water year data summary

2003 and 2004

October 1, 2002 - September 30, 2004

by the DNR Waters Staff
St. Paul, MN

May 2005

Minnesota
Department of Natural Resources
Waters

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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 on page iv) 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 website 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, 1999, 2001 and 2003. This edition is also available on our website.

water year

The climatology, surface water and ground water data presented are for Water Years 2003 and 2004.

WY 2003: October 1, 2002 - September 30, 2003
WY 2004: October 1, 2003 - September 30, 2004

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, and especially Jim Zicopula for assistance with layout and design.

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

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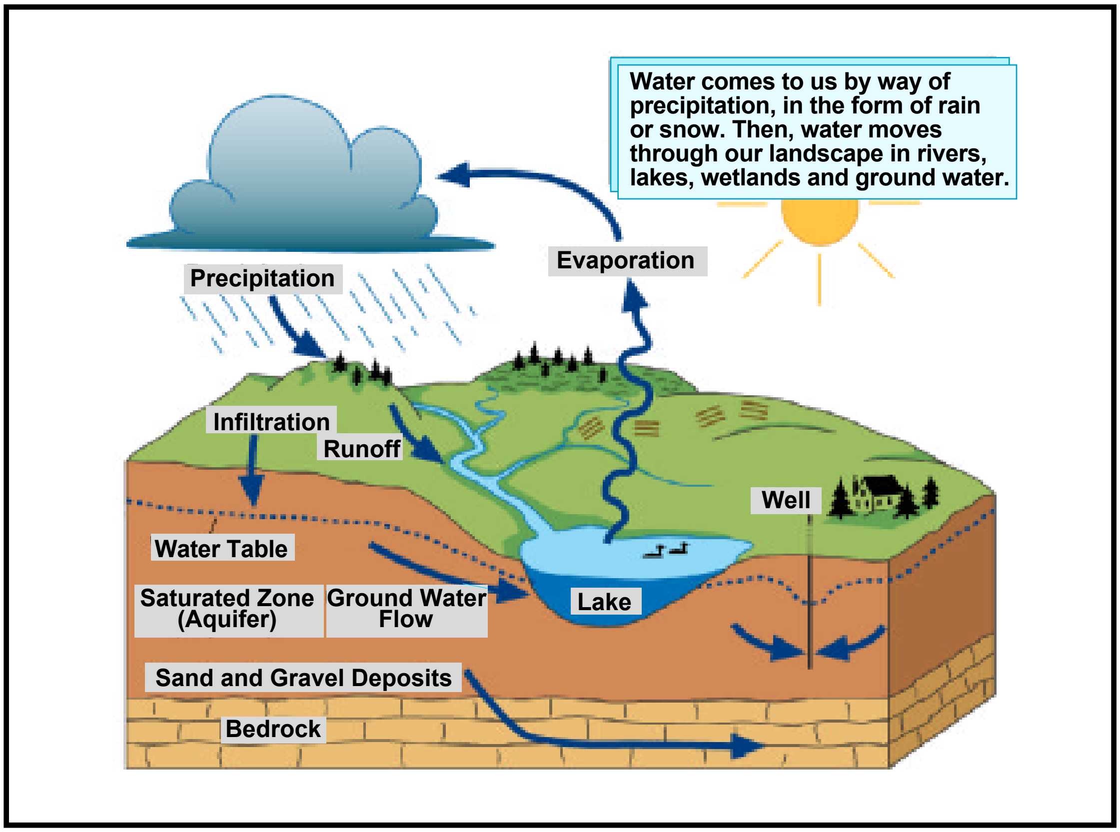
hydrologic cycle

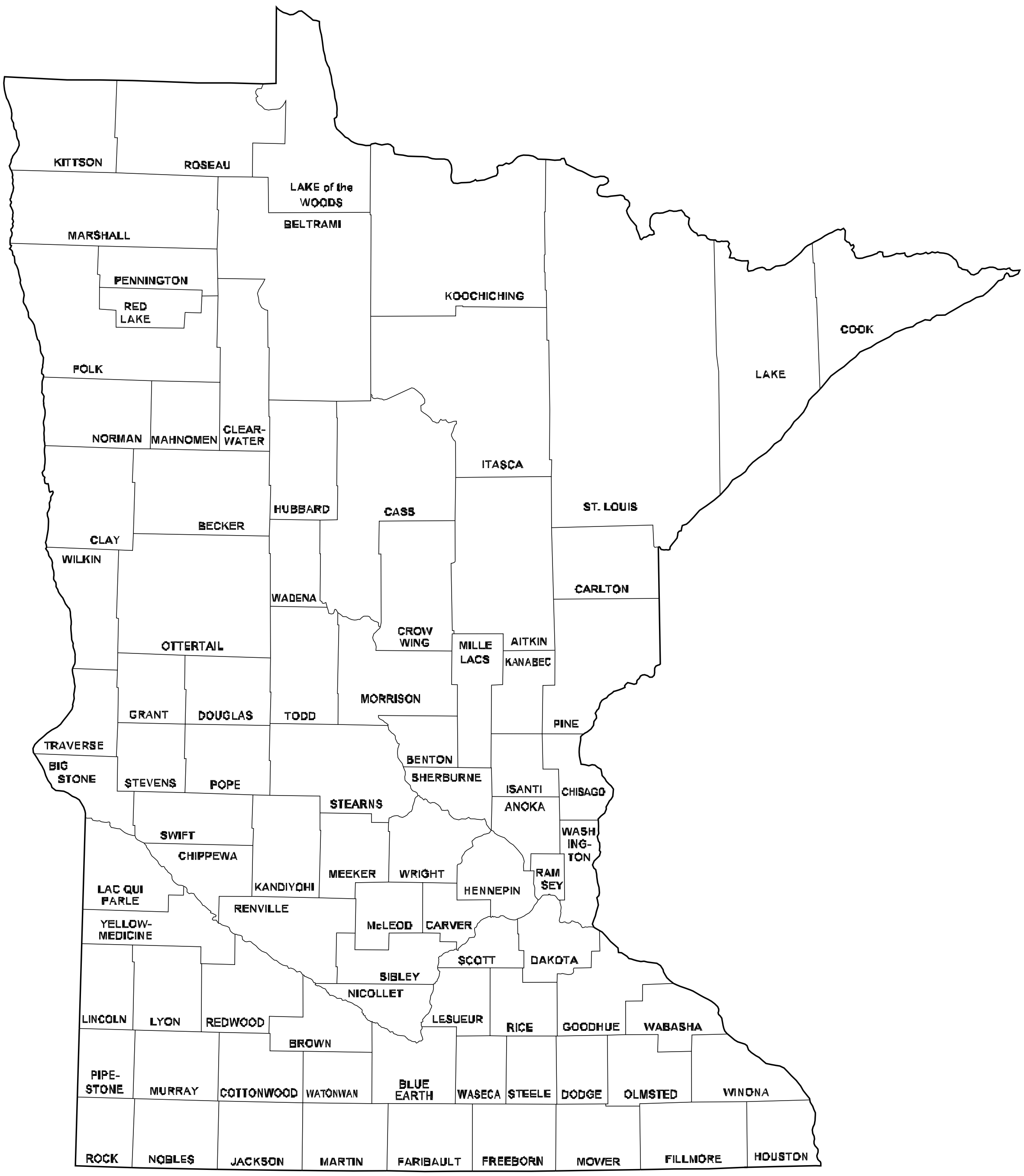


The hydrologic cycle is a concept used to explain the movement of water around the earth. This movement is continuous and has no beginning or end. Change at any point in the cycle will be reflected later in the cycle.

Surface water, which predominantly 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.

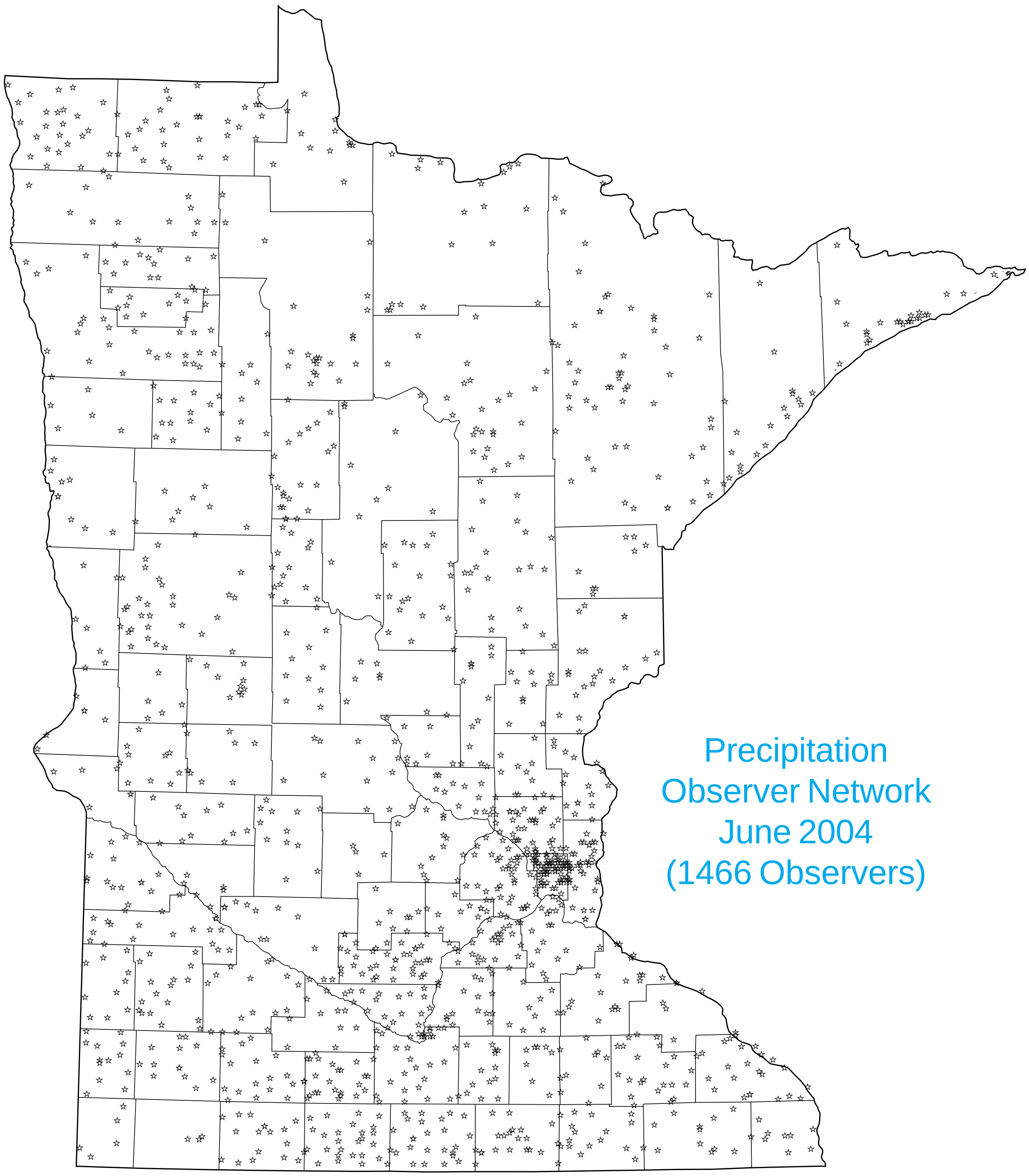
At any point where water is on the ground surface, it is subject to evaporation into the atmosphere or infiltration into the soil.

minnesota counties



chapter one

climatology



Introduction

The DNR Waters 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 provide climate data. These organizations rely primarily on the efforts of volunteer observers. The data are consolidated into a unified database 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 research animal health and mortality. Agricultural specialists use temperature and precipitation data to determine the types of crops that will grow in Minnesota. Others who rely on 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
- *Division of Forestry*
- *Division of Parks*
- *Division of Trails and Waterways*

State Climatology Office Back Yard Network
Metropolitan Mosquito Control District
Minnesota Association of Watershed Districts
Metropolitan Waste Control Commission
Minnesota Power and Light Company
Emergency Management Offices
County Environmental Services

"Normal"

The word *'normal'* in this chapter refers to a 30-year mathematical average of measurements made over the period 1971-2000. Many individuals tend to (erroneously) perceive 'normal' weather as what they should expect. Dr. Helmut E. Landsberg, former Director of Climatology for 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 2003

October 1, 2002 -
September 30, 2003

Highlights

- Wet, cold October 2002
- Very dry November 2002-January 2003
- Deep frost problems February-March 2003
- Scattered rains April-May 2003
- Dry summer 2003
- Rainy September 2003

October temperatures across the state were the coldest since 1925. Mean monthly temperatures were five to eight degrees colder than the historical average, a pattern more typical of early to mid-November. Many daily low temperature records were set throughout the month.

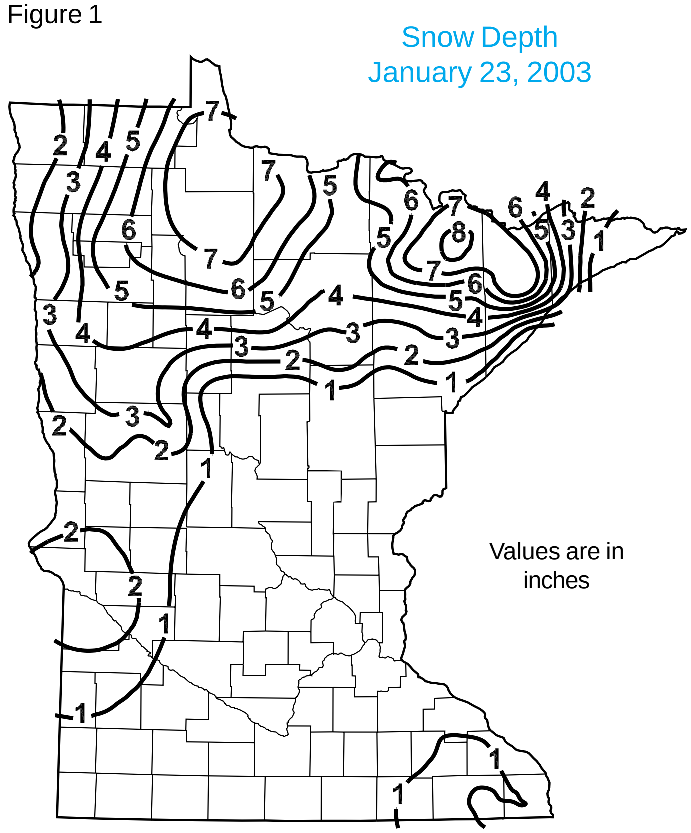
Despite the early start of winter with snow and cold across the state, November 2002 was very dry with seasonal temperatures. Precipitation totals fell short of historical averages by one to two inches and, in many communities, this November was among the driest on record. Mean temperatures were within one degree of historical averages, although temperatures in the northeast were cooler, averaging around three degrees below normal.

Autumn 2002

October 2002 was a damp and cold month, with precipitation totals well above normal for all but north central and northeastern Minnesota. Substantial rains across the southern two-thirds of the state, plus mid-month snow events over northern and central areas, pushed precipitation totals above historical averages by one to two inches.

A storm system moved through the midwest on October 20 and 21, leaving a band of heavy snow across central Minnesota. Snowfall totals ranging between six and eight inches were reported along a 20-mile wide band from Fergus Falls to Hinckley. This snow event, along with other lesser snow events, set new daily and monthly October snowfall records in some communities.

Figure 1



Winter 2002-2003

Similar to November, December 2002 precipitation was quite light across much of Minnesota. Totals for the month fell short of historical averages by approximately one half inch in all but the northwest, where precipitation was near normal. In many communities, November plus December precipitation totals were among the driest on record. The only significant event of the month was a December 18 ice storm that created travel problems in central, north central and northeastern Minnesota.

Dry weather continued in January 2003, with precipitation totals generally less than a quarter inch in most locations, and short of the historical average by more than a half inch. This marked the third consecutive month of very light precipitation and, in the Twin Cities, the November through January total was the driest on record. Many communities were nearly devoid of snow cover until modest snowfalls covered the ground during the last week of the month (Figure 1).

The January thaw came early with temperatures 30 degrees or more above normal on January 7 and 8. A 60-degree temperature at Fairmont on the 7th was a new state record for the date.

The real start of winter for central Minnesota was an early February storm that dropped six to ten inches of snow along a 50-mile wide band either side of a line from Montevideo to Forest Lake. The highest total was at Montevideo with 11 inches. Winds up to 63 mph in some areas reduced visibilities to near zero. The half inch of moisture associated with this event was the most precipitation received in these areas since mid-October of 2002. Snow was sparse across the rest of Minnesota for the month and precipitation totals in February were generally below normal for most of the state. Monthly totals averaged around a half inch statewide, which is approximately a quarter inch below the historical average.

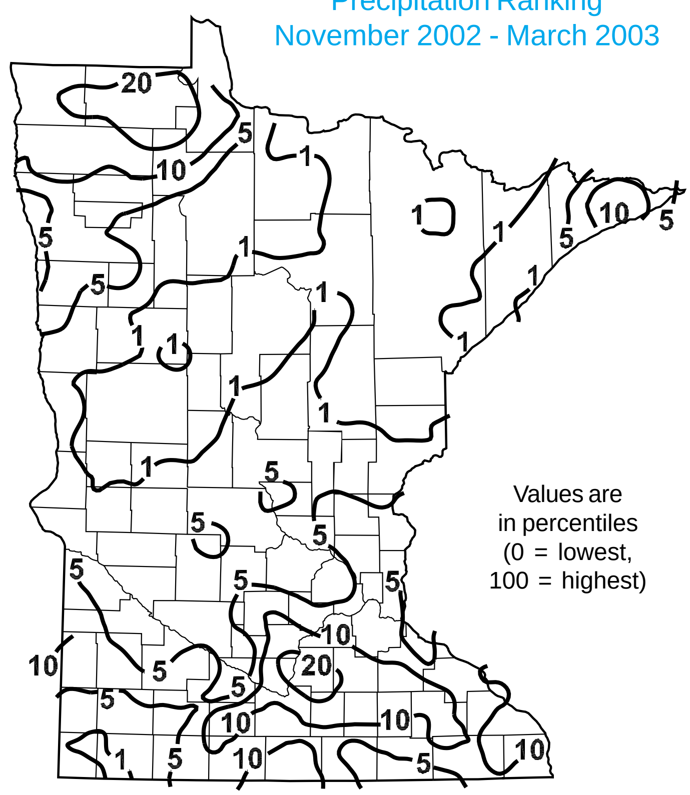
While many places missed significant snow, and there were some brief intrusions of warm air, February was generally a cold month. Across Minnesota, monthly temperatures were from two to seven degrees below normal.

