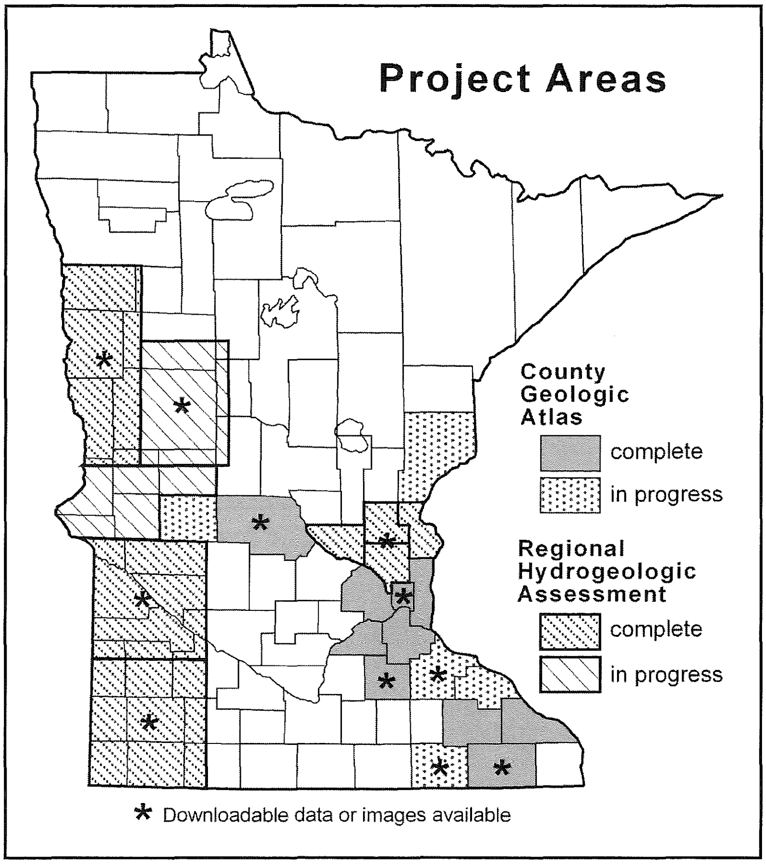
Local, state and federal water management agencies are aware of and have access to the location of the obwells. The Minnesota Pollution Control Agency is reviewing obwell locations for their newest monitoring program. The Minnesota Department of Agriculture and the Minnesota Department of Health have used obwells for other monitoring studies and the Minnesota Geological Survey has recently been using obwells for their Prairie du Chien fracture flow study. Ground water level wells are also used for water quality sampling by DNR Waters' hydrogeologists to determine the geochemical properties of the ground water for use in mapping aquifers and ground water flow patterns.

County Geologic Atlas and Regional Hydrogeologic Assessment Program

Ground Water Data Use

For nearly twenty years the Minnesota Geological Survey (MGS) has been conducting county and regional-scale basic geologic and hydrogeologic data gathering and interpretation. About ten years ago, DNR Waters joined the MGS in this effort, concentrating on the hydrogeology of the study areas. The results of this work are the County Geologic Atlases and Regional Hydrogeologic Assessments.

In addition to the well and geologic data collected by the MGS, project staff utilize DNR Waters databases, particularly data available from the Observation Well Program. Other DNR Waters data sources are also used, including climatology, water use permits, and geophysical study reports. Project staff also measure water levels in wells and collect water samples for chemical and isotopic analysis.

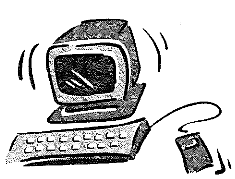


Minnesota DNR Waters

Data Available Online

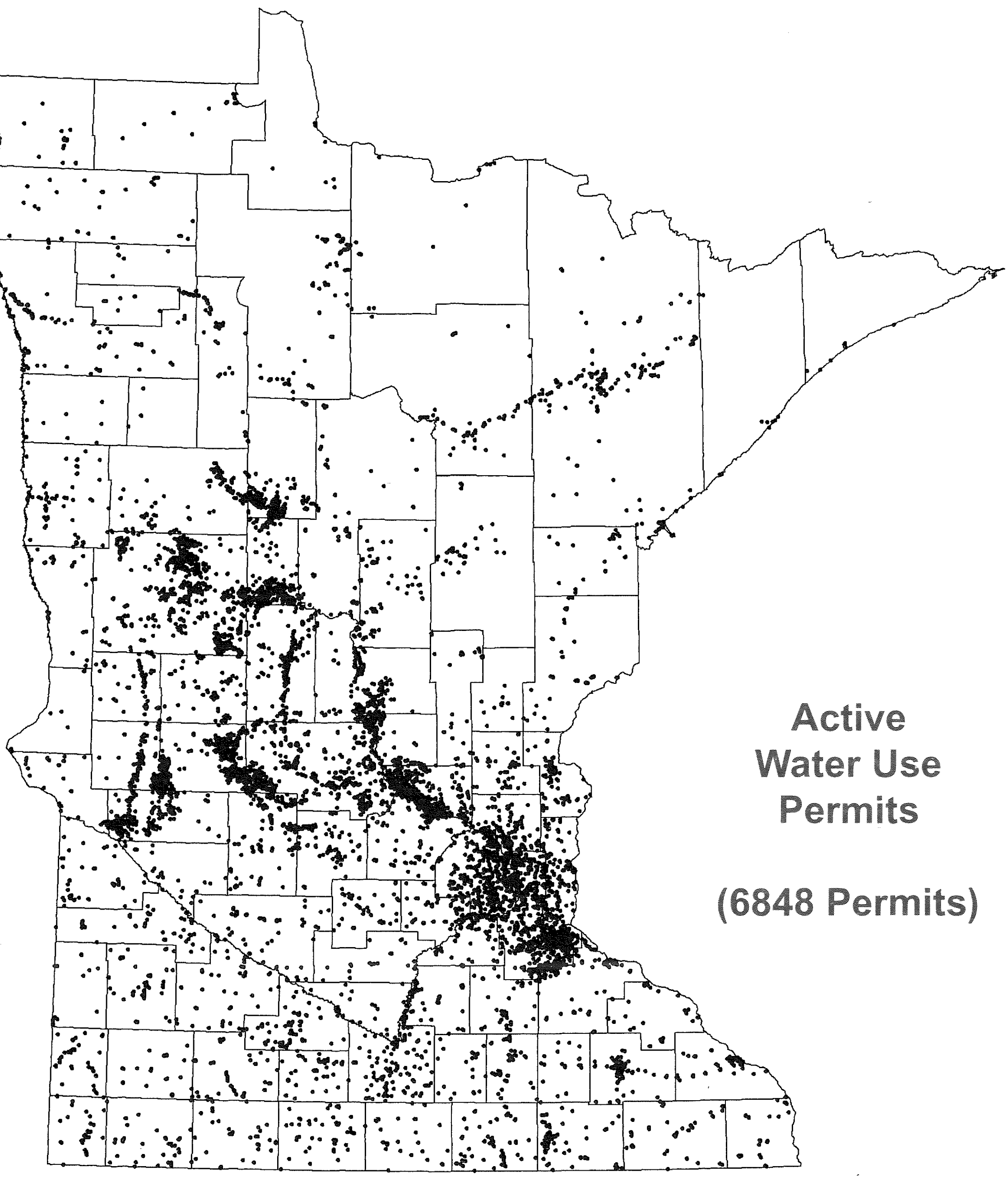
Digital data for many Atlas and Assessment projects, including geographical information systems (GIS) and related resource data can be downloaded over the internet. Some map plate images and documents are also available as portable document format (PDF) files. Many GIS files have detailed data descriptions (metadata) available.

Digital data for many projects can be downloaded for use in GIS programs such as ArcInfo and ArcView. Map viewers (at no or low cost) such as ArcExplorer can also be used to visualize the downloaded data. Some project digital data is not downloadable but is available on request.



Project data can be found on the DNR Waters web site at **http://www.dnr.state.mn.us/waters/programs/gw_section/cgarha/status.html**. Links to MGS project data on their ftp site are also on the DNR Waters web site. For more information on MGS project data see the MGS web site at **http://www.geo.umn.edu/mgs/**.

Chapter Four WATER USE



Active
Water Use
Permits

(6848 Permits)

Introduction

DNR water appropriations permits are required for all users withdrawing more than ten thousand gallons of water per day or one million gallons per year. Appropriations lower than these thresholds, such as for rural domestic use, do not require a permit from the DNR and therefore are not included in this chapter.

As a condition of each permit, the holder must report the volume of water withdrawn for the previous year within an accuracy of 10%. The data collected is used for many purposes, such as documenting water conflicts, understanding the hydrology of aquifers from which water is withdrawn and evaluating existing water supplies by monitoring use and the impact of that use. The data are reported on a calendar year basis. This chapter summarizes the reported water use data for calendar years 1998 and 1999.

MAJOR WATER USE CATEGORIES

THERMOELECTRIC POWER GENERATION - water used to cool power generating plants. This is historically the largest volume use and relies almost entirely on surface water sources. Thermoelectric power generation is primarily a nonconsumptive* use in that most of the water withdrawn is returned to its source.

PUBLIC WATER SUPPLY - water distributed by community suppliers for domestic, commercial, industrial and public users. This category relies on both surface water and ground water sources.

INDUSTRIAL PROCESSING - water used in mining activities, paper mill operations, food processing, etc. Three-fourths or more of withdrawals are from surface water sources. Consumptive use varies depending on the type of industrial process.

IRRIGATION - water withdrawn from both surface water and ground water sources for major crop and noncrop uses. Nearly all irrigation is considered to be consumptive use.

OTHER - large volumes of water withdrawn for activities including air conditioning, construction dewatering, water level maintenance and pollution confinement.

*Consumptive use is defined as water that is withdrawn from its source and is not directly returned to the source (M.S. 103G.005, Subd.8). Under this definition, all ground water withdrawals are consumptive unless the water is returned to the same aquifer. Surface water withdrawals are considered consumptive if the water is not directly returned to the source so that it is available for immediate further use.

Statewide Water Use Comparison for 1998 and 1999

Total water use for calendar years 1998 and 1999 remained relatively stable. However, the totals for these two years average about 10% higher than the previous two-year period. The reported water use in 1999 was 1300 billion gallons (BG), up from 1281 BG in 1998. Figure 1 is a comparison of the two years showing use by major category and the volume and percent change between the years. The largest increase in use was for power generation which changed by 27 BG or 3%. The largest decrease in use was for irrigation which changed by 5 BG or 4%.

Figure 2 graphically shows the changes in use patterns for four main use categories (excluding power generation) from 1986 to 1999. Note the low irrigation use in 1986 and 1993, the peak of irrigation use in 1988 and the overall increase in industrial processing use since 1986. The pattern seen in irrigation reflects low use in times of high precipitation and high use in times of drought. The changes in industrial processing appear to be due to local economic factors.