The dry spell that began in November 2002 intensified in March 2003, with precipitation rankings at (or near) the lowest on record for parts of west central and northeastern Minnesota (Figure 2). March precipitation fell short of normal by more than one inch in west central, central, and southwestern Minnesota, but was somewhat above normal in portions of the far northwest, south central, and southeast. Near the end of March, a spring storm dropped more than an inch of rain in some southeastern counties, and more than a foot of snow in north central and northeast Minnesota.

The absence of snow cover, coupled with some very cold temperatures in late winter, lead to widespread frozen septic tanks and water lines. Northern Minnesota was particularly hard hit where frost depths plummeted to six feet in some areas, the deepest since the mid 1980s. Ice damage to lakeshore property due to "ice jacking" was reported in some areas. Cold

Figure 2

Precipitation Ranking
November 2002 - March 2003

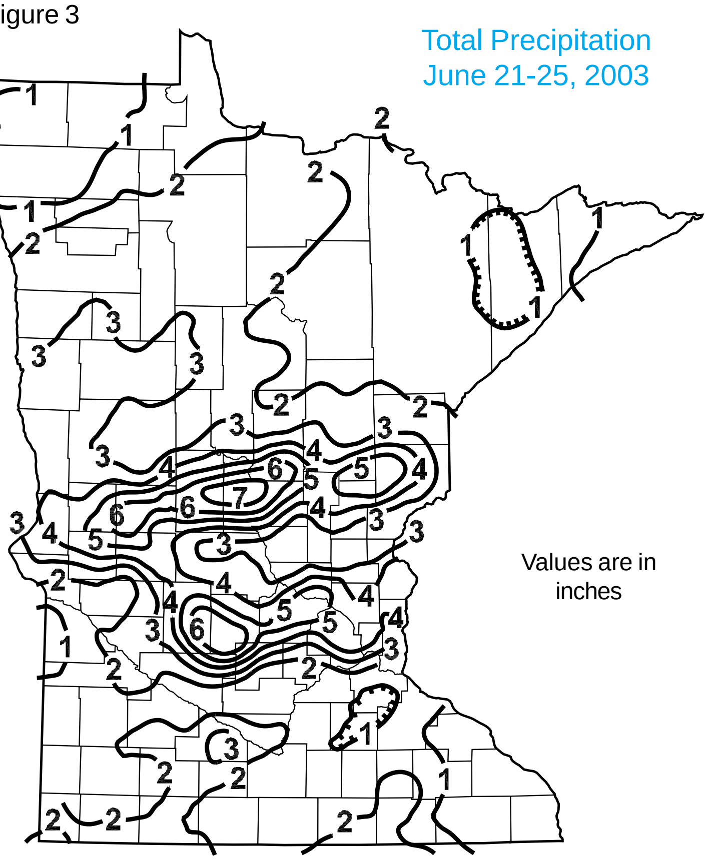


temperatures led to near complete ice cover on Lake Superior in early March for the first time since the winter of 1996-1997. Conversely, record-setting high temperatures were reported in many communities on March 14 through 17, and on March 24.

The winter 2002-2003 snowfall totals were below normal statewide, with amounts in the 30 to 37 inch range across much of the central and south, and in the 50 to 60 inch range across the far north and northeast. Lack of a substantial late winter snow pack significantly reduced runoff, and led to below average stream discharge in spring 2003.

Figure 3

Total Precipitation
June 21-25, 2003



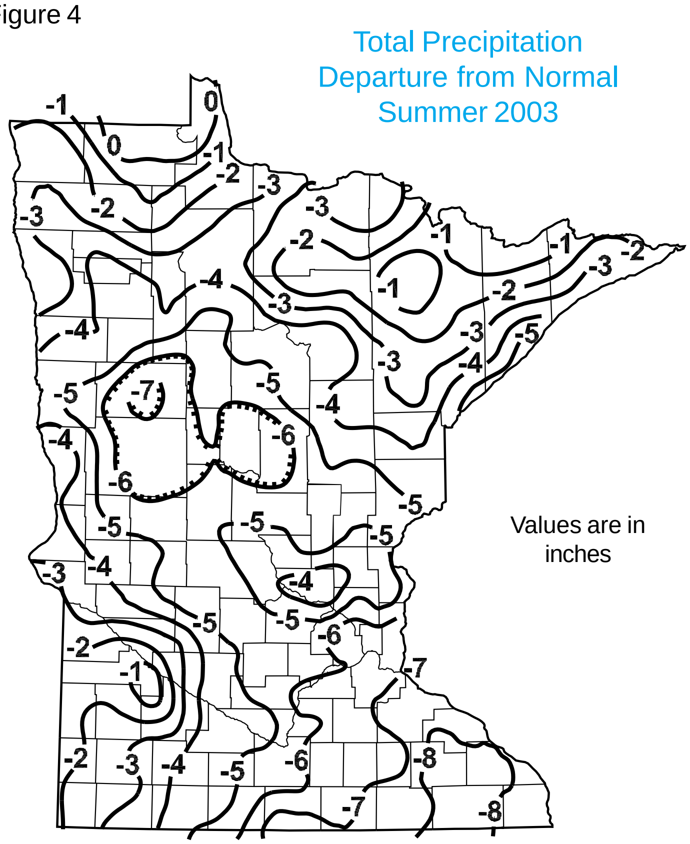
Spring 2003

April 2003 precipitation totals exceeded the historical average by more than one inch in central and far southwestern Minnesota. An April 7 snowstorm dropped a foot of snow at the Cities of Fairmont, Blue Earth and Winnebago. The City of Pipestone received over four inches of rain on April 15-17, and over seven inches for the month. While these few areas received some relief from the dry spell of the previous five months, precipitation totals were a half inch to an inch below normal across much of the southern third of the state. Most counties in the northern third of Minnesota reported below-average totals as well.

April temperatures were near to somewhat above normal across Minnesota, however, air temperatures varied a great deal from week to week and from place to place. On April 6, some northeastern communities awoke to below-zero temperatures, while mid-April temperatures topped 90 degrees in west central Minnesota. The warm temperatures were accompanied by extremely low relative humidity that led to many grass fires. Several communities set new all-time maximum temperature records on April 13, 14 and 15.

Rains helped to ease moisture deficits across much of the southern two thirds of Minnesota in May. However, precipitation deficits had impacted north central and northeastern counties, as well as scattered areas of southern Minnesota, since early 2002. By the end of May 2003, the U. S. Drought Monitor indicated that portions of north central and northeastern Minnesota were in the "D2 - Drought Severe" category, while most of the remainder of the northern third was classified "D1 - Drought Moderate" or "D0 - Abnormally Dry." The NDMC index is a blend of science and subjectivity where intensity categories are based on six key indicators. May temperatures were more or less normal across the state.

Figure 4



A persistent weather pattern in July 2003 produced geographically isolated thunderstorm complexes throughout the month. These clusters of thunderstorms were often short-lived, and led to above normal precipitation totals for a handful of communities, mainly in northern Minnesota. July rainfall was below normal in most communities, falling short of historical averages by a half to one and a half inches.

July temperatures were near to slightly cooler than normal across Minnesota, although for the fifth time in the past six summers, some areas experienced July dewpoints in the 80s. On July 26th, the combined influence of high temperatures and high dewpoints created heat index values at or near 110 degrees.

Persistent dryness continued for the rest of the summer of 2003. August finished as one of the driest ever, and was the driest since 1976. Rainfall totals were generally below one and a half inches, with many communities reporting less than one inch for the month. Precipitation totals fell short of the historical average by one and a half to three and a half inches.

Summer 2003

June 2003 rainfall totals varied widely across Minnesota. Monthly precipitation topped historical averages by one to six inches over portions of northwestern and central Minnesota. Heavy rains on June 21-25 exceeded six inches along a 30-mile wide band stretching from Traverse County to Pine County, and exceeded eight inches in some areas (Figure 3). Rainfall amounts also surpassed six inches in some areas of Kandiyohi, Renville, Meeker, Wright, Sherburne, Hennepin and Chisago Counties during the week, leading to numerous reports of urban and rural flooding. In addition to the downpours, the thunderstorms also spawned tornadoes, damaging winds and hail. A tornado damaged the City of Buffalo Lake in Renville County during the evening of June 24. Elsewhere across Minnesota, rainfall was near to somewhat below normal.

The monthly average temperature for June was one to two degrees below the historical average for most communities.

Not only was August a dry month, but a hot one as well. Average monthly temperatures ranged from two to five degrees above normal, one of the warmest Augusts in the modern record.

No significant widespread rainfall events occurred during the seven-week period from mid-July through early September. Large areas of northwestern, west central, central, and southeastern Minnesota received less than one and a half inches of rain for the interval, short of normal by two to five inches. When compared with similar time periods in the historical database, mid-July through early September 2003 rainfall totals rank among the lowest on record, below the 5th percentile (1 out of 20 years) across large areas of Minnesota. Rainfall totals for many locations were at or below the 1st percentile, indicating that rainfall was near or below all-time minimum values for the period. The summer of 2003 was exceedingly dry across much of Minnesota, with departures from normal precipitation as high as eight inches in the southeast (Figure 4).

Early Autumn 2003

Some heavy rains brought relief to many areas during the four-day period from September 9 to September 12. A very slow moving cold front dropped from one to three inches of rain on southwestern, central, and northeastern Minnesota, while some areas of the southwest received over four inches. September rainfall totals in southwestern, northwestern, and northeastern counties exceeded normal by one to two inches, but were near normal across the central third of Minnesota. Rainfall totals in north central, south central, and southeastern communities fell short of normal by about one inch.

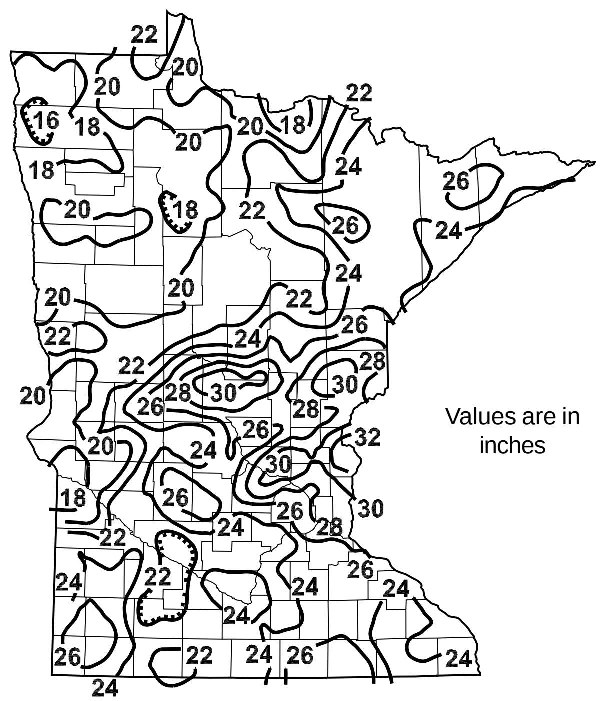
September 2003 began with the high heat that was common in August, but the second half of the month cooled considerably with monthly mean temperatures very close to historical averages. 90-degree temperatures were common over central and southern Minnesota during the first ten days of the month. International Falls recorded an 89-degree high in early September, then received an inch of snow on September 30.

Water Year 2003 Summary

Water Year 2003 (October 2002-September 2003) was overall one of the driest water years in a decade (Figure 5). A drought that began in November 2002 began to ease a bit in September 2003. However, many locations reported below-normal precipitation, with the most severe shortages in north central and the southeast (Figure 6).

Figure 5

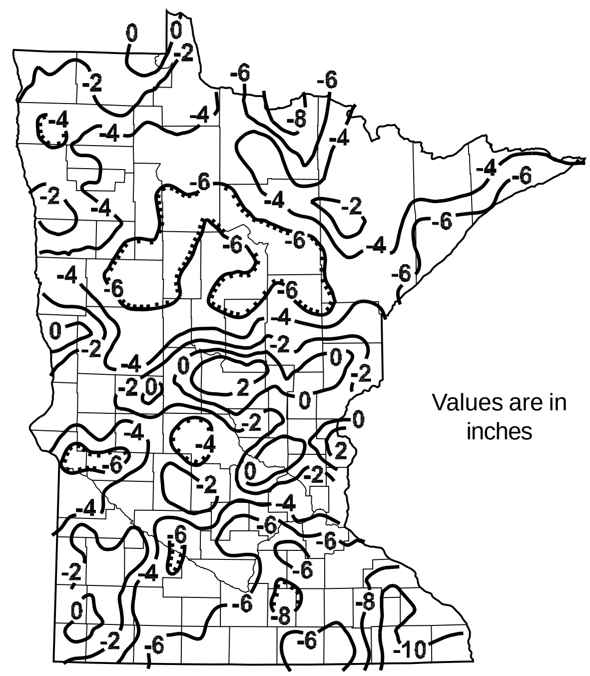
Water Year Precipitation
October 2002 - September 2003



Values are in inches

Figure 6

Water Year Precipitation
Departure from Normal
October 2002 - September 2003



Values are in inches

Water Year 2003

October 1, 2003 -
September 30, 2004

Highlights

- Dry October, November 2003
- Snowy December 2003 - January 2004
- Wet February 2004
- Mild March 2004
- Dry April 2004
- Exceedingly wet May 2004
- Cool summer 2004
- Very warm September 2004

Autumn 2003

Generally dry weather continued into October 2003. Precipitation totals fell short of normal by one to one and a half inches across nearly all of Minnesota, and continued a pattern of dryness that had persisted since mid-July. The largest single precipitation event of the month occurred at Ada (Norman County) when 1.07 inches of rain was reported on October 11. A winter storm brought accumulating snow to many northern communities on October 27 and 28 with four to eight inches reported in some areas.

The chilly conditions of September persisted for the first few days of October 2003. A hard freeze occurred in many central and southern locations on October 2 with temperatures in the upper 20s, even in the urban core of the Twin Cities. Just when it seemed winter was on the doorstep, 70 and 80 degree temperatures were observed from the 6th to the 10th, including 90s at Willmar and Glenwood on October 7th. All-time daily maximum temperature records were set during this warm spell and again in parts of Minnesota on October 19 and 20. Even though the month ended with a week of below normal temperatures, October temperatures were above normal by one to four degrees across the state.

November 2003 stayed rather dry with precipitation totals short of normal by one half to one inch in most counties. The most significant precipitation event of the month was a winter storm on November 22 and 23, when four or more inches of snow fell across most of the state. Eight to twelve inches of snow were reported along a 30-mile wide band from Yellow Medicine County to Lake County.

Temperatures were at or slightly below normal for the month. At the end of the first week, a host of record minimum temperatures were set, including a record low of minus 13 at International Falls on November 8th. Soil froze quickly during the first half of November, to a depth of five inches in some areas. Warmer mid-month temperatures allowed the soil to thaw a bit, although seasonal temperatures returned by the end of November.

Winter 2003-2004

While December 2003 was a snowy month, there was little moisture in the dry, powdery snow. December totals fell short of normal by a quarter to a half inch in approximately two thirds of Minnesota counties, and continued a pattern of dryness that began in mid-July 2003. Precipitation was near to somewhat above normal only in portions of northwestern, west central, and southern Minnesota. The most significant storm dropped up to eight inches of snow in the east central and southwest portions of the state.

December mean monthly temperatures across Minnesota were warmer than average, exceeding the norm by six to ten degrees in most communities. Records were set in some locations on December 27, 28, and 29 when maximums climbed above 40 and minimums remained in the upper 30s.

More typical winter weather visited Minnesota in January 2004. Snow and cold air were abundant, a switch from some of the balmy winters over the past seven years. Monthly snowfall totals ranged from one to three feet over much of southwest, central and northern Minnesota. Some locations along the north shore saw snowfall totals of four feet while Rochester and vicinity received approximately nine inches for the month.

Despite the hefty amounts of snow, most was accompanied by very cold temperatures, so the snow-to-water ratio was very high. Precipitation totals fell short of historical averages by around a half inch in many places. Only in far northwestern and northeastern Minnesota did January precipitation meet or exceed normal. A large snowstorm on January 25 through 27 affected much of Minnesota over this three-day period, with the greatest amounts along the Lake Superior shore. Lake-enhanced snowfall totals topped two feet in some locations, and over 27 inches fell in Duluth, making this storm the third largest snow producer in the city's history.

While some communities missed the heavy snow, everyone saw cold temperatures, although the first few days of January were deceptive with balmy temperatures well above normal, including 51 degrees at Canby. However, the statewide low for the month would be a hundred degrees lower, as the coldest air in seven years spread across Minnesota by the end of January. While nearly every community experienced at least one day of minus 20-degree temperatures or colder, the lowest reported was minus 50 at Fosston (Polk County) on January 30th. The early warmth at the beginning of the month balanced the mean monthly temperatures, which finished near normal over the south, while the north finished from three to seven degrees below normal.