Figure 1

Water Use Comparison by Major Category: 1998 & 1999 (Billions of Gallons)

Use Category	1998 BG	1998 % of Total	1999 BG	1999 % of Total	BG Change	% Change
Power Generation	785.3	61%	811.8	62%	27	3%
Public Supply	191.8	15%	184.4	14%	-7	-4%
Industrial Processing	168.9	13%	166.2	13%	-3	-2%
Irrigation	77.1	6%	71.9	6%	-5	-7%
Other	58.2	5%	65.3	5%	7	12%
Totals	**1,281.3**	**100%**	**1,299.6**	**100%**	**18 ***	**1.4% ***

* change in totals from 1998 to 1999

Water Use by Major Category: 1986 to 1999 (Billions of Gallons)

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Power Generation	539	637	663	664	698	694	679	722	765	748	710	701	785	812
Public Supply	170	192	203	174	164	170	175	164	178	180	189	185	192	184
Industrial Processing	76	69	94	120	102	115	158	127	120	160	147	159	169	166
Irrigation	30	67	103	86	71	60	63	30	56	62	80	58	77	72
Other	42	38	42	48	53	52	58	63	64	60	57	63	58	65
Total	**857**	**1003**	**1105**	**1092**	**1088**	**1091**	**1133**	**1106**	**1183**	**1210**	**1183**	**1166**	**1281**	**1299**

Note: column totals may not sum due to independent rounding

A comparison of surface water versus ground water use for 1999 (Figure 3) shows that the majority of appropriations are from surface water sources. In 1999, 83% of withdrawals in Minnesota were from surface water sources, which compares closely with the national average of 80% (USGS data). However, if the non-consumptive use for most power generation is removed, use of ground water and surface water are more even (non-consumptive means water that is immediately returned to its source after use). 60 to 65 percent of water use in Minnesota is for power plant cooling, a relatively non-consumptive use.

Surface water use increased slightly from 1998 to 1999, primarily due to increased appropriation for power generation and uses described in other uses . Ground water use decreased slightly from 1998 to 1999 primarily due to decreased demand for irrigation and public supply.

Figure 2

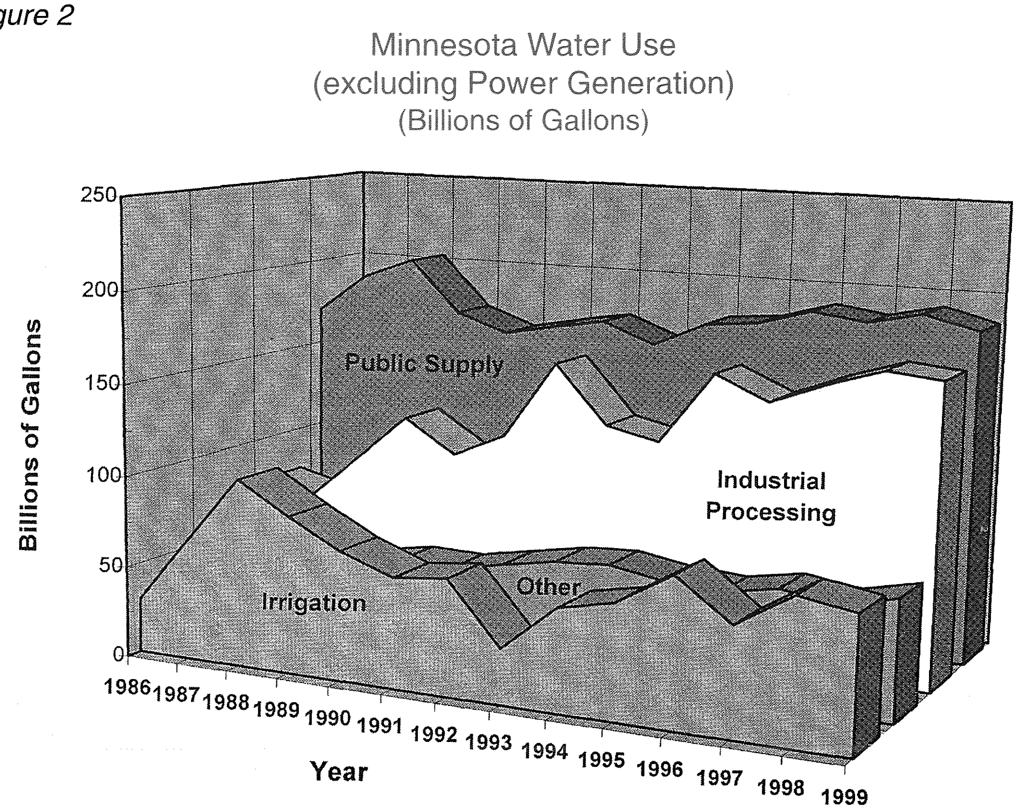
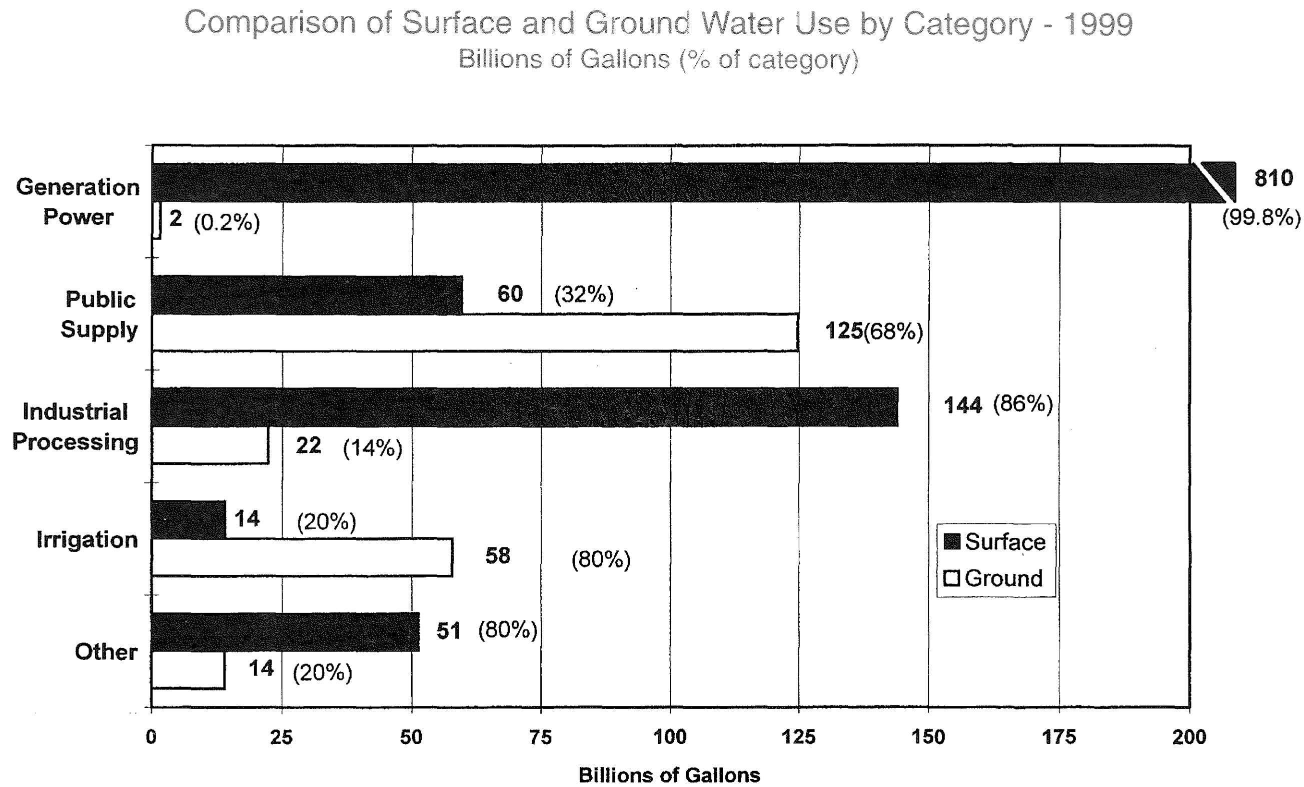


Figure 3



Surface Water Total: 1079 BG
83% of 1999 Use

Ground Water Total: 220 BG
18% of 1999 use

Power Generation

Power generation (nuclear power cooling and steam power cooling) was the primary use in 8 of the 11 counties reporting the highest totals in 1999 (Figure 4). Power generation accounted for 62% of all use in Minnesota for the year. The combination of power generation use for 1998 and 1999 is 13% more than the combination during the 1996-1997 period. Power generation in Goodhue and Wright Counties accounted for 27% of all reported use in 1999, largely due to nuclear power plant cooling. Surface water sources supply nearly all of the water used for power generation. Most of the water is for cooling purposes and is returned to the surface water source after use.

Public Water Supply

Water use for public supply remained fairly constant from 1989 to 1999 (Figure 2), dipping slightly in 1990 and 1993. Reported use for 1998 and 1999 was 192 BG and 184 BG respectively. Public supply has slowly increased from 1990 to 1998 due to population increases and industrial demands. 1998 use approached the high level associated with the spike in 1988 due to drought conditions. 68% of public water supply in Minnesota comes from ground water sources, compared to 39% nationally (USGS data, 1986-1990).

Local water conservation programs that implement measures to improve water use efficiencies and promote the wise use of water can help communities reduce the need for expensive new municipal wells and water/wastewater treatment plants. Public water suppliers that serve more than 1,000 people are required to develop water emergency and conservation plans and also to implement demand management measures before requesting approval for new municipal wells. These efforts can help water customers and communities save money while helping to protect Minnesota s valuable water resources for future domestic and economic uses.

Figure 4

Appropriations by the Counties with the Greatest Use in CY 1999

	County	Surface Water	Ground Water	Total	Primary Use
1)	Goodhue	222.9	2.4	225.3	Nuclear Power Cooling
2)	Wright	126.9	2.7	129.6	Nuclear Power Cooling
3)	Washington	99.9	11.3	111.2	Steam Power Cooling
4)	St Louis	109.1	2.1	111.2	Steam Power Cooling
5)	Hennepin	73.4	35.1	108.5	Steam Power Cooling
6)	Dakota	66.7	22.3	89.0	Steam Power Cooling
7)	Itasca	70.9	1.2	72.2	Steam Power Cooling
8)	Ramsey	44.5	14.5	59.0	Steam Power Cooling
9)	Cook	49.1	< 1	49.1	Mine Processing
10)	Lake	48.7	< 1	48.7	Mine Processing
11)	Anoka	38.1	10.1	48.2	Municipal Waterworks
	Total	**950.2**	**101.7**	**1052.0**	
	millions of gallons	*88% of* SW Use	*46% of* GW Use	*81% of* Total Use	

Irrigation

Water use for irrigation has dropped considerably since the peak usage of 103 BG in 1988. Yearly variation in the amount and distribution of rainfall greatly affects the demand for irrigation water. The combined irrigation use for 1998-99 was 8% higher compared to the previous two-year period.

Irrigation accounts for only a small amount (6%) of total water use in Minnesota. However, this use is significant because it is almost entirely consumptive and the majority is from ground water sources (80%). The timing of irrigation can be significant when evaluating regional water supplies and the potential for well interferences. Nearly all major crop irrigation use is compacted into the five-month period from May to September of each year (Figure 5).