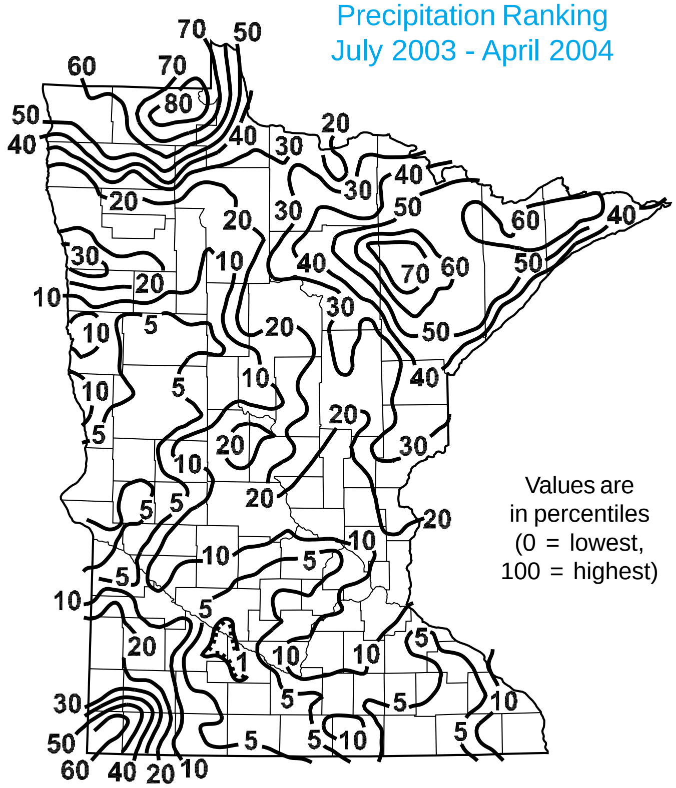
A storm marked the beginning of February 2004 with snowfall amounts that ranged from three inches to a foot over southeastern Minnesota. It was a prolonged event that began late on January 30 and lasted until February 2. This storm, as well as other snows throughout the month, pushed the monthly average precipitation totals above normal for the first time since June 2003. While the abundant February snowfalls were of great benefit to the winter recreation industry, their impact on Minnesota's hydrologic systems was modest.

The first half of February continued the cold trend from January, but the second half of the month featured a warming trend. The Twin Cities saw its streak of 31 below-freezing days end on February 17. While that wasn't a record, it had been 19 years since a similar streak occurred. The latter half of February was unseasonably warm with daily temperatures climbing 10 to 15 degrees above normal. The perennial hot spot of Canby in Yellow Medicine County saw a 56-degree high. Mean monthly temperatures finished near or slightly above normal across the state.

A classic sloppy spring snowstorm brought some badly needed moisture to parts of the state on March 4 and 5, 2004. The storm dropped four to eight inches of snow on south central, southeastern, and east central Minnesota and was also responsible for heavy rains of an inch or more in the far southeast. Significant rain also fell on March 27 in the southern one third of the state and in far northwestern counties. Rainfall totals ranged from a half inch to just over an inch in these areas. The rain in the northwest coincided with a rapidly melting snow pack and led to some flooding along the Red River and its tributaries.

Figure 7

Precipitation Ranking
July 2003 - April 2004



Spring came early, with March temperatures about one degree above normal in northern Minnesota, and three to five degrees above normal over southern parts of the state. The highest temperature for the month was 74 degrees at Worthington on the 24th.

Spring 2004

Despite some welcome rains, totals were generally a half inch to one and a half inches short of the historical average in April 2004. It was extremely dry in sections of west central and northwestern Minnesota, where monthly precipitation totals were less than 20 percent of normal. A series of thunderstorm complexes dropped a half inch to two inches of rain on April 18, south and east of a line from Worthington to Duluth. The thunderstorms also brought high winds, very large hail and at least two tornadoes.

The dry spell that began in July 2003 continued into April 2004. The ten-month period saw precipitation deficits of four to six inches over central Minnesota and eight to twelve inches over the southeast. Only in the far northeast and the far northwest did precipitation amounts approach normal. When compared with similar time periods, the July 2003 through April 2004 combined rainfall totals rank among the driest on record for many areas of western and southern Minnesota (Figure 7).

The parched landscape and warm temperatures in April contributed to the threat of grass and brush fires. Record heat was observed on April 28 with many communities reaching 90 degrees or above, setting dozens of maximum temperature records for that date. However, overall mean monthly temperatures were two to three degrees above normal in the southern two-thirds of Minnesota, and were near normal in the northern third of the state.

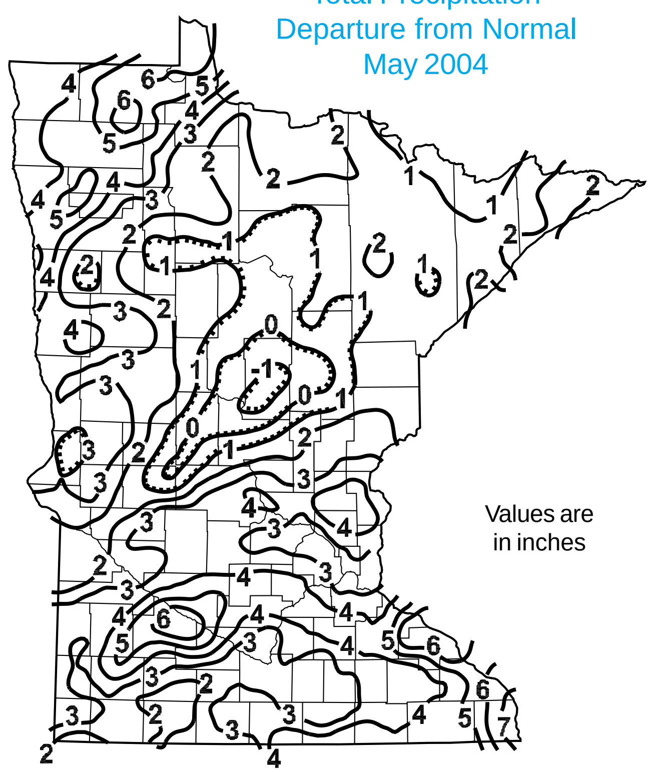
Precipitation totals across large sections of northwestern and southern Minnesota were three or more inches above normal for May 2004. Positive departures topped six inches in some areas (Figure 8), essentially nullifying the deficits built up over the previous ten months. When compared with other May rainfall totals in the historical database, those of May 2004 were at or near all-time record highs in some locations.

Significant weather events in May included heavy rain (and some snow) in northwest Minnesota on May 11 and 12. Precipitation totals for the event exceeded four inches over a large area, with overland and stream flooding reported in Roseau and Marshall Counties. One of the heaviest amounts of rain reported was 5.37 inches in Lake Township just west of Warroad.

During the second half of May, Minnesota was on the cool side of a boundary that separated hot and muggy air to the south from cool, cloudy and wet weather to the north. Monthly temperatures were quite cool, especially in northern Minnesota, where mean monthly temperatures were six or more degrees below normal. For some northern communities, it was among the coldest Mays on record. Elsewhere across the state, mean monthly temperatures were generally two to four degrees below the historical average. The cool weather significantly delayed crop growth and spring green-up, especially in the north.

Figure 8

Total Precipitation Departure from Normal May 2004



Summer 2004

June 2004 saw a return to drier than normal conditions with rainfall generally one to three inches below normal in most communities. Rainfall totals for some north central locations were less than one inch, ranking among the driest on record. However, not all locations reported precipitation deficits. Portions of south central and southeastern Minnesota were extraordinarily wet, especially during the first half of the month.

Although June was relatively dry statewide, a few significant precipitation events were reported during the month. Very heavy rains fell across south central and southeastern Minnesota on June 8 and 9. A series of thunderstorm complexes dropped five or more inches of rain along a band that extended from just west of Mankato, to Rochester and southeast to Preston. Urban and rural flooding and road closures were common in these areas. Highway 169 was closed for a time due to mudslides that covered the road. Another mudslide was reported across Highway 250, just north of Lanesboro in Fillmore County.

On June 15 and 16, intense thunderstorms swamped portions of Pipestone and Murray Counties with more than four inches of rain in a short period of time and over areas that were already saturated in May. The highest total reported for this event was 6.35 inches in Cameron Township just north of Lake Wilson. Township roads were reported to be under water in Murray County.

As was the case in May, June monthly mean temperatures were generally from three to five degrees below normal. In some northern communities, the May plus June mean temperature was among the coldest on record. Daily low temperature records were set throughout the month in many locations.

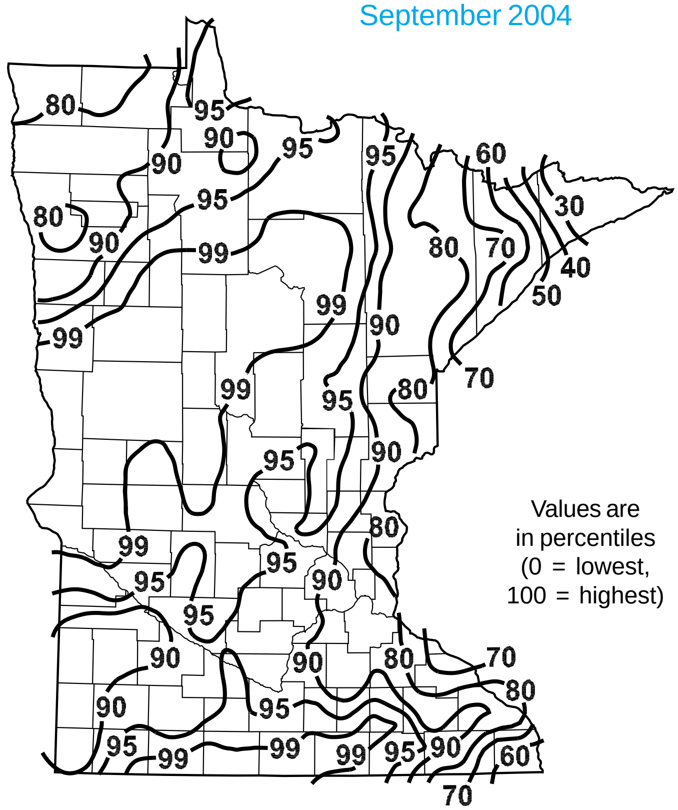
Rainfall totals across Minnesota were highly variable in July 2004. As is often the case during a midwestern summer, thunderstorm-delivered rainfall occurred in striped patterns that affect one locale, while leaving a neighboring community dry. The heaviest precipitation in July occurred in portions of south central Minnesota where rainfall totals topped historical averages by two to four inches. However, rainfall was short of average by one to two inches in some sections of the northeast.

Heavy rains were reported in a few communities in July, the most significant of which occurred in Freeborn County on July 5. Very heavy rains of two to five inches fell in the Albert Lea area, leading to street flooding and the temporary closure of some rural roads.

Continuing the cool temperatures that began in May and June, mean monthly temperatures in July were one to four degrees below normal. Daily minimum temperature records were set throughout the month in many locations.

Figure 9

Precipitation Ranking
September 2004



August 2004 had many Minnesotans scratching their heads and wondering where the summer of 2004 went. Yet another cool, dry month summed up August with rainfall short of the historical average by one to two inches in many locations. Above-normal precipitation was reported only in some areas of northwest, south central and southwest Minnesota. The most intense rainfall event of August occurred on the 23rd and 24th over a small southwest area, where a stalled thunderstorm complex dropped more than six inches of rain on portions of Yellow Medicine, Lyon, and Lincoln Counties. The heaviest reported rainfall total was 8.75 inches near Porter in northeastern Lincoln County.

August was a cool month, with daily high temperatures below 60 degrees for parts of central and southern Minnesota on August 8. On August 10, 49 degrees was a record low maximum temperature at International Falls for the month of August. The continued cold temperatures sparked fears of reduced crop yields.

Early Autumn 2004

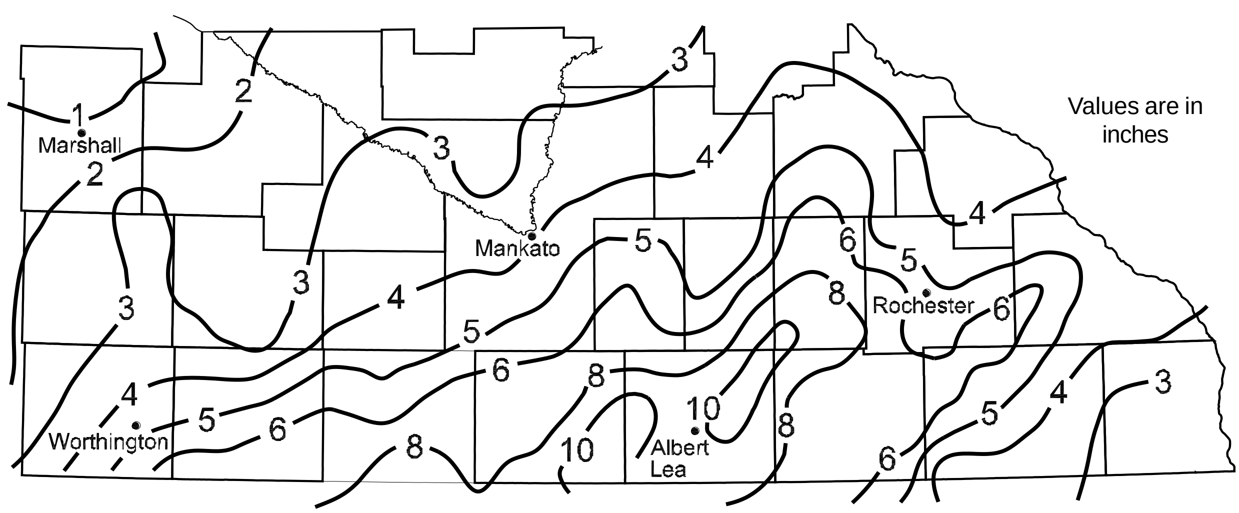
September 2004 was the opposite of August, much to the relief of farmers, with much warmer than normal temperatures and generous amounts of rain. Among the wettest Septembers in the modern climate record, many locations in southern, west central, and north central Minnesota received rainfall totals for the month that topped seven inches. Rainfall totals at many locations in the southern tier of counties exceeded ten inches with monthly rainfall totals of three or more inches above normal across large sections of the state. September rainfall totals were at, or near, all-time record high values in many communities (Figure 9).

In the southern tier of counties, rainfall totals were dominated by a single event. Extremely heavy rains on September 14 and 15 produced one of the most significant flash flood events in Minnesota's climate history (Figure 10). During this event, large sections of north central Iowa and south central Minnesota received more than eight inches of rain over a 36-hour period, which led to numerous reports of stream flooding, urban flooding, mudslides, and road closures. Austin reported very high to record high crests on the Cedar River and its tributaries. Two people died as a result of the event. A 20-year-old man, who was walking to work, was swept away by high water, and a 51-year-old man died of a heart attack while sandbagging.

Halting the generally cool weather that started in May and continued throughout the summer, September temperatures were very warm. Monthly mean temperatures topped normal by three to seven degrees and, for some communities, was among the warmest Septembers on record. In many locations, September temperatures were actually warmer than August temperatures, an occurrence seen only once before in the modern climate record.

Figure 10

Total Rainfall
September 14-15, 2004



Water Year 2004 Summary

Water Year 2004 (October 2003-September 2004) continued the drought that started in July 2003. Some areas received limited precipitation from month to month, but most of Minnesota remained on the dry side through April 2004. In May, rains fell statewide and erased the ten-month drought, although the summer of 2004 was cool with spotty rain. Paradoxically, September was warmer than August for most places in Minnesota, with generous amounts of rain.

Water Year 2004 was much wetter than the previous year (Figure 11). Most locations reported above-normal precipitation totals, although parts of the northeast remained below normal for the year (Figure 12).