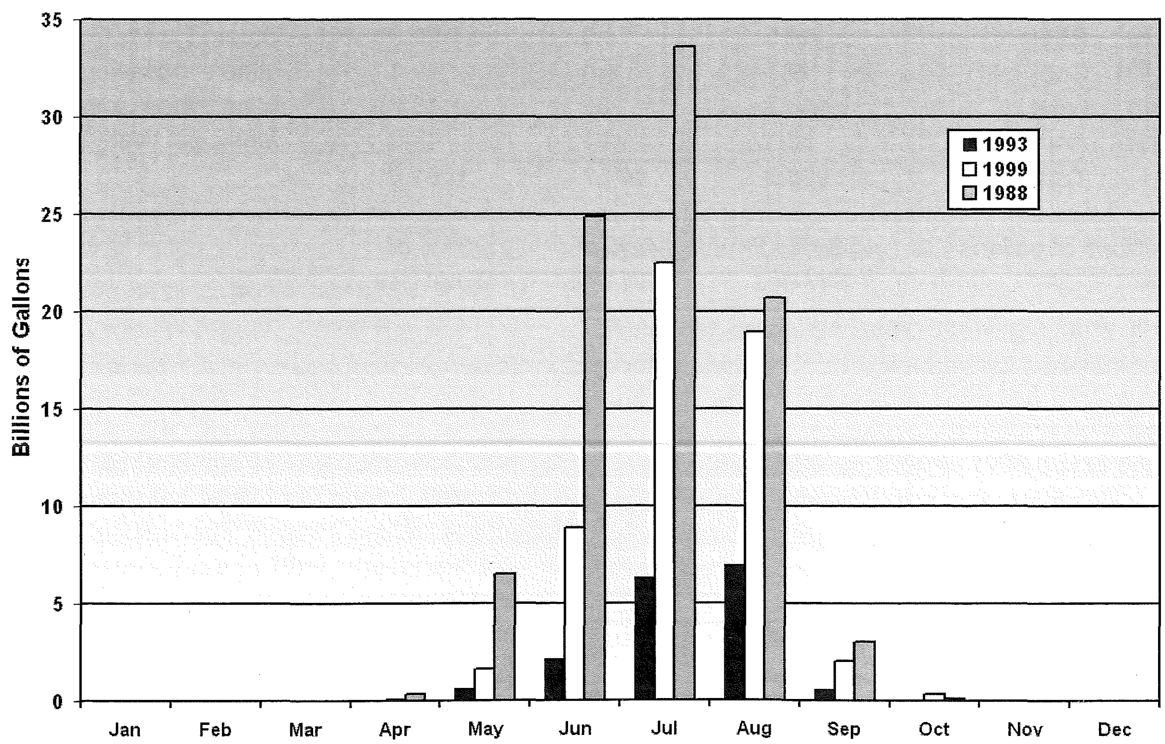
Otter Tail and Sherburne Counties reported the highest amounts for irrigation in 1999, using 8.4 BG and 7.1 BG respectively. Roseau and Mahnomen were the only counties that reported no use for irrigation in 1999. Carlton, Lake and Traverse Counties reported less than 4 million gallons used for irrigation in 1999.

Industrial Processing

Industrial processing use decreased 2% from 1998 to 1999. However, the combination of industrial processing use for 1998 and 1999 is 10% more than the 1996-1997 period. Mine processing accounted for 65% of the reported industrial process total, while pulp and paper processing and agricultural processing accounted for 17% and 6% respectively.

Figure 5

Major Crop Irrigation Use by Month
Comparison of 1999 to 1993 (wet) & 1988 (dry)



Other Uses

Other uses include air conditioning, water level maintenance, fisheries, temporary construction dewatering, pollution confinement and other specialty uses that represent about 5% of Minnesota s total.

Once-Through Systems

In 1988, approximately 100 active appropriation permits existed for office buildings and other types of structures that used ground water for heating and air-conditioning purposes. These once-through systems pump water through heating, ventilation or air conditioning systems, then discharge the water without recirculating or reusing it for another purpose. This is not the best or most efficient use of Minnesota s high quality ground water resources.

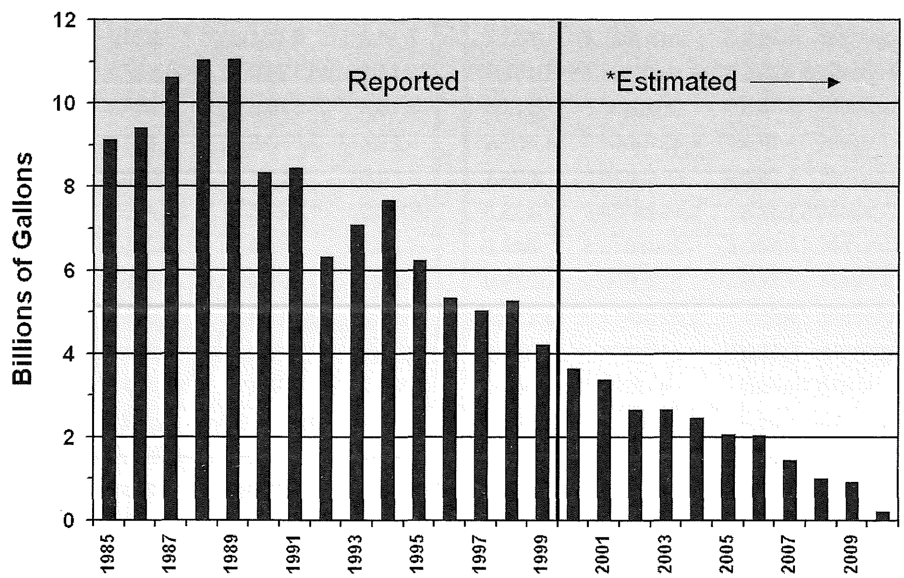
Once-through systems reached a peak use of 11 BG in 1989 and accounted for approximately 19% of the total ground water use in the Twin Cities Metropolitan Area. 1990 legislation requires once-through systems to be phased out at the end of the design life of the equipment, but no later than the year 2010. Through the conversion of once-through systems to water efficient alternatives, ground water withdrawals for this purpose have dropped from 11 BG to just over 4 BG per year by the end of 1999 (Figure 6).