Figure 11

Water Year Precipitation
October 2003 - September 2004

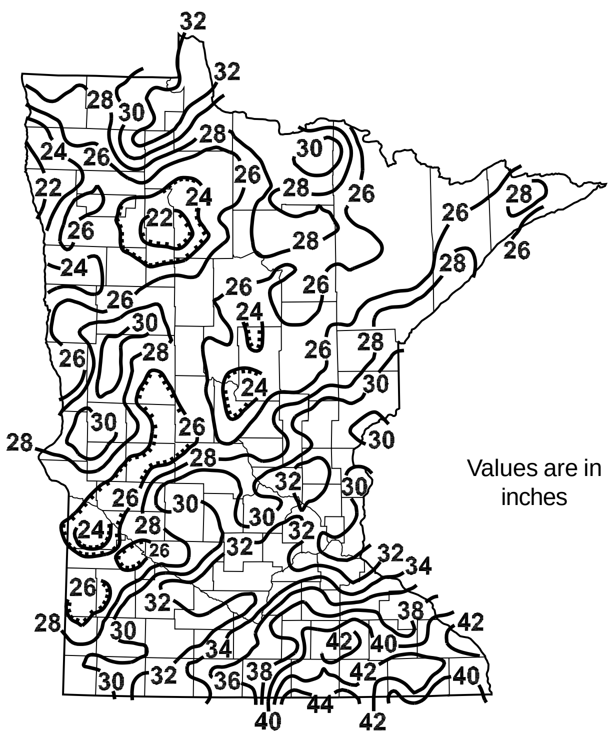
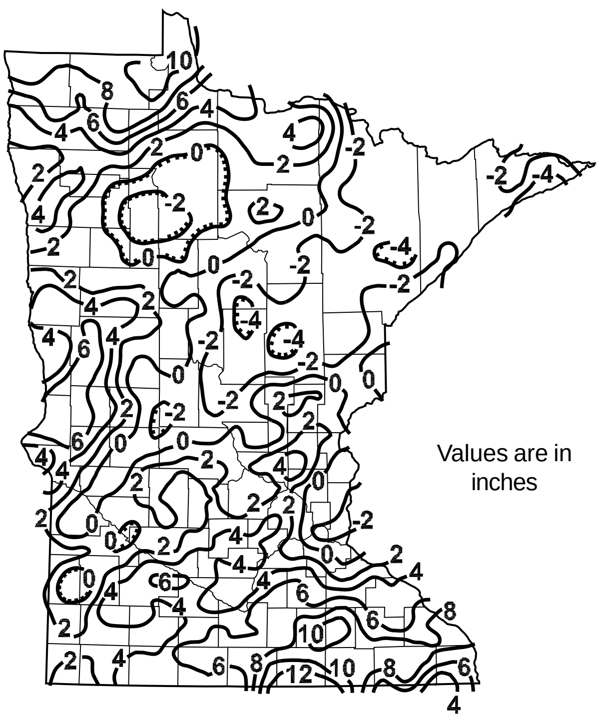


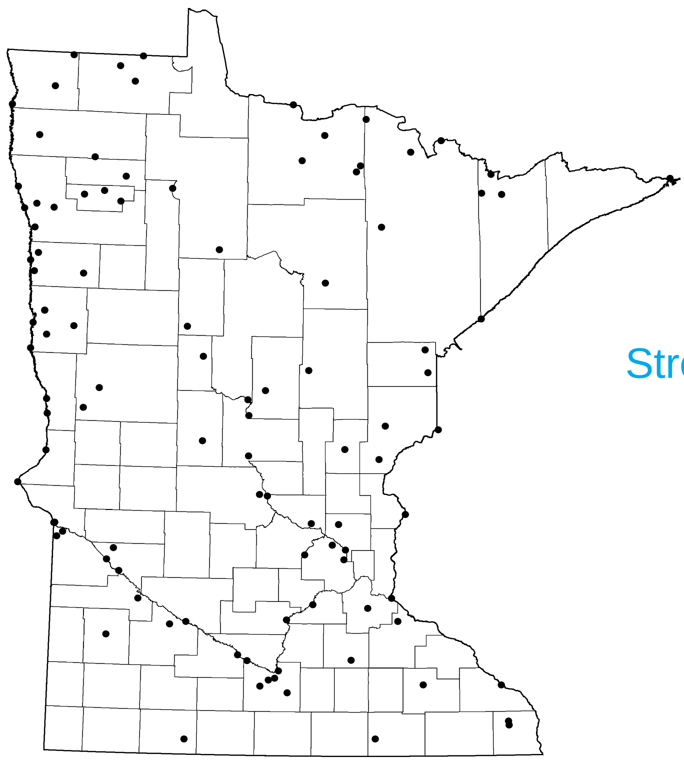
Figure 12

Water Year Precipitation
Departure from Normal
October 2003 - September 2004

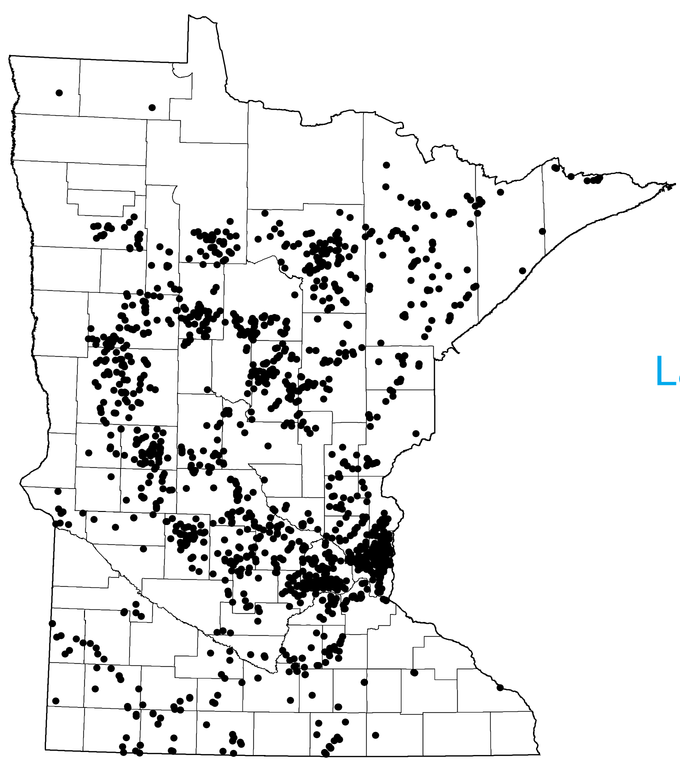


chapter two

surface water



Stream Gage Network
2004
(101 Gages)



Lake Gage Network
2004
(984 Gages)

Stream Flow

Introduction

The Stream Hydrology Unit is responsible for collecting, analyzing and distributing 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 sidebar).

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, as well as for the development of municipal and industrial works.

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.

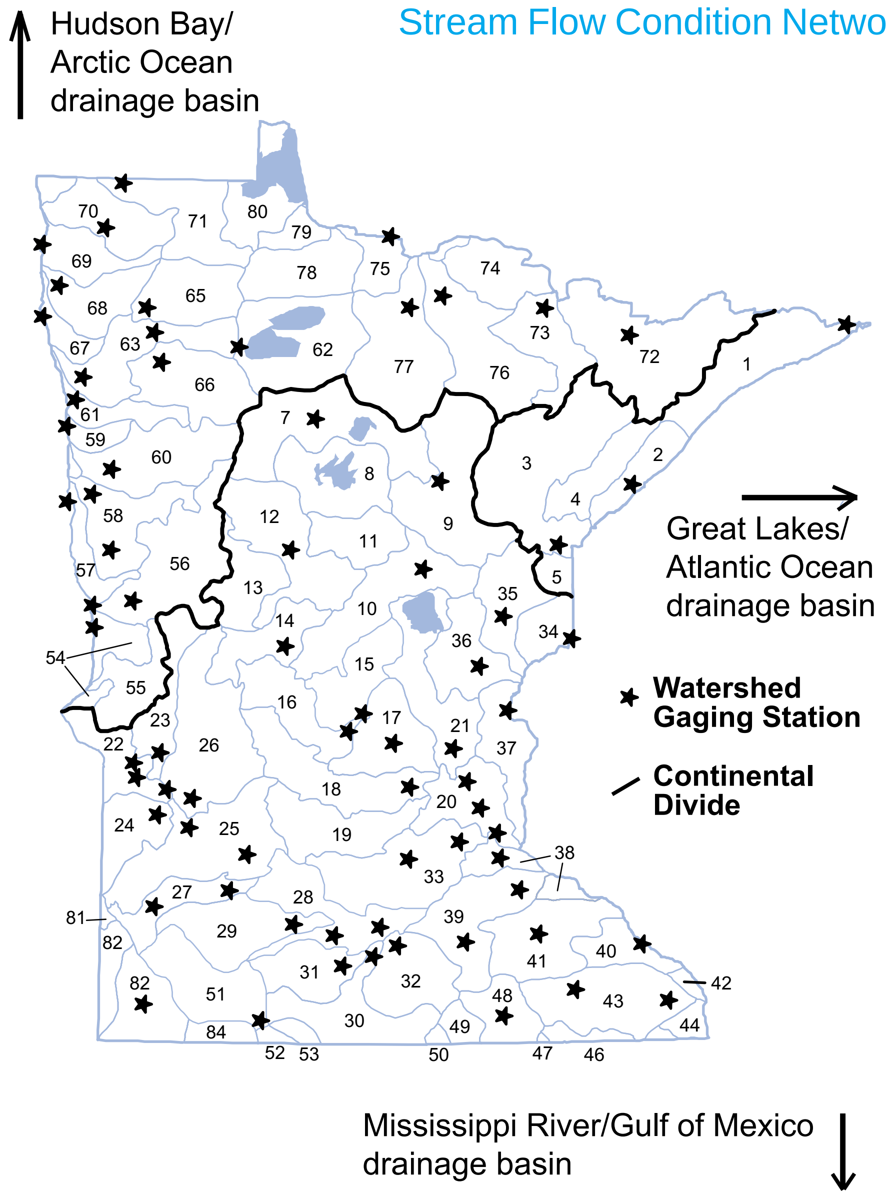
Stream flow reports are based upon the following exceedence values during the open water season.

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

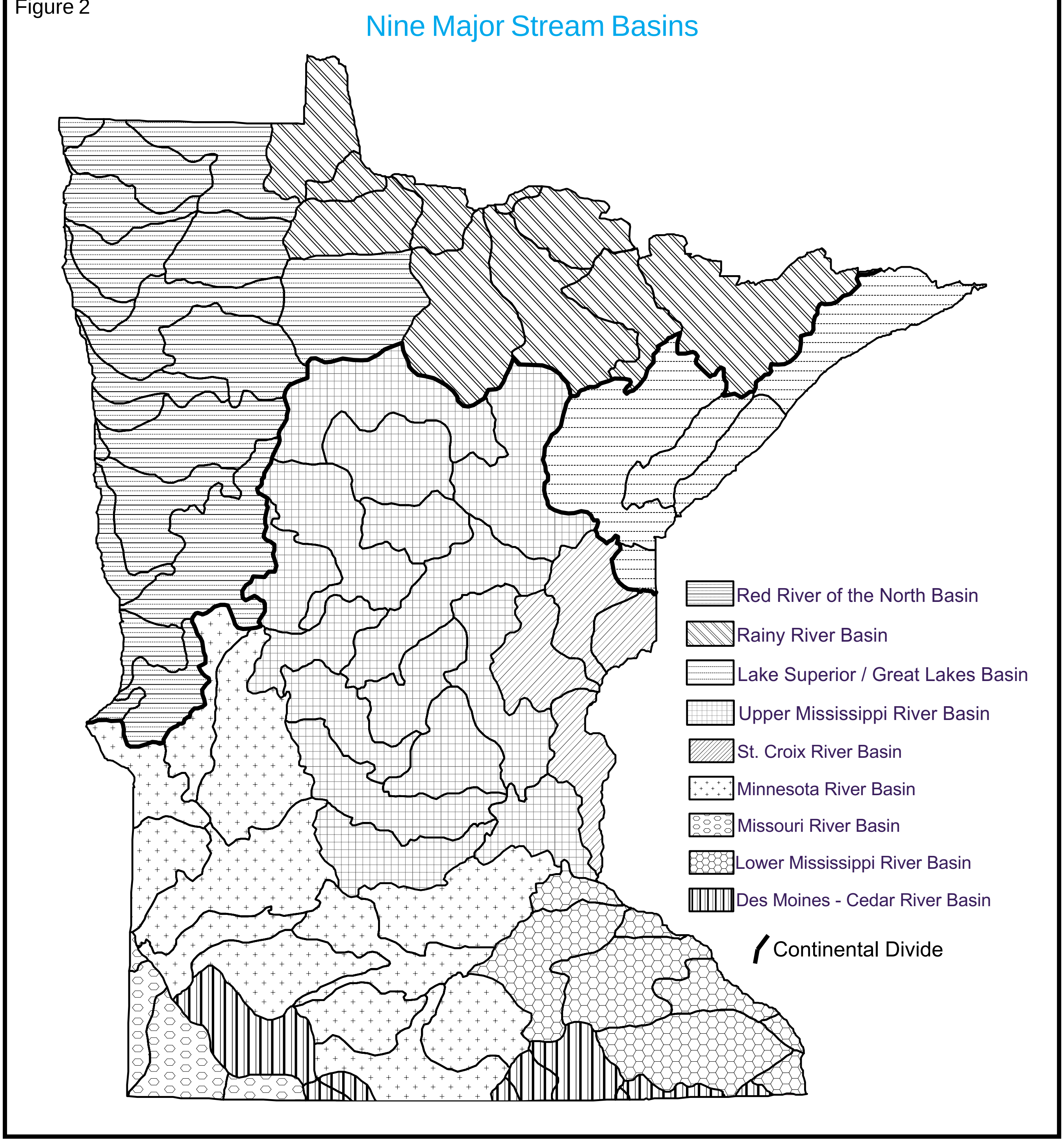
Figure 1

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 streams in the southeast blufflands.

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.

Water Year 2003

Stream flow conditions at the end of Water Year 2002 were generally in the high or the high side of normal range. The exception was along the Canadian border in the northeast where flows were in the protected range.

Due to below-normal snowfall totals (statewide) during the winter of 2002-2003, April 2003 stream flows for approximately half of the state were in the low range, and were on the dry side of normal for the rest of the state. As April progressed into May, increased precipitation moved stream flow conditions for the southern half of the state into the normal range, and a few streams into the high range. Spring flooding, which was somewhat common in the past decade, generally did not occur although minor flooding was observed in the Cannon River and the lower St. Croix River watersheds.

By early June, most of the state experienced normal stream flow conditions. The exceptions were the Mississippi River headwaters with very low (protected) flows, and the Mississippi in the central part of the state with high flow conditions. As June progressed, conditions in the central part of Minnesota regressed to normal, while the dry Mississippi River headwaters area expanded to include most of the northeast.

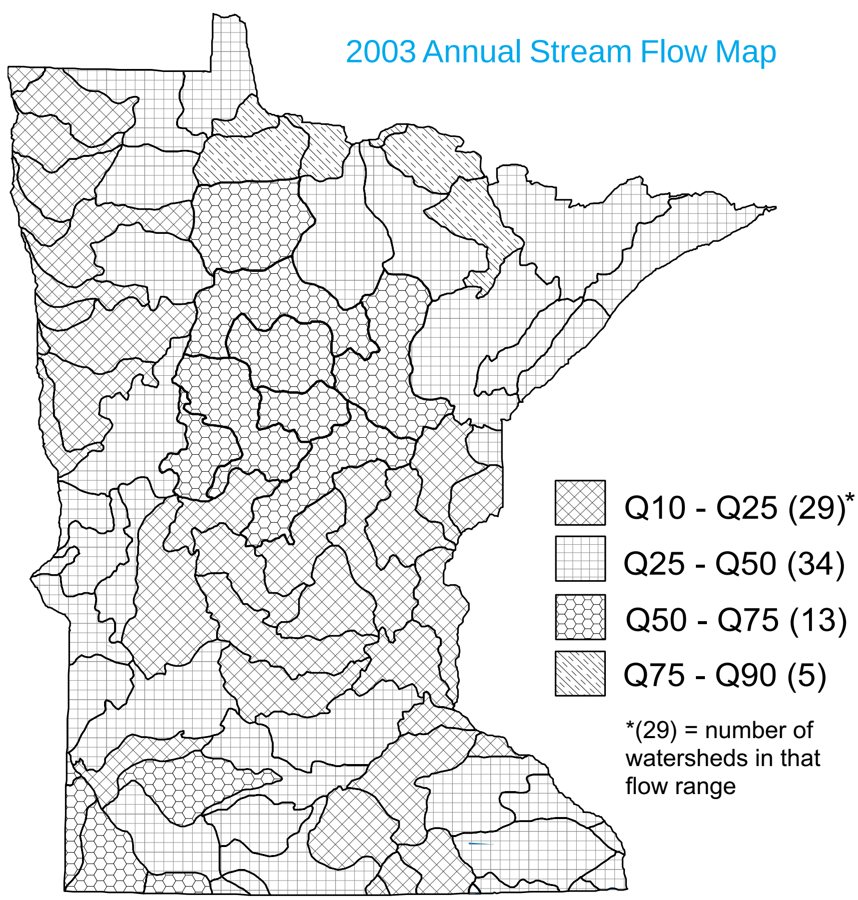
Major storms occurred over much of central Minnesota in late June, including the lower two-thirds of the Red River Valley. As a result, stream flows quickly moved into the high range for much of the state, and flooding was observed at several sites in the headwaters of the Red River, the Twin Cities metropolitan area and the Long Prairie River. Conditions would remain above flood stage for almost a month in the Long Prairie River watershed.

Throughout July, stream flow conditions in the high-flow areas of the state gradually receded into the normal range, while other rivers continued to experience normal flows. However, by mid-August, low and protected flow conditions returned to the upper Mississippi River basin, extending into the northeast. Additional low and protected flows occurred in the Minnesota River basin by the end of August.

Low flow conditions dominated the early half of September, with 27 watersheds in the protected flow range and 21 in the low flow range on September 8. The protected flow conditions were predominantly located in the Upper Mississippi River basin and in the St. Louis River basin. Rains improved conditions slightly by mid-month for much of the state, but protected flow conditions remained in the Mississippi River headwaters well into winter.

Figure 3 is the annual stream flow map for Water Year 2003. By definition, the range of stream flow conditions from Q25 to Q75 is classified as the "normal" flow range. For 2003, the normal flow range was divided into the Q25 to Q50 range and the Q50 to Q75 range to differentiate those watersheds that were on the wet side of normal from those on the dry side of normal. Those watersheds in the high flow range, predominantly the Mississippi River below the headwaters and the Red River of the North watersheds, moved into the high flow range primarily as a result of the heavy rains in late June.

Figure 3



Water Year 2004

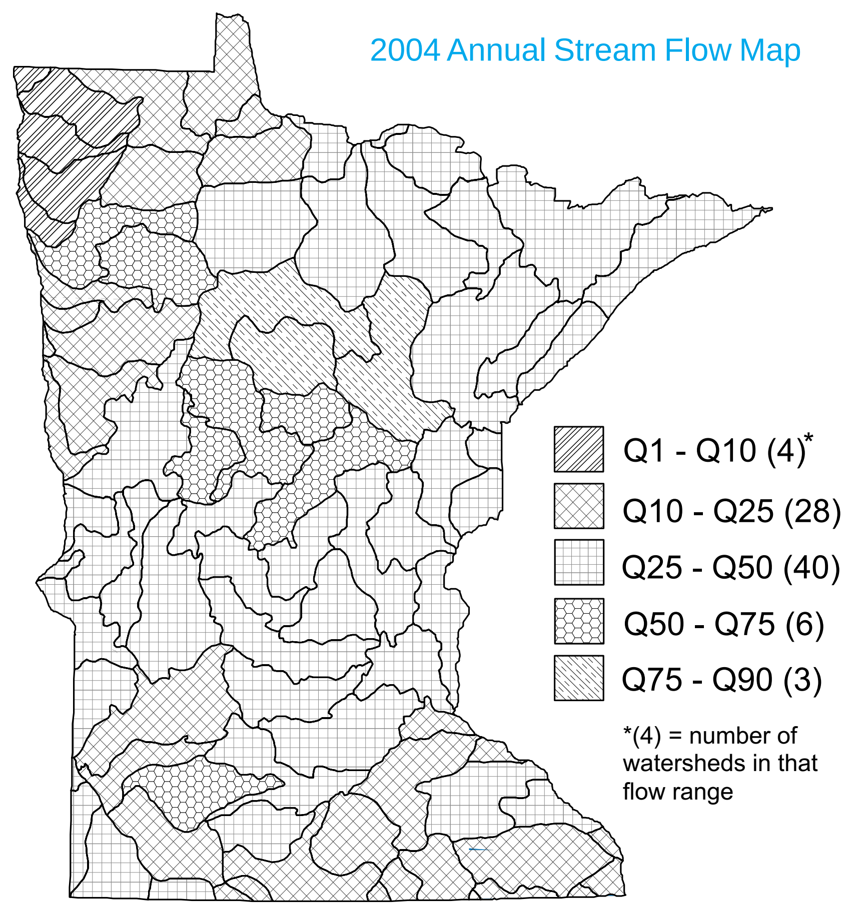
April 2004 stream flow conditions were in the normal range over Minnesota. However, some high flows and flooding occurred in the northwest corner of the state and some low flows occurred in the upper Minnesota River basin and in the lower Mississippi River basin. Stream flow conditions remained in the low to normal ranges well into May, although conditions for most of the state could be found in the normal range by late May. Heavy rains in the upper portion of the Red River of the North produced flooding in that part of the state for the remainder of the month.

Heavy rains over much of the state in May continued the flooding in the northwest, and moved most of the remainder of the state into the high flow range in early June. As June diminished, stream flows declined. By the end of June, low flow conditions returned to much of the upper Mississippi River and Great Lakes watersheds, while normal to high flow conditions could be found in the southern half of the state.

Normal conditions existed throughout much of the state in July, with an occasional low flow in the north. However, a series of strong thunderstorms in northern Iowa created high flow conditions in the watersheds along the Minnesota-Iowa border well into August. A lack of precipitation for most of August caused stream flows to fall into the protected range in the northern half of the upper Mississippi River basins and much of the notheast. In early September, weather patterns changed and precipitation occurred over much of the state. Stream flows improved from slightly higher than normal in the early days to high flows statewide by the end of the month.

Figure 4 is the annual stream flow map for Water Year 2004. A high (Q10-Q25) to very high (Q1-10) flow region existed in the Red River of the North watershed as a result of May and June storms, while a second zone of high flows occured along the Iowa border due to July storms. Average flows, on the low side of normal (Q50-Q75) to low flows (Q75-Q90), could be found in the upper Mississippi River basin. Flows for the remainder of the state averaged in the normal range.

Figure 4



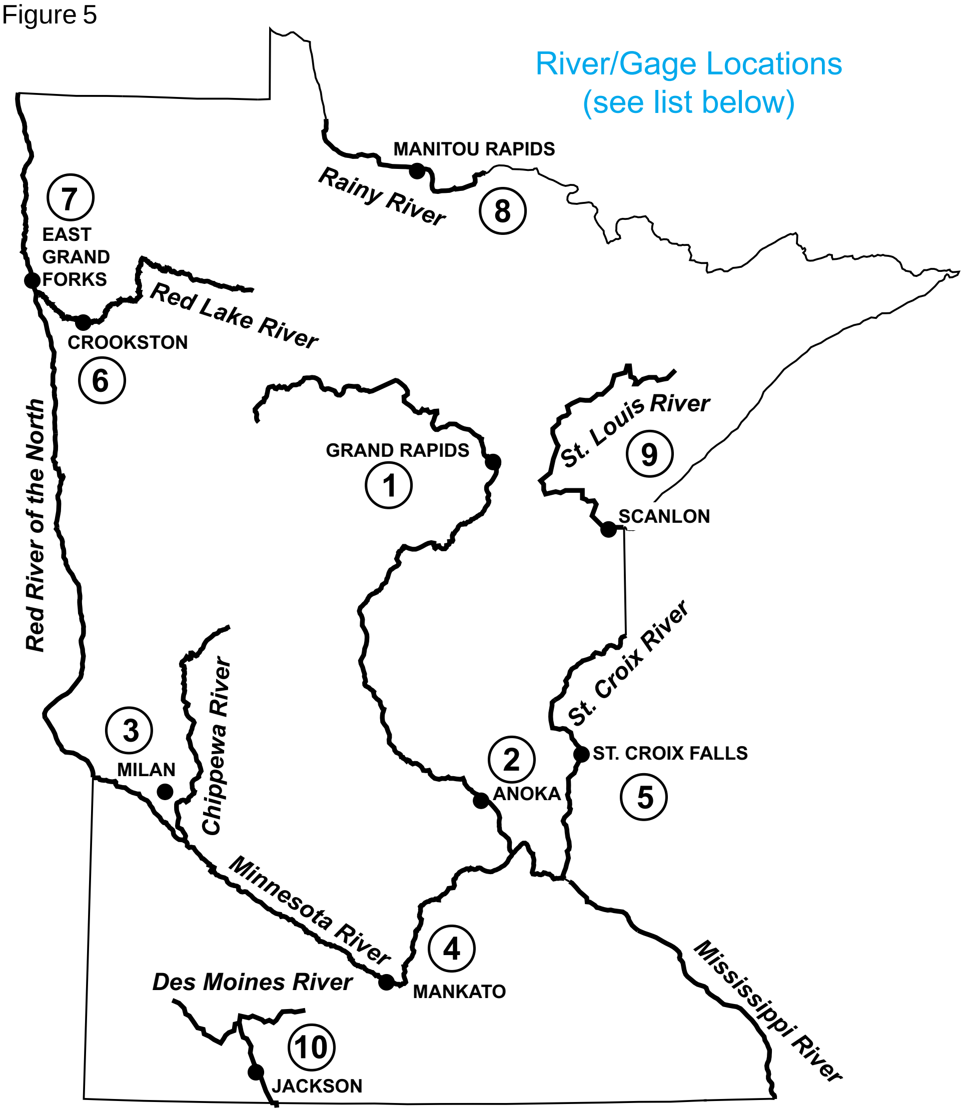
Hydrographs

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.

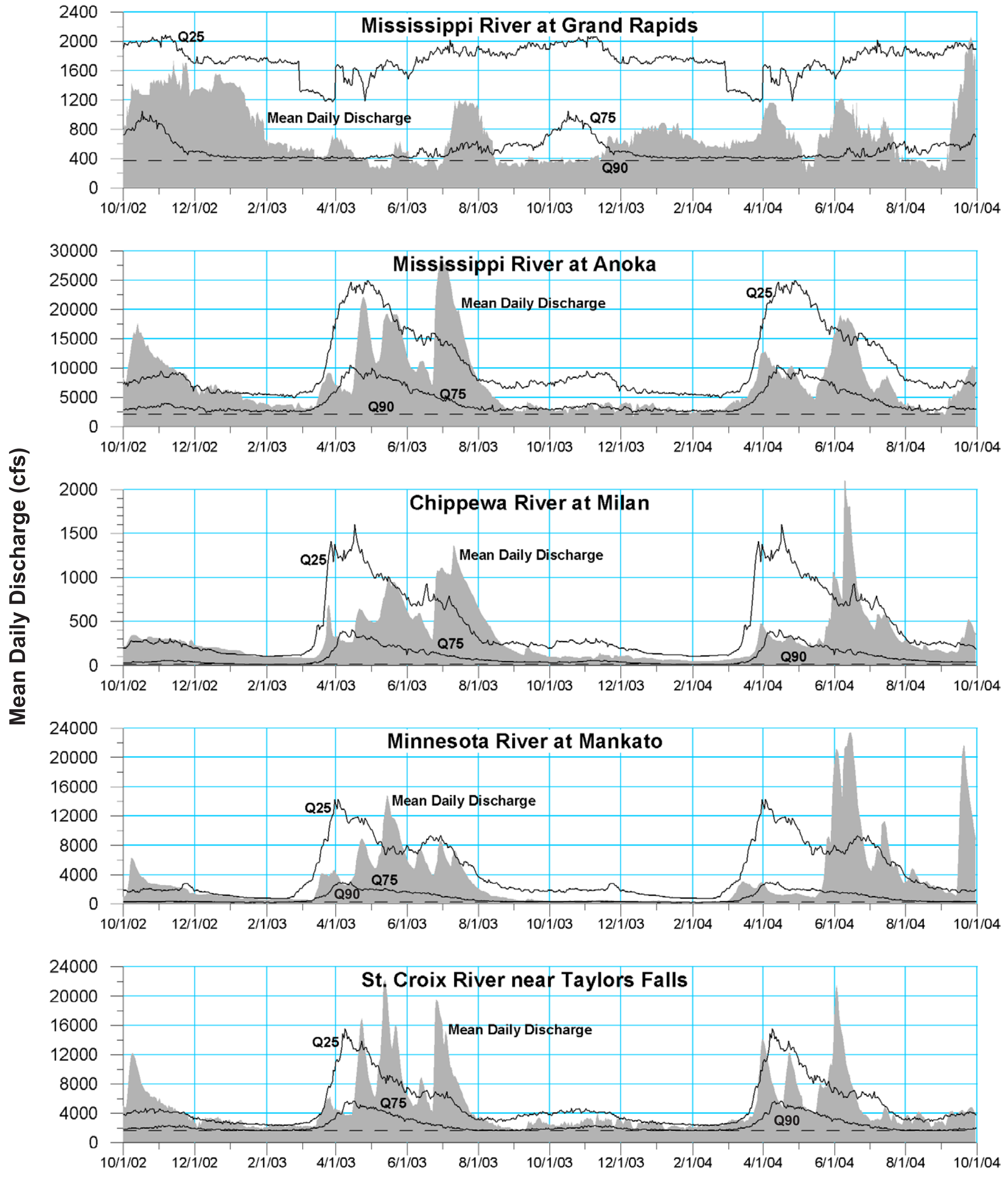
Figures 7 and 9 are period of record hydrographs for the same ten sites. The hydrographs show the average annual volume of water discharged during the water year, the annual Q25 and Q75 exceedence values and a 30-year moving average of the annual discharges. The 30-year moving average shows the trend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

Figure 5



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

Figure 6



October 1, 2002 to September 30, 2004

Figure 7

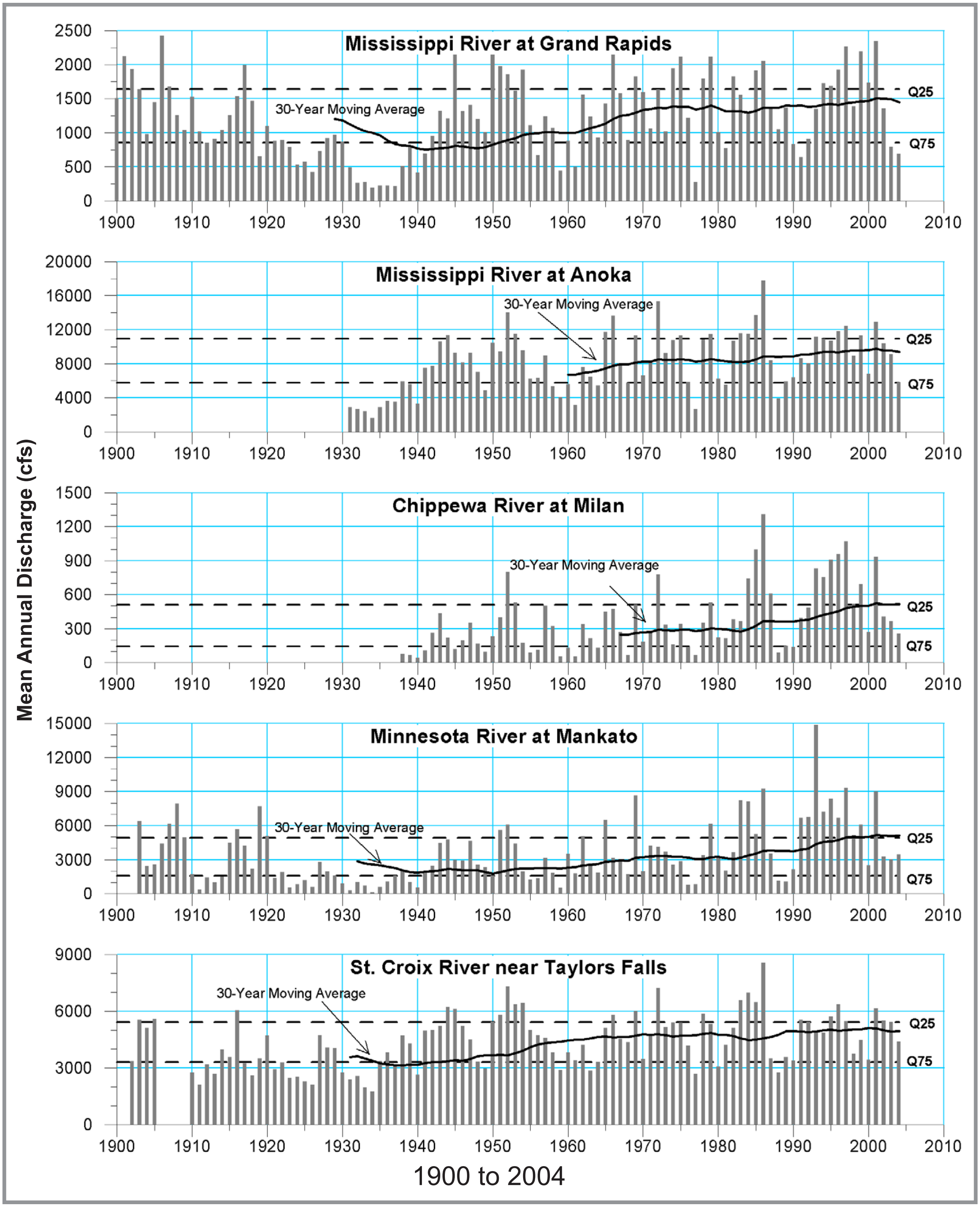

Mississippi River at Grand Rapids
Mississippi River at Anoka
Chippewa River at Milan
Minnesota River at Mankato
St. Croix River near Taylors Falls
30-Year Moving Average
Q25
Q75
Mean Annual Discharge (cfs)
1900 to 2004