Summary

Total water use from 1998 to 1999 remained relatively constant, increasing by about 1% overall. Power generation continues to account for the majority of use totaling 812 BG of the 1300 BG reported for 1999 (63%). Surface water accounts for 82% of all appropriations.

Figure 6 Once-Through Systems Use

(2000-2010 values are estimates based on existing permits)



Reported Water Use by County
1998 - 1999 (Millions of Gallons)

Reported Water Use

County		1998 Surface	1998 Ground	1998 Total	1999 Surface	1999 Ground	1999 Total	Primary Use	Percent of 1999 Total
1	Aitkin	2,115.7	91.0	2,206.7	1,732.2	91.2	1,823.4	Wild Rice Irrigation	93
2	Anoka	40,387.4	11,661.9	52,049.3	38,063.1	10,056.1	48,119.2	Municipal Waterworks	96
3	Becker	23.5	2,079.2	2,102.7	8.2	1,982.2	1,990.4	Major Crop Irrigation	53
4	Beltrami	1,557.0	760.7	2,317.7	1,691.0	629.4	2,320.4	Wild Rice Irrigation	71
5	Benton	3,367.7	3,449.2	6,816.9	3,492.7	3,142.5	6,635.2	Industrial Processing	52
6	Big Stone	40.1	413.9	454.0	12.2	412.7	424.9	Major Crop Irrigation	49
7	Blue Earth	7,775.0	3,683.8	11,458.8	7,847.5	3,714.9	11,562.4	Steam Power Cooling	67
8	Brown	100.8	829.3	930.1	125.8	930.0	1,055.8	Municipal Waterworks	46
9	Carlton	1,235.0	696.2	1,931.2	2,225.0	640.8	2,865.8	Pulp/Paper Processing	63
10	Carver	20.7	2,666.7	2,687.4	28.1	2,338.6	2,366.7	Municipal Waterworks	82
11	Cass	40.6	1,078.9	1,119.5	20.4	889.0	909.4	Hatcheries & Fisheries	25
12	Chippewa	362.6	467.4	830.0	303.0	491.2	794.2	Municipal Waterworks	55
13	Chisago	266.1	1,005.6	1,271.7	127.4	866.9	994.3	Municipal Waterworks	61
14	Clay	1,544.9	944.0	2,488.9	1,717.3	877.4	2,594.7	Municipal Waterworks	73
15	Clearwater	5,206.9	126.6	5,333.5	4,200.9	115.0	4,315.9	Wild Rice Irrigation	96
16	Cook	54,025.3	12.5	54,037.8	49,062.9	13.2	49,076.1	Mine Processing	99.7
17	Cottonwood	192.2	952.2	1,144.4	202.8	1,011.1	1,213.9	Municipal Waterworks	35
18	Crow Wing	1,566.3	1,833.7	3,400.0	1,554.7	1,811.6	3,366.3	Pulp/Paper Processing	41
19	Dakota	67,279.2	21,183.9	88,463.1	66,742.2	22,255.6	88,997.8	Steam Power Cooling	70
20	Dodge	61.8	429.2	491.0	13.0	421.0	434.0	Municipal Waterworks	75
21	Douglas	121.4	1,417.2	1,538.6	132.6	1,377.4	1,510.0	Municipal Waterworks	41
22	Faribault	0.0	738.4	738.4	0.0	721.8	721.8	Municipal Waterworks	69
23	Fillmore	3,729.6	580.6	4,310.2	3,854.8	673.3	4,528.1	Hatcheries & Fisheries	85
24	Freeborn	17.4	1,692.0	1,709.4	4.0	1,706.6	1,710.6	Municipal Waterworks	94
25	Goodhue	200,492.4	2,495.8	202,988.2	222,940.3	2,390.1	225,330.4	Nuclear Power Cooling	92
26	Grant	0.0	743.7	743.7	0.0	623.1	623.1	Major Crop Irrigation	68
27	Hennepin	76,965.3	38,190.3	115,155.6	73,414.9	35,123.0	108,537.9	Steam Power Cooling	67
28	Houston	4.8	518.2	523.0	6.8	528.0	534.8	Municipal Waterworks	76
29	Hubbard	19.5	4,431.4	4,450.9	17.4	3,673.9	3,691.3	Major Crop Irrigation	72
30	Isanti	0.0	604.4	604.4	0.8	560.1	560.9	Municipal Waterworks	57
31	Itasca	70,254.8	1,197.5	71,452.3	70,937.0	1,222.8	72,159.8	Steam Power Cooling	85
32	Jackson	164.1	284.1	448.2	50.9	274.5	325.4	Municipal Waterworks	74
33	Kanabec	11.9	227.1	239.0	27.6	159.3	186.9	Municipal Waterworks	77
34	Kandiyohi	600.1	2,621.5	3,221.6	644.8	3,037.8	3,682.6	Municipal Waterworks	44
35	Kittson	28.5	348.0	376.5	24.3	269.7	294.0	Rural Waterworks	58
36	Koochiching	17,540.0	42.0	17,582.0	18,130.2	42.1	18,172.3	Pulp/Paper Processing	97
37	Lac Qui Parle	48.9	1,349.7	1,398.6	37.2	1,303.7	1,340.9	Agricultural Processing	49
38	Lake	49,184.8	0.1	49,184.9	48,701.1	0.1	48,701.2	Mine Processing	99
39	Lake of the Woods	268.0	68.5	336.5	251.2	70.0	321.2	Wild Rice Irrigation	76
40	Le Sueur	2,342.6	1,053.2	3,395.8	2,319.3	978.9	3,298.2	Quarry/Mine Dewatering	70
41	Lincoln	5.1	544.0	549.1	6.1	551.3	557.4	Rural Waterworks	76
42	Lyon	196.4	1,677.2	1,873.6	170.9	1,541.7	1,712.6	Municipal Waterworks	67
43	McLeod	302.5	2,082.1	2,384.6	289.2	1,964.9	2,254.1	Municipal Waterworks	54
44	Mahnomen	0.0	78.0	78.0	0.0	85.0	85.0	Municipal Waterworks	100