Figure 8

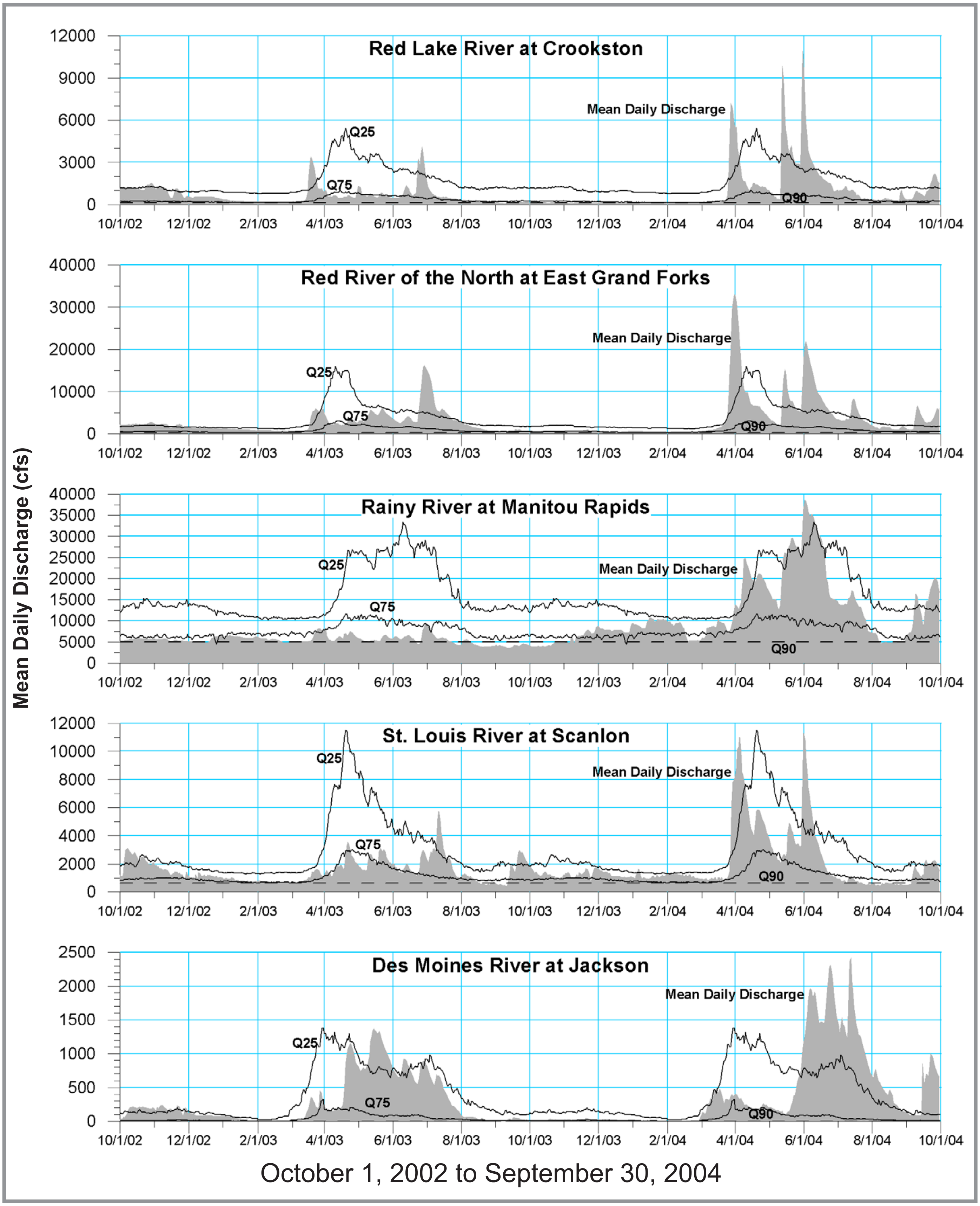
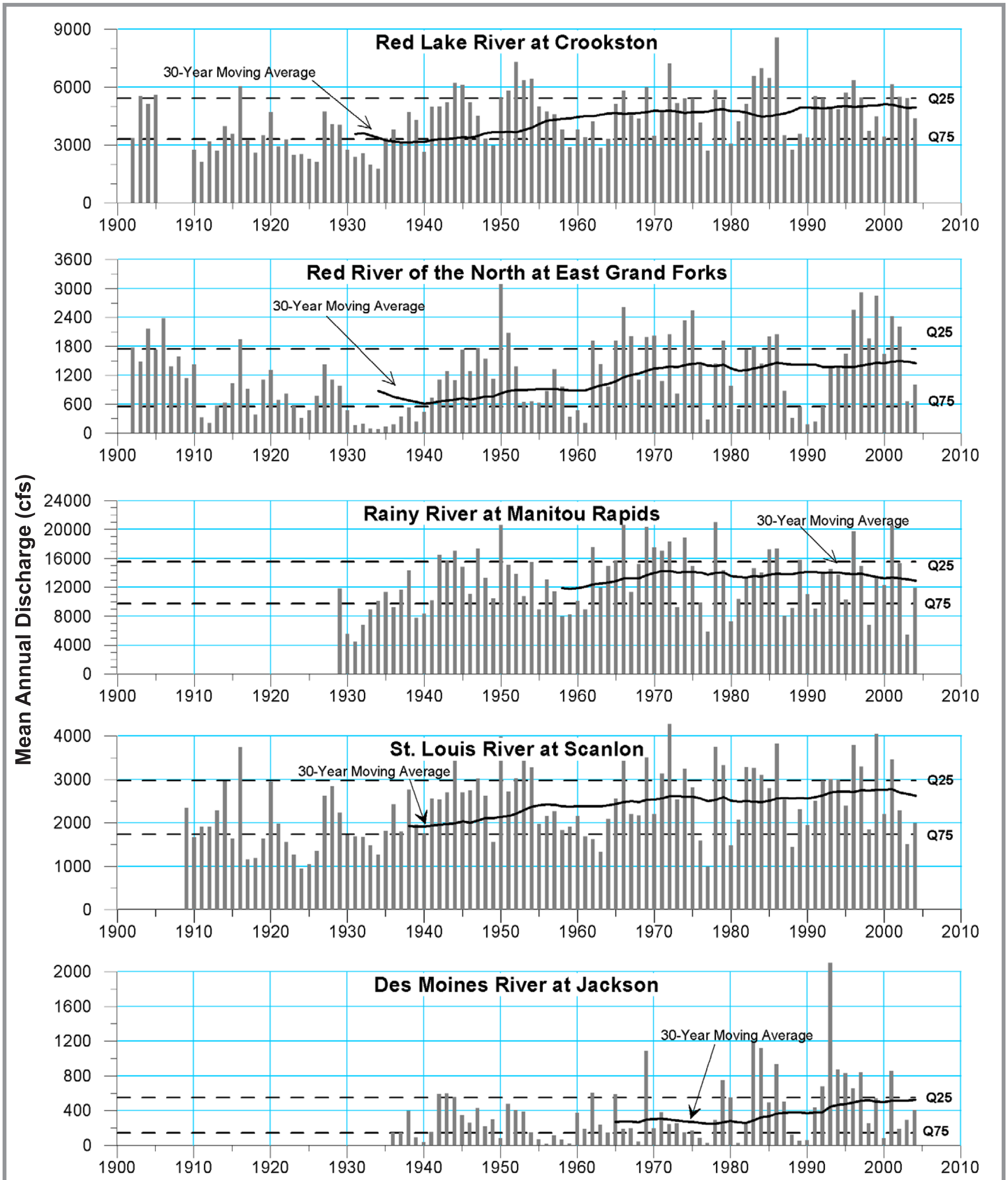

Mean Daily Discharge (cfs)
Red Lake River at Crookston
Red River of the North at East Grand Forks
Rainy River at Manitou Rapids
St. Louis River at Scanlon
Des Moines River at Jackson
Mean Daily Discharge
Q25
Q75
Q90
10/1/02
12/1/02
2/1/03
4/1/03
6/1/03
8/1/03
10/1/03
12/1/03
2/1/04
4/1/04
6/1/04
8/1/04
10/1/04
October 1, 2002 to September 30, 2004

Figure 9



1900 to 2004

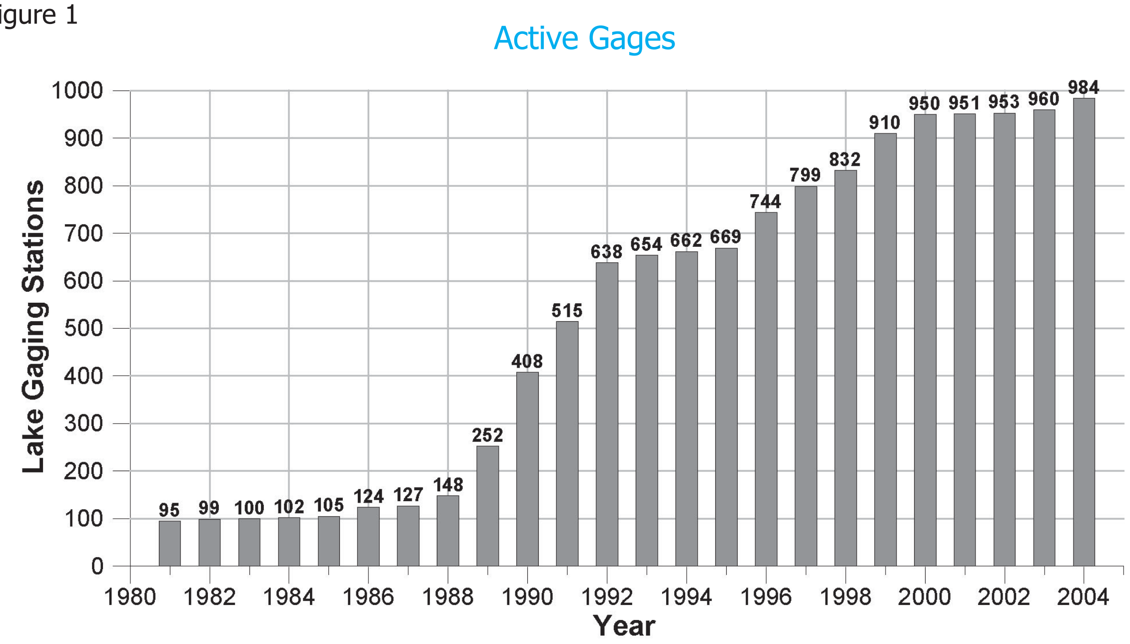
Lake Levels

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 and snow). Other factors that contribute to water level changes are outlet conditions, beaver dams, ground water movement and watershed characteristics. 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 help watershed management authorities and other governmental units to prepare 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 2004 by citizen volunteers and cooperative organizations (Figure 1). 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



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 duplication of efforts, DNR Waters has initiated cooperative programs with these organizations. This component of LLM accounts for approximately 300 lakes.

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 (Figure 2).

Lake Level Trends

November 2002 through March 2003 was one of the driest five-month periods in Minnesota's climate history. In response to the lack of precipitation, many lakes throughout the state receded to low water levels. Others were at their all-time recorded low water levels, including many in the north and northeast.

On the heels of this dry spell another three-month dry period, from mid-July through mid-October 2003, intensified across most of central and southern Minnesota. Rainfall totals ranked among the lowest on record in many areas of central, south central and southeastern Minnesota. Lake levels continued to drop significantly across the entire region and many additional lakes experienced their lowest recorded water levels. However, several isolated thunderstorms in late June and early July in west central Minnesota elevated many lakes to their highest recorded water levels, including approximately 30 lakes in the Alexandria and Brainerd areas.

Precipitation increased in 2004 and lake levels rebounded across the state, except in the northeast. Total precipitation for the April through October period exceeded 30 inches across most of southern Minnesota. Contributing to the totals were two extraordinarily wet months, May and September. As a result, much of the state exhibited saturated soils and many lakes, particularly in central and southern locations, returned to more average water levels.

Figure 2

Lake Level Data on the DNR Website

Storing and Retrieving Data
Lake level readings received from volunteers and organizations are entered into Lakes-DB©, a data base program for easy management and access of recorded lake levels and other useful information.

“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 sample lake below).

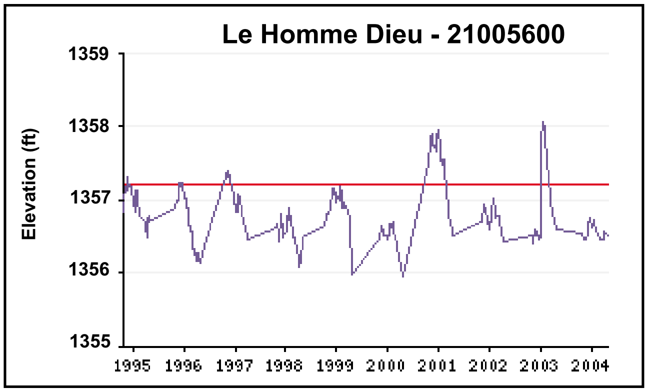
Most of the recorded water levels for each lake are collected by volunteers involved with the Lake Level Minnesota program. DNR Waters presently has water level information (10 or more readings) for approximately 4000 lakes.

Lake Name: Le Homme Dieu

County: Douglas

Water Level Data

Period of record: 05/1/1991 to 10/12/2004
# of readings: 474
Highest recorded: 1358.06 ft (07/10/2003)
Lowest recorded: 1355.78 ft (10/19/1992)
Recorded range: 2.28 ft
Average Water Level: 1356.83 ft
Last reading: 1356.50 ft (10/12/2004)
OHW elevation: 1357.20 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 appropriate link and choosing the “Save...As” option.)

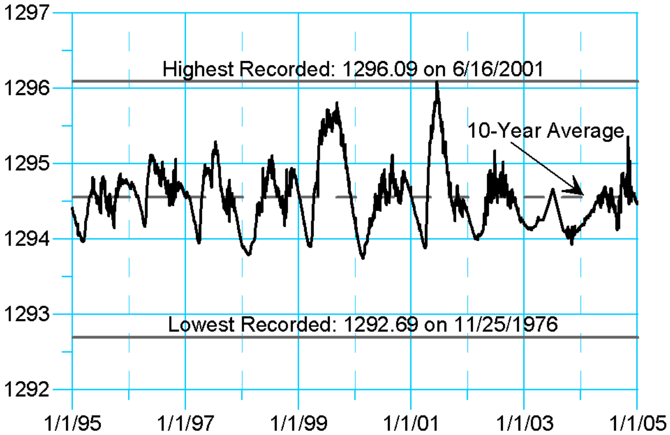
Benchmarks

Elevation: 1366.73 ft **Date Set:** 07/09/1985
Datum: 1929 (ft)

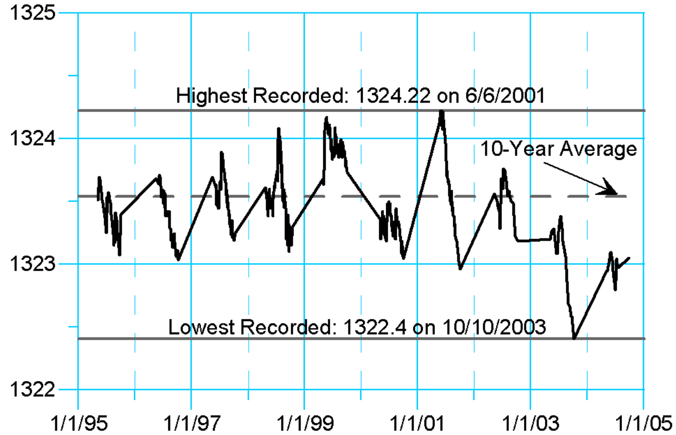
Benchmark Location
Township: 129 Range: 37 Section: 32

Description: Top of concrete ledge at SE corner of bridge, directly below SW corner of south concrete guardrail (BM + 2.71’ to corner of guardrail).

Leech Lake (11-203) Cass County

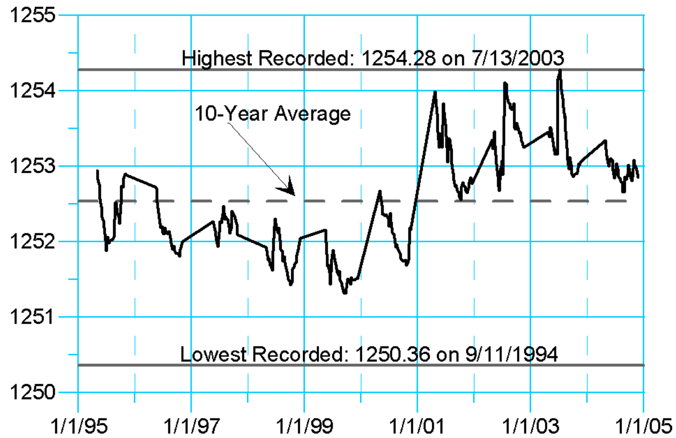


Woman Lake (11-201) Cass County

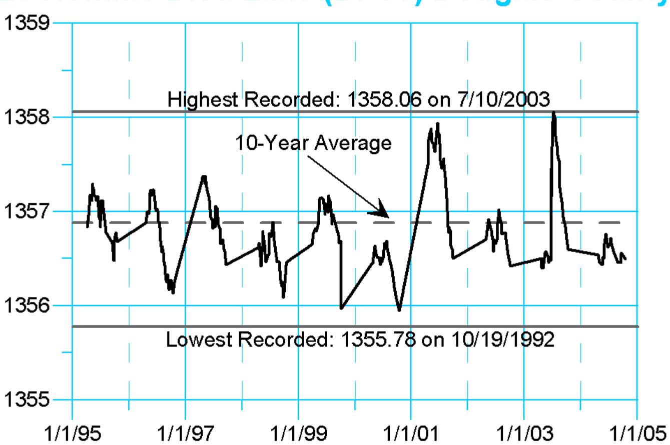


Lake Level Trends

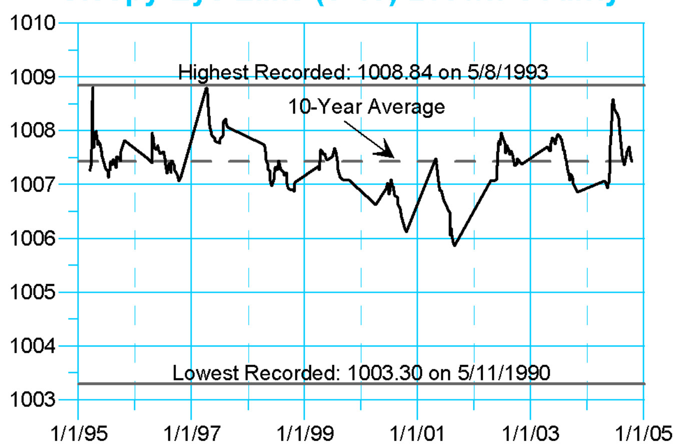
Whitefish Lake (18-1) Crow Wing County



Le Homme Dieu Lake (21-56) Douglas County



Sleepy Eye Lake (8-45) Brown 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 29 represent water levels for five landlocked basins that have receded a bit, largely due to the exceptionally dry conditions in 2003.

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.

The lakes graphed on pages 30 and 31 show levels generally receding toward (and below) normal in Water Year 2003 in response to below-average precipitation (see Figure 6 on page 6). Many lakes rebounded in Water Year 2004 in response to above-normal precipitation across most of the state (see Figure 12 on page 12).

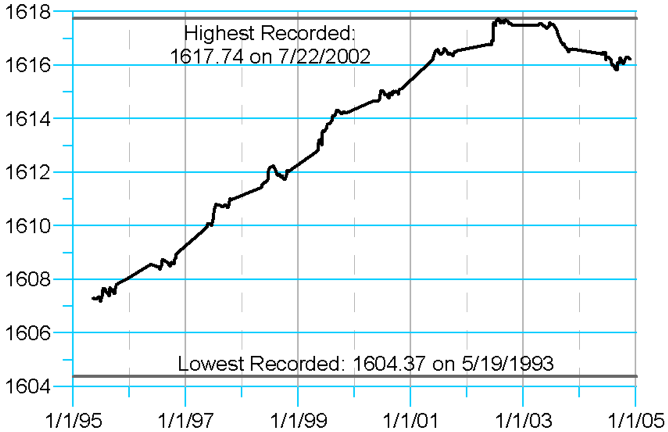
Annual Lake Level Fluctuation

Minnesota lakes typically fluctuate one to two vertical feet in a given year, but historical fluctuations have been recorded in excess of ten feet. Statewide average fluctuation for Water Year 2003 was 1.42 feet, while average fluctuation during Water Year 2004 was 1.24 feet (averages for the past ten years are shown in Figure 3). The tables on pages 32 to 38 display fluctuations for Water Year 2003, Water Year 2004, an average fluctuation for the indicated period of record and the range between the historical high and low.