Reported Water Use by County
1998 - 1999 (Millions of Gallons)

Reported Water Use

County		1998 Surface	1998 Ground	1998 Total	1999 Surface	1999 Ground	1999 Total	Primary Use	Percent of 1999 Total
45	Marshall	148.5	304.5	453.0	83.2	220.6	303.8	Municipal Waterworks	34
46	Martin	7,556.6	259.9	7,816.5	7,550.5	356.5	7,907.0	Steam Power Cooling	89
47	Meeker	16.9	1,268.2	1,285.1	15.2	1,461.8	1,477.0	Major Crop Irrigation	53
48	Mille Lacs	39.8	512.1	551.9	55.2	458.7	513.9	Municipal Waterworks	67
49	Morrison	103.5	3,862.3	3,965.8	53.5	3,494.7	3,548.2	Major Crop Irrigation	76
50	Mower	176.3	2,567.1	2,743.4	186.8	2,426.6	2,613.4	Municipal Waterworks	47
51	Murray	49.0	224.0	273.0	60.2	216.1	276.3	Municipal Waterworks	77
52	Nicollet	40.9	1,854.2	1,895.1	27.2	1,884.1	1,911.3	Municipal Waterworks	83
53	Nobles	50.7	1,104.6	1,155.3	63.6	1,167.8	1,231.4	Municipal Waterworks	94
54	Norman	0.0	163.0	163.0	0.0	146.2	146.2	Municipal Waterworks	95
55	Olmsted	5,533.3	6,072.9	11,606.2	5,868.2	5,998.0	11,866.2	Steam Power Cooling	48
56	Ottertail	24,696.0	11,696.6	36,392.6	24,167.7	9,538.5	33,706.2	Steam Power Cooling	68
57	Pennington	588.7	25.8	614.5	808.4	25.1	833.5	Wild Rice Irrigation	46
58	Pine	16.1	570.9	587.0	17.2	483.7	500.9	Municipal Waterworks	63
59	Pipestone	44.5	857.1	901.6	29.6	906.2	935.8	Rural Waterworks	43
60	Polk	5,089.9	376.4	5,466.3	5,195.0	409.7	5,604.7	Municipal Waterworks	56
61	Pope	71.9	4,931.8	5,003.7	112.0	5,782.6	5,894.6	Major Crop Irrigation	93
62	Ramsey	54,179.3	13,462.3	67,641.6	44,545.8	14,488.3	59,034.1	Steam Power Cooling	75
63	Red Lake	270.9	399.3	670.2	256.8	375.4	632.2	Municipal Waterworks	59
64	Redwood	120.4	436.6	557.0	38.8	474.5	513.3	Municipal Waterworks	79
65	Renville	86.7	872.6	959.3	106.4	899.6	1,006.0	Municipal Waterworks	46
66	Rice	65.2	2,495.0	2,560.2	74.5	2,465.0	2,539.5	Municipal Waterworks	79
67	Rock	39.4	510.6	550.0	52.0	604.3	656.3	Municipal Waterworks	48
68	Roseau	0.0	341.1	341.1	0.0	335.0	335.0	Municipal Waterworks	92
69	St. Louis	100,173.3	2,097.0	102,270.3	109,102.6	2,086.8	111,189.4	Steam Power Cooling	52
70	Scott	2,273.5	3,650.8	5,924.3	2,454.6	3,785.7	6,240.3	Municipal Waterworks	43
71	Sherburne	22,515.6	8,804.2	31,319.8	24,471.0	8,599.6	33,070.6	Steam Power Cooling	63
72	Sibley	7.5	653.9	661.4	11.5	665.8	677.3	Municipal Waterworks	82
73	Stearns	3,518.6	7,566.4	11,085.0	2,980.7	7,930.7	10,911.4	Major Crop Irrigation	46
74	Steele	425.3	1,707.8	2,133.1	949.0	1,643.4	2,592.4	Municipal Waterworks	60
75	Stevens	90.9	1,410.7	1,501.6	80.2	1,436.5	1,516.7	Major Crop Irrigation	65
76	Swift	31.9	3,563.8	3,595.7	40.7	3,216.6	3,257.3	Major Crop Irrigation	86
77	Todd	161.0	2,587.0	2,748.1	175.6	2,308.1	2,483.7	Major Crop Irrigation	70
78	Traverse	2.7	131.6	134.3	1.6	114.2	115.8	Municipal Waterworks	99
79	Wabasha	0.4	1,094.8	1,095.2	0.2	1,121.0	1,121.2	Municipal Waterworks	78
80	Wadena	444.0	2,999.8	3,443.8	393.2	2,190.8	2,584.0	Major Crop Irrigation	87
81	Waseca	30.5	849.6	880.1	29.8	726.5	756.3	Municipal Waterworks	91
82	Washington	91,016.3	11,407.0	102,423.3	99,911.0	11,336.8	111,247.8	Steam Power Cooling	88
83	Watonwan	10.9	905.6	916.5	6.1	902.4	908.5	Municipal Waterworks	72
84	Wilkin	92.1	245.5	337.6	17.2	180.4	197.6	Municipal Waterworks	72
85	Winona	1,049.0	2,666.4	3,715.4	1,087.1	2,598.5	3,685.6	Municipal Waterworks	42
86	Wright	122,950.4	2,364.1	125,314.5	126,872.1	2,696.3	129,568.4	Nuclear Power Cooling	98
87	Yellow Medicine	89.7	748.1	837.8	82.8	716.6	799.4	Rural Waterworks	50
	Total			**1,281,308**			**1,299,611**		