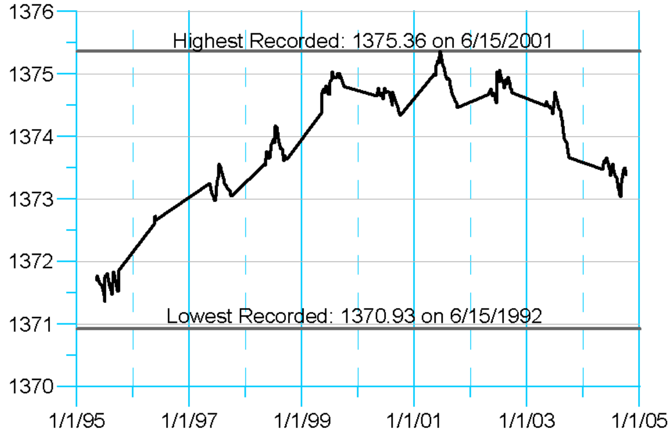
Figure 3

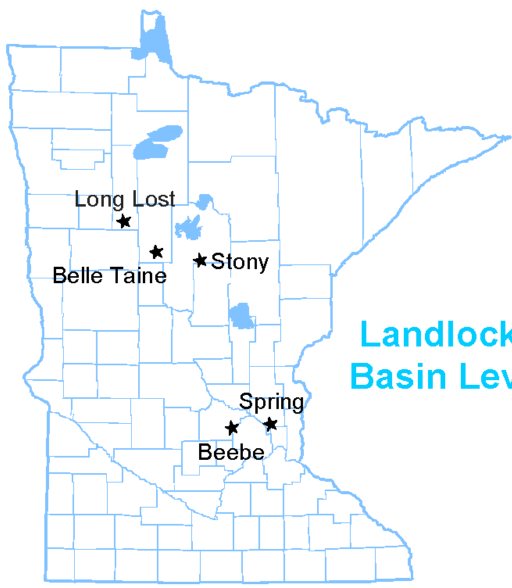
Water Year	Average Fluctuation Statewide (ft)
1995	1.03
1996	1.24
1997	1.55
1998	1.04
1999	1.24
2000	1.05
2001	1.97
2002	1.33
2003	1.42
2004	1.24

Long Lost Lake (15-68) Clearwater County



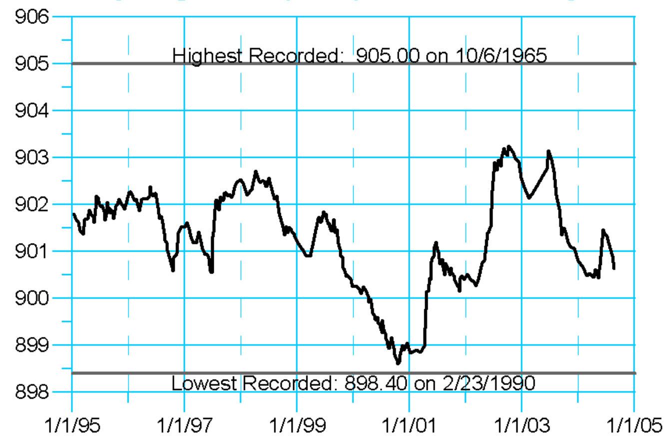
Stony Lake (11-371) Cass County



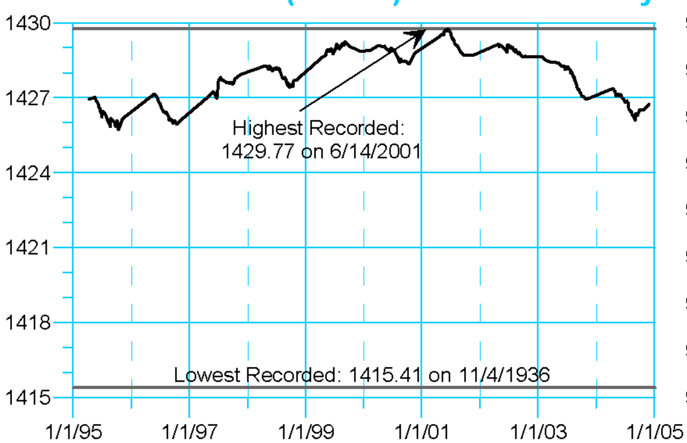


Landlocked Basin Levels

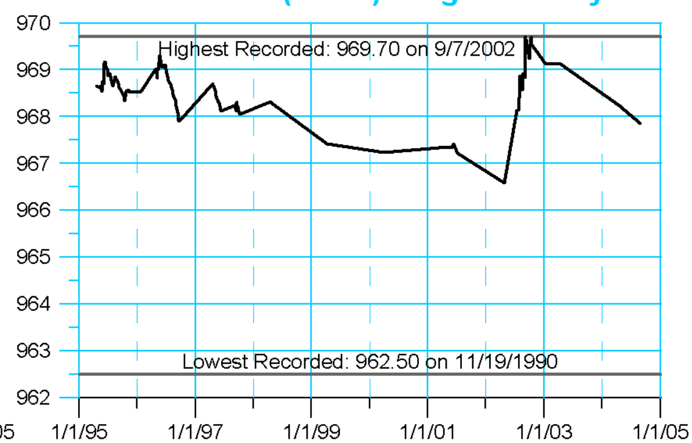
Spring Lake (2-71) Anoka County



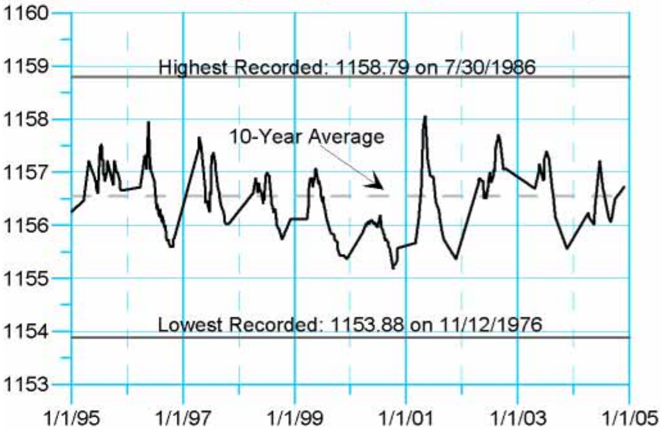
Belle Taine Lake (29-146) Hubbard County



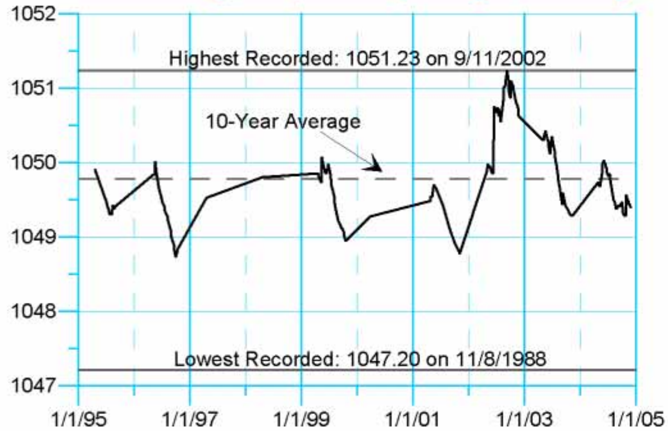
Beebe Lake (86-23) Wright County



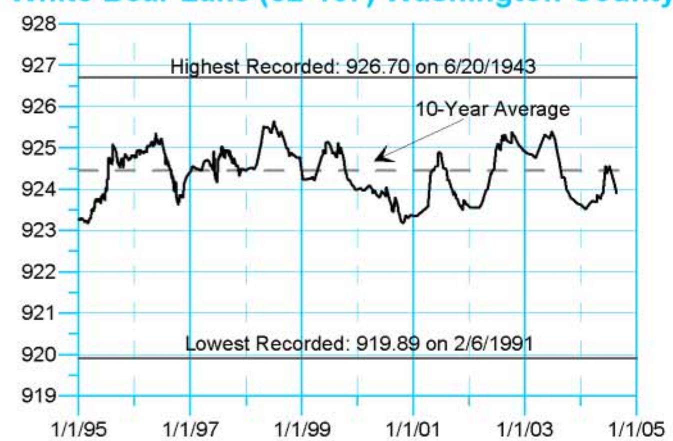
Green Lake (34-79) Kandiyohi County



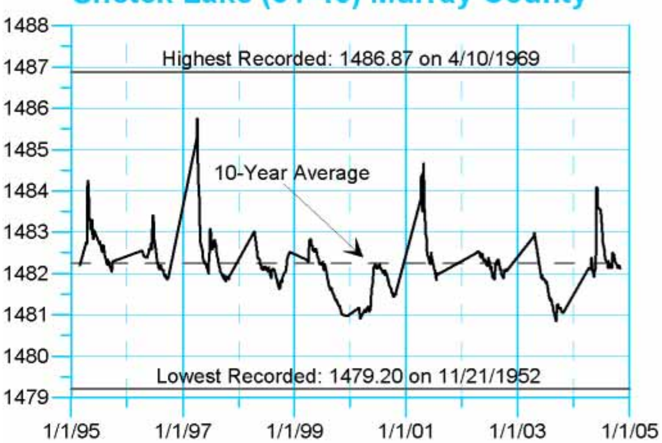
East Lake Sylvia (86-289) Wright County



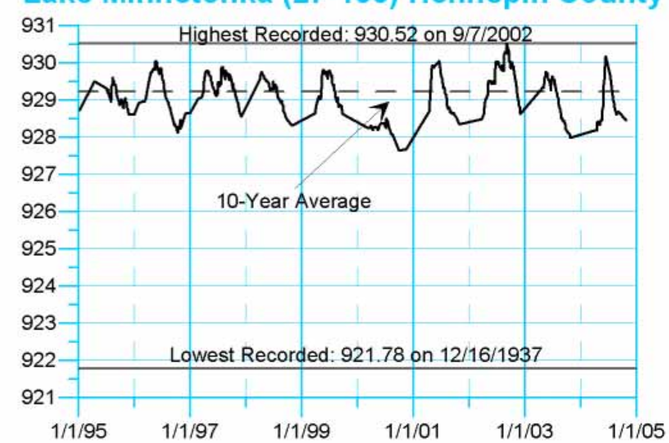
White Bear Lake (82-167) Washington County



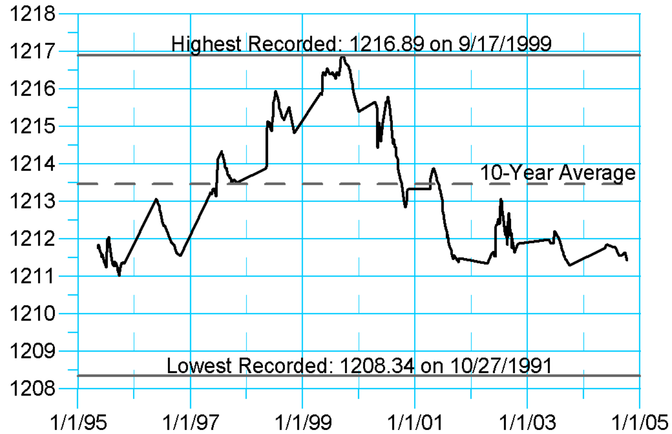
Shetek Lake (51-46) Murray County



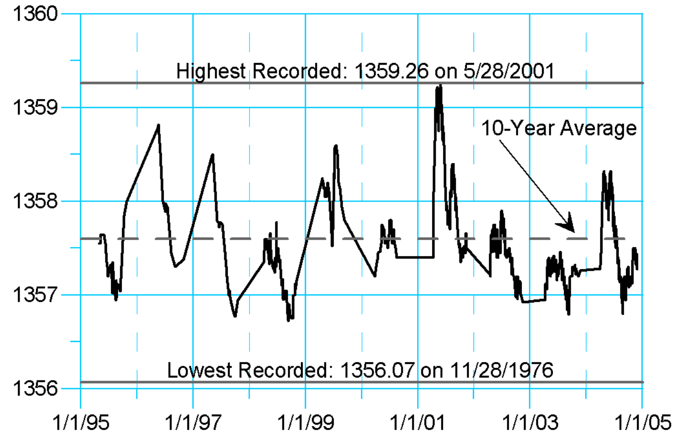
Lake Minnetonka (27-133) Hennepin County

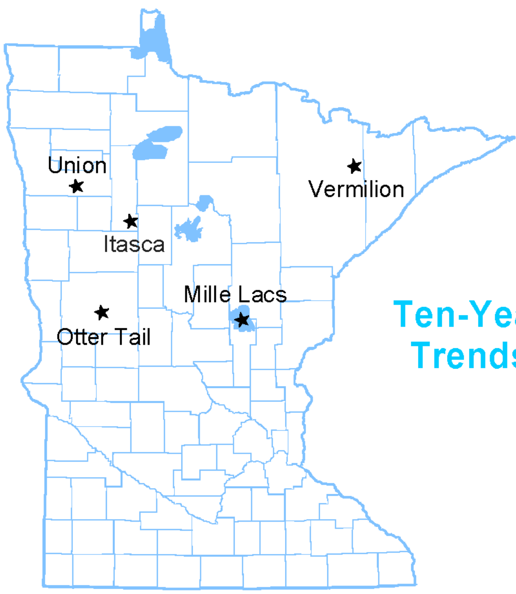


Union Lake (60-217) Polk County



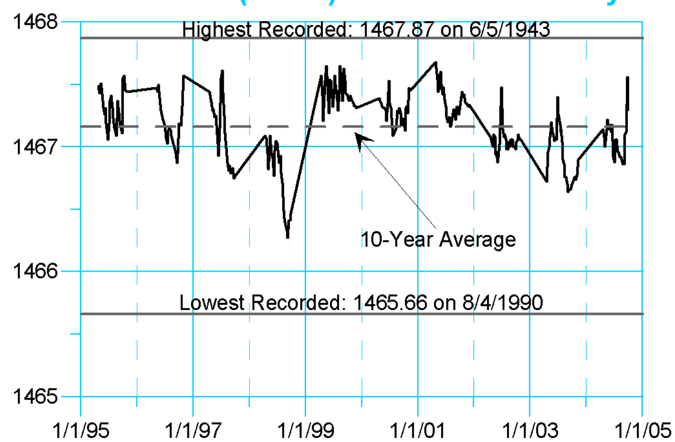
Vermilion Lake (69-378) St. Louis County



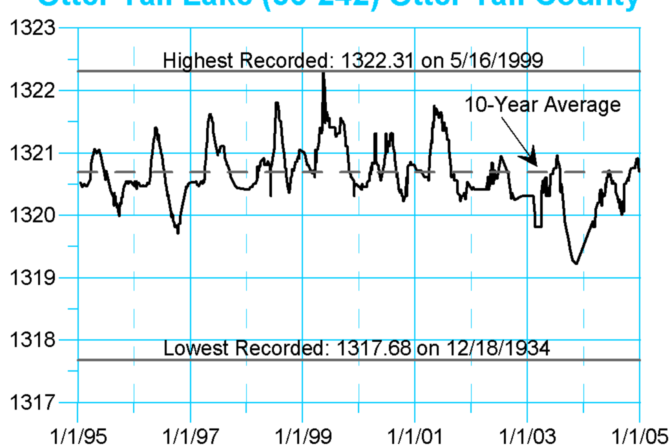


Ten-Year Trends

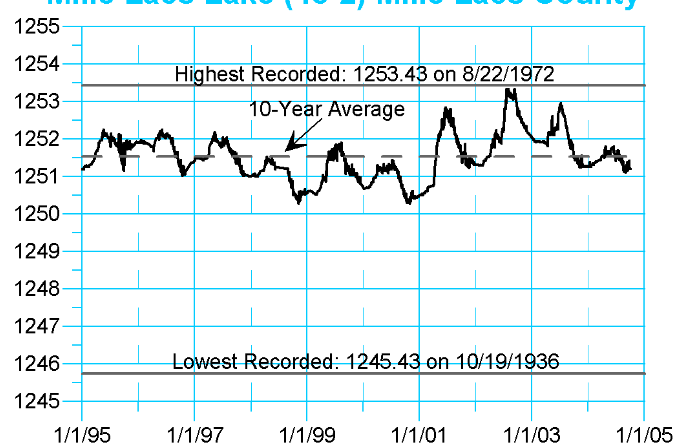
Lake Itasca (15-16) Clearwater County



Otter Tail Lake (56-242) Otter Tail County



Mille Lacs Lake (48-2) Mille Lacs County



Annual Lake Level Fluctuation (feet)