Minnesota Reported Water Use

Category	1998	1999
Power Generation	(Millions of Gallons)	
Nuclear Power		
surface	305,432.4	333,578.8
ground	0.0	0.0
Steam Power Cooling		
surface	390,044.8	378,796.7
ground	636.9	764.4
Other Power		
surface	88,460.6	97,900.2
ground	740.9	760.3
Subtotal	**785,315.6**	**811,800.4**
Percent of Total	**61%**	**62%**
surface	783,937.8	810,275.7
ground	1,377.8	1,524.7
Public Supply		
Municipal Water Works		
surface	64,396.0	59,546.0
ground	123,325.0	120,523.2
Private Water Works		
surface	8.6	9.6
ground	779.2	800.2
Comercial & Institutional		
surface	0.0	0.0
ground	1,448.0	1,595.6
Cooperative Water Works		
surface	0.0	0.0
ground	1.9	1.9
Fire Protection		
surface	0.0	0.0
ground	23.9	23.4
State Parks, Waysides, Rest Areas		
surface	0.0	0.0
ground	29.0	22.4
Rural Water Districts		
surface	0.0	0.0
ground	1,830.0	1,848.8
Subtotal	**191,841.6**	**184,371.1**
Percent of Total	**15%**	**14%**
surface	64,404.6	59,555.6
ground	127,437.0	124,815.5

	1998	1999
Irrigation		
Golf Course		
surface	1,221.6	1,193.2
ground	4,607.9	4,343.7
Cemetary		
surface	0.0	0.0
ground	54.6	42.9
Landscaping		
surface	58.3	41.0
ground	570.4	454.1
Sod		
surface	152.7	66.2
ground	272.5	119.4
Nursery		
surface	18.2	117.5
ground	471.6	339.9
Orchard		
surface	0.0	0.0
ground	4.5	3.1
Non Crop		
surface	19.6	18.9
ground	29.5	12.9
Temporary		
surface	0.0	0.0
ground	0.0	16.3
Major Crop		
surface	2,230.9	1,897.8
ground	56,036.2	52,480.9
Wild Rice		
surface	11,304.9	10,743.9
ground	17.5	0.0
Subtotal	**77,070.9**	**71,891.7**
Percent of Total	**6%**	**6%**
surface	15,006.2	14,078.5
ground	62,064.7	57,813.2

	1998	1999
Industrial Processing		
Agricultural		
surface	391.0	328.8
ground	9,406.0	9,753.3
Pulp and Paper		
surface	27,394.8	28,701.6
ground	695.5	725.2
Mine		
surface	112,246.3	108,268.9
ground	25.5	30.1
Sand and Gravel Washing		
surface	2,288.5	2,119.7
ground	1,134.1	1,367.9
Sewage Treatment		
surface	1.8	2.5
ground	985.7	898.0
Petroleum or Chemical		
surface	257.2	257.2
ground	3,456.8	3,177.8
Metal		
surface	0.0	0.0
ground	1,086.8	1,192.9
Non-Metal		
surface	0.9	1.1
ground	1,747.6	1,892.0
Other		
surface	4,229.0	4,285.1
ground	3,547.4	3,246.9
Subtotal	**168,894.9**	**166,249.0**
Percent of Total	**13%**	**13%**
surface	146,809.5	143,964.9
ground	22,085.4	22,284.1
Other		
Air Conditioning		
Commercial & Institutional Building AC		
surface	7.8	8.0
ground	189.6	205.3

	1998	1999
Heat Pumps & Coolant Pumps		
surface	728.9	402.9
ground	0.0	0.0
District Heating		
surface	0.0	0.0
ground	0.0	0.0
Once Through Heating or AC		
surface	0.0	0.0
ground	5,273.3	4,221.9
Other AC		
surface	70.9	55.6
ground	0.0	0.0
Temporary		
Temporary Construction Non-Dewatering		
surface	18.6	4.9
ground	0.0	0.2
Temporary Construction Dewatering		
surface	24.1	50.6
ground	2,035.9	1,395.8
Temporary Pipeline and Tank Testing		
surface	21.8	56.5
ground	0.0	0.0
Other Temporary		
surface	278.1	312.9
ground	32.2	2.5
Water Level Maintenance		
Basin (Lake) Level Maintenance		
surface	1,004.2	4,109.4
ground	207.3	147.3
Mine Dewatering		
surface	23,551.3	28,813.4
ground	13.0	12.6
Quarry Dewatering		
surface	11,000.5	10,574.5
ground	0.0	0.0
Sand/Gravel Pit Dewatering		
surface	570.0	759.2
ground	0.0	0.0

	1998	1999
Tile Drainage & Pumped Sumps		
surface	29.4	21.0
ground	9.3	9.5
Other Water Level Maintenance		
surface	35.3	35.1
ground	560.8	1,002.1
Special Categories		
Pollution Confinement		
surface	0.1	5.0
ground	5,056.1	5,258.5
Hatcheries & Fisheries		
surface	5,721.9	5,955.2
ground	751.0	711.0
Snow Making		
surface	112.8	113.0
ground	292.5	306.1
Peat Fire Control		
surface	0.0	0.0
ground	1.1	0.3
Livestock Watering		
surface	0.0	0.0
ground	536.8	685.2
Other Special Categories		
surface	1.2	14.2
ground	49.8	49.6
Subtotal	**58,185.6**	**65,299.3**
Percent of Total	**5%**	**5%**
surface	43,176.9	51,291.4
ground	15,008.7	14,007.9
Grand Total (Millions of Gallons)	**1,281,308**	**1,299,611**
surface	1,053,335	1,079,166
ground	227,973	220,445

This document is also available on our web site at www.dnr.state.mn.us/waters

Water year data summary