Lake Name	WY03	WY04	WYAv.	#Yrs.	Range
AITKIN COUNTY					
Blackface (1-45)	1.03	0.59	0.76	(13 yrs.)	1.53
Cedar (1-209)	1.26	0.94	1.66	(53 yrs.)	4.02
Clear (1-93)	0.73	0.49	0.85	(34 yrs.)	4.39
Dam (1-96)	1.66	1.26	1.30	(21 yrs.)	2.77
Davis (1-71)	2.92	1.45	2.76	(7 yrs.)	4.53
Elm Island (1-123)	2.10	0.59	1.60	(11 yrs.)	2.84
Farm Island (1-159)	1.10	0.58	1.08	(27 yrs.)	3.64
Fleming (1-105)	1.06	0.75	0.82	(14 yrs.)	1.93
French (1-104)	0.94	1.30	1.32	(7 yrs.)	3.52
Hanging Kettle (1-170)	1.76	0.50	1.49	(19 yrs.)	3.77
Lone (1-125)	0.73	0.52	0.72	(14 yrs.)	4.65
Long (1-101)	0.64	0.32	0.54	(12 yrs.)	1.40
Minnewawa (1-33)	0.60	0.54	0.83	(22 yrs.)	1.82
Rabbit (1-91)	0.65	0.70	0.91	(13 yrs.)	1.72
Rat (1-77)	1.27	1.22	1.11	(12 yrs.)	4.29
Rock (1-72)	0.87	0.64	0.82	(11 yrs.)	2.05
Round (1-23)	0.56	0.46	0.63	(12 yrs.)	1.43
Sugar (1-87)	0.76	0.49	0.72	(34 yrs.)	2.65
Waukenabo (1-136)	0.50	0.78	1.34	(23 yrs.)	4.34
Wilkins (1-102)	0.68	0.75	0.83	(8 yrs.)	2.51
ANOKA COUNTY					
Baldwin (2-13)	4.62	4.11	3.21	(30 yrs.)	6.86
Bunker (2-90)	1.58	0.79	1.81	(19 yrs.)	7.87
Coon (2-42)	1.05	1.11	1.11	(36 yrs.)	4.84
Crooked (2-84)	1.17	0.76	0.98	(20 yrs.)	3.40
Fawn (2-35)	0.94	0.70	1.03	(16 yrs.)	4.64
George (2-91)	0.82	1.27	1.21	(19 yrs.)	6.14
Golden (2-45)	1.04	1.09	0.91	(16 yrs.)	2.44
Ham (2-53)	1.37	0.75	1.24	(20 yrs.)	4.78
Howard (2-16)	1.59	1.52	1.10	(15 yrs.)	2.46
Itasca (2-110)	1.09	0.72	1.62	(15 yrs.)	8.25
Laddie (2-72)	1.54	1.20	1.21	(13 yrs.)	4.19
Linwood (2-26)	1.09	0.88	0.75	(28 yrs.)	2.29
Martin (2-34)	1.50	1.36	1.22	(26 yrs.)	4.08
Moore (2-75)	1.29	1.34	1.01	(16 yrs.)	2.06
Netta (2-52)	1.25	0.79	1.25	(21 yrs.)	5.56
Otter (2-3)	1.04	1.54	1.62	(82 yrs.)	6.72
Pet (2-36)	0.79	0.80	1.12	(9 yrs.)	3.41
Reshanau (2-9)	1.73	2.43	2.01	(15 yrs.)	4.54
Rice (2-8)	4.62	4.11	3.50	(16 yrs.)	6.64
Rogers (2-104)	1.20	0.84	1.53	(16 yrs.)	5.35
Rondeau (2-15)	1.38	1.22	1.04	(13 yrs.)	1.94
Round (2-89)	1.31	0.74	1.24	(20 yrs.)	5.93
Sand Shore (2-102)	1.02	0.94	1.03	(13 yrs.)	2.41
Sandy (2-80)	1.45	0.73	1.46	(13 yrs.)	3.44
Spring (2-71)	1.90	1.07	1.63	(50 yrs.)	6.60
BECKER COUNTY					
Bad Medicine (3-85)	1.05	0.70	0.90	(18 yrs.)	6.99
Big Cormorant (3-576)	0.95	1.60	1.09	(39 yrs.)	10.30
Big Sugar Bush (3-304)	1.25	0.50	0.99	(10 yrs.)	4.76
Cotton (3-286)	0.92	0.74	0.97	(38 yrs.)	5.15
Detroit (3-381)	1.24	0.94	0.95	(26 yrs.)	2.44
Elbow (3-159)	0.73	1.19	1.13	(13 yrs.)	3.73
Eunice (3-503)	1.02	0.99	0.64	(14 yrs.)	1.55
Fox (3-358)	0.61	0.46	0.36	(11 yrs.)	0.91
Height of Land (3-195)	1.82	1.36	1.52	(47 yrs.)	4.45
Ida (3-582)	0.94	0.71	0.94	(17 yrs.)	4.50
Island (3-153)	1.02	0.84	0.66	(9 yrs.)	1.74
Juggler (3-136)	1.04	0.78	0.81	(12 yrs.)	5.62
Little Bemidji (3-234)	0.44	1.03	0.90	(9 yrs.)	2.74
Little Cormorant (3-506)	1.10	0.78	0.85	(6 yrs.)	3.81
Little Floyd (3-386)	0.84	1.05	1.01	(22 yrs.)	2.16
Little Toad (3-189)	0.64	0.30	0.62	(11 yrs.)	1.81
Long (3-383)	0.74	0.60	0.52	(18 yrs.)	1.64

Lake Name	WY03	WY04	WYAv.	#Yrs.	Range
(Becker County continued)					
Melissa (3-475)	0.89	1.25	1.07	(29 yrs.)	6.30
Middle Cormorant (3-602)	0.98	0.84	0.77	(9 yrs.)	4.27
Muskrat (3-360)	1.03	1.06	0.90	(31 yrs.)	2.81
Pickerel (3-287)	1.16	0.87	0.98	(13 yrs.)	5.83
Round (3-155)	1.16	1.11	1.23	(22 yrs.)	2.97
Sallie (3-359)	0.96	1.63	1.25	(36 yrs.)	5.58
Straight (3-10)	0.25	0.20	0.47	(19 yrs.)	6.16
Strawberry (3-323)	0.99	0.77	0.91	(6 yrs.)	3.96
Talac (3-619)	0.95	0.95	1.22	(12 yrs.)	9.72
Toad (3-107)	0.80	1.14	1.18	(24 yrs.)	5.20
Turtle (3-657)	1.36	1.34	1.36	(8 yrs.)	6.53
Two Inlets (3-17)	1.15	0.61	1.19	(23 yrs.)	3.91
Upper Cormorant (3-588)	0.93	0.86	1.04	(29 yrs.)	3.89
White Earth (3-328)	1.06	1.42	1.06	(23 yrs.)	3.34
BELTRAMI COUNTY					
Bemidji (4-130)	1.24	1.24	1.80	(21 yrs.)	4.25
Big (4-49)	0.70	0.30	0.93	(7 yrs.)	1.91
Blackduck (4-69)	0.54	0.90	0.65	(7 yrs.)	3.58
Cass (4-30)	1.30	1.15	1.90	(58 yrs.)	4.83
Long (4-76)	0.63	0.80	0.74	(18 yrs.)	2.85
Movil (4-152)	0.56	0.60	0.74	(20 yrs.)	1.91
Pimushe (4-32)	0.65	1.35	1.63	(8 yrs.)	3.22
Stump (4-130)	1.26	1.13	2.16	(21 yrs.)	5.70
Turtle River (4-111)	1.22	1.02	1.76	(32 yrs.)	5.06
Wolf (4-79)	2.36	1.81	2.31	(6 yrs.)	4.04
BIG STONE COUNTY					
Big Stone (6-152)	1.60	1.35	2.40	(35 yrs.)	10.83
East Toqua (6-138)	1.04	1.15	1.44	(14 yrs.)	5.01
BLUE EARTH COUNTY					
Duck (7-53)	0.94	1.86	1.21	(14 yrs.)	3.21
Madison (7-44)	1.10	2.31	1.68	(47 yrs.)	15.98
BROWN COUNTY					
Hanska (8-26)	1.30	1.61	1.99	(12 yrs.)	5.79
Sleepy Eye (8-45)	0.86	1.73	1.44	(17 yrs.)	5.54
Somsen (8-18)	1.64	2.80	3.21	(14 yrs.)	8.93
CARLTON COUNTY					
Bear (9-34)	1.54	1.19	1.26	(7 yrs.)	2.15
Big (9-32)	0.71	0.44	0.65	(12 yrs.)	1.99
Chub (9-8)	1.08	0.60	0.93	(18 yrs.)	3.94
Eagle (9-57)	0.64	0.52	0.72	(12 yrs.)	1.88
Eddy (9-39)	1.95	2.05	2.68	(11 yrs.)	4.55
Hay (9-10)	0.60	0.24	0.90	(7 yrs.)	3.56
Park (9-29)	0.80	0.58	0.74	(14 yrs.)	2.02
Torch Light (9-25)	0.86	0.73	0.91	(12 yrs.)	2.16
CARVER COUNTY					
Assumption (10-63)	1.22	1.61	1.16	(7 yrs.)	1.99
Bavaria (10-19)	1.37	1.40	1.21	(7 yrs.)	2.35
Benton (10-69)	1.20	1.90	1.48	(7 yrs.)	2.31
Berliner (10-103)	0.42	0.98	1.28	(14 yrs.)	3.95
Church (10-46)	1.22	2.22	1.57	(7 yrs.)	3.21
Eagle (10-121)	1.11	1.08	1.25	(7 yrs.)	2.47
Firemen's Clayhole (10-226)	0.78	1.07	0.81	(6 yrs.)	1.58
Goose (10-89)	1.34	1.76	1.49	(7 yrs.)	3.11
Hazeltine (10-14)	1.37	2.10	1.44	(6 yrs.)	3.09
Hydes (10-88)	1.22	1.60	1.06	(11 yrs.)	4.31
Kelser's Pond (10-47)	1.35	2.12	1.27	(7 yrs.)	2.45
Lotus (10-6)	1.28	2.01	1.38	(34 yrs.)	3.90
Maria (10-58)	0.40	0.64	1.03	(7 yrs.)	2.70

Annual Lake Level Fluctuation (feet)

Lake Name	WY03	WY04	WYAv.	#Yrs.	Range
(Carver County continued)					
Meuwissen (10-70)	1.06	1.98	1.68	(7 yrs.)	2.66
Miller (10-29)	1.95	2.81	2.24	(7 yrs.)	3.61
Minnewashta (10-9)	1.28	2.05	1.37	(19 yrs.)	3.46
Oak (10-93)	1.68	1.34	1.43	(10 yrs.)	3.85
Parley (10-42)	1.87	2.80	1.63	(21 yrs.)	4.87
Patterson (10-86)	1.28	1.63	1.36	(15 yrs.)	3.40
Piersons (10-53)	1.40	2.00	1.38	(7 yrs.)	2.02
Reitz (10-52)	2.34	2.52	2.05	(7 yrs.)	3.42
Riley (10-2)	1.32	2.27	1.47	(34 yrs.)	4.74
St. Joe (10-11)	1.19	1.28	1.13	(7 yrs.)	1.65
Stone (10-56)	0.94	1.22	1.17	(6 yrs.)	3.16
Swede (10-95)	1.29	1.09	1.19	(9 yrs.)	6.06
Tamarack (10-10)	1.42	1.50	1.41	(7 yrs.)	3.36
Tiger (10-108)	1.42	1.58	1.26	(7 yrs.)	2.29
Turbid (10-51)	1.48	2.36	1.31	(6 yrs.)	2.36
Unnamed (Grace) (10-218)	1.08	1.32	0.93	(6 yrs.)	1.49
Virginia (10-15)	1.50	1.70	1.39	(7 yrs.)	2.50
Waconia (10-59)	1.31	2.23	1.23	(36 yrs.)	5.90
Wassermann (10-48)	1.82	3.01	1.87	(7 yrs.)	8.12
Winkler (10-66)	2.09	2.16	2.12	(7 yrs.)	4.03
Zumbra-Sunny (10-41)	1.63	1.98	1.96	(20 yrs.)	7.28
CASS COUNTY					
Ada (11-250)	1.14	0.60	0.84	(15 yrs.)	2.87
Agate (11-216)	0.44	0.94	0.76	(14 yrs.)	3.62
Barnum (11-281)	0.89	0.44	0.67	(11 yrs.)	2.12
Bass (11-69)	0.76	0.46	0.68	(9 yrs.)	2.46
Big Rice (11-73)	1.70	1.80	2.19	(37 yrs.)	5.23
Birch (11-412)	0.96	0.53	0.92	(14 yrs.)	2.18
Blackwater (11-274)	0.50	0.83	0.55	(10 yrs.)	3.93
Child (11-263)	1.12	0.62	0.95	(15 yrs.)	1.98
Five Point (11-351)	0.08	0.10	0.29	(11 yrs.)	1.09
Hand (11-242)	0.91	0.68	0.84	(21 yrs.)	4.90
Hay (11-199)	0.66	0.84	0.84	(14 yrs.)	3.52
Inguadona (11-120)	0.93	1.50	1.39	(11 yrs.)	3.10
Island (11-257)	0.52	0.70	0.58	(6 yrs.)	1.41
Laura (11-104)	0.69	0.88	0.74	(19 yrs.)	2.23
Little Boy (11-167)	0.60	1.02	1.07	(12 yrs.)	2.50
Long (11-142)	0.87	0.16	0.88	(14 yrs.)	5.16
Lower Trelipe (11-129)	0.70	0.67	1.05	(25 yrs.)	4.63
Norway (11-307)	0.24	0.30	0.44	(8 yrs.)	0.94
Paquet (11-381)	1.98	0.18	1.04	(12 yrs.)	2.32
Pine Mountain (11-411)	0.94	0.74	1.10	(13 yrs.)	2.38
Pleasant (11-383)	0.83	0.43	0.71	(8 yrs.)	2.65
Ponto (11-234)	1.16	0.53	0.79	(6 yrs.)	7.62
Portage (11-476)	0.99	0.55	0.92	(14 yrs.)	4.62
Stony (11-371)	0.98	0.63	0.61	(13 yrs.)	4.43
Ten Mile (11-413)	0.99	0.90	0.79	(30 yrs.)	2.74
Woman (11-201)	0.80	0.69	0.84	(15 yrs.)	1.82
CHISAGO COUNTY					
Comfort (13-53)	1.92	1.60	1.22	(31 yrs.)	3.52
Ellen (13-47)	0.92	0.60	0.85	(8 yrs.)	2.02
Goose (13-83)	2.70	2.98	1.83	(17 yrs.)	3.70
Green (13-41)	0.53	0.46	1.03	(27 yrs.)	9.10
Kroon (13-13)	0.86	1.08	1.06	(9 yrs.)	2.63
North Center (13-32)	1.66	1.38	1.65	(32 yrs.)	7.26
North Lindstrom (13-35)	1.58	1.34	1.75	(28 yrs.)	11.42
Rush (13-69)	1.73	1.91	1.44	(38 yrs.)	3.28
South Center (13-27)	1.66	1.38	1.64	(32 yrs.)	7.26
South Lindstrom (13-28)	1.52	1.24	1.70	(42 yrs.)	15.59
Sunrise (13-31)	1.05	0.50	0.99	(17 yrs.)	4.00
Wallmark (13-29)	0.94	0.94	0.90	(9 yrs.)	2.19
CLEARWATER COUNTY					
Itasca (15-16)	0.76	0.82	0.71	(37 yrs.)	2.21
Long Lost (15-68)	0.84	0.86	1.33	(13 yrs.)	13.37
Upper Rice (15-59)	0.66	2.26	1.47	(8 yrs.)	3.66
Upper Rice (HW) (15-59)	2.90	0.74	1.28	(7 yrs.)	4.10

Lake Name	WY03	WY04	WYAv.	#Yrs.	Range
COOK COUNTY					
Bearskin (16-228)	0.84	1.34	1.12	(6 yrs.)	2.01
Clearwater (16-139)	0.79	1.12	1.06	(10 yrs.)	1.57
Flour (16-147)	0.26	0.68	0.62	(15 yrs.)	1.88
Gunflint (16-356)	1.00	1.96	1.72	(13 yrs.)	3.43
Poplar (16-239)	0.75	1.20	1.10	(14 yrs.)	3.70
Saganaga (16-633)	1.18	2.80	1.88	(14 yrs.)	5.26
COTTONWOOD COUNTY					
Cottonwood (17-22)	0.77	2.69	2.14	(17 yrs.)	9.90
Mountain (17-3)	0.70	1.98	1.52	(21 yrs.)	5.00
CROW WING COUNTY					
Bass (18-256)	0.94	0.71	0.69	(16 yrs.)	3.21
Bonnie (18-259)	0.40	0.67	0.63	(15 yrs.)	3.10
Clark (18-374)	0.72	0.36	0.78	(16 yrs.)	1.73
Crooked (18-41)	0.96	0.60	0.86	(16 yrs.)	2.39
Crow Wing (18-155)	1.64	0.78	1.38	(13 yrs.)	3.85
East Fox (18-298)	0.58	0.44	0.57	(24 yrs.)	2.32
Edna (18-396)	0.92	0.52	0.78	(7 yrs.)	1.90
Edward (18-305)	0.90	0.97	0.89	(37 yrs.)	7.18
Emily (18-203)	0.80	0.56	1.21	(37 yrs.)	3.39
Garden (18-329)	0.67	1.08	0.55	(16 yrs.)	1.36
Gilbert (18-320)	1.34	1.30	1.20	(15 yrs.)	4.71
Gladstone (18-338)	0.74	0.64	0.65	(16 yrs.)	1.23
Goodrich (18-226)	0.67	0.61	0.55	(12 yrs.)	1.30
Grave (18-110)	1.58	0.38	1.08	(27 yrs.)	3.54
Hamlet (18-70)	0.84	0.60	1.03	(41 yrs.)	6.70
Horseshoe (18-251)	1.04	0.69	0.72	(16 yrs.)	2.72
Hubert (18-375)	0.96	0.62	0.96	(24 yrs.)	3.56
Island (18-183)	0.81	1.43	1.47	(16 yrs.)	2.98
Little Hubert (18-340)	1.94	1.62	1.05	(16 yrs.)	3.64
Little Pelican (18-351)	0.86	0.36	0.68	(16 yrs.)	1.94
Lougee (18-342)	0.66	0.88	0.74	(16 yrs.)	2.49
Lower Mission (18-243)	0.76	0.53	0.68	(28 yrs.)	2.20
Markee (18-343)	0.62	0.62	0.98	(9 yrs.)	2.42
Mary (18-185)	0.80	0.41	1.27	(27 yrs.)	3.16
Mollie (18-335)	0.88	0.79	0.78	(16 yrs.)	3.27
North Long (18-372)	0.84	0.58	0.90	(34 yrs.)	2.88
O'Brien (18-227)	0.58	0.50	0.43	(12 yrs.)	1.79
Ossawinnamakee (18-352)	0.56	0.62	0.76	(21 yrs.)	1.82
Pelican (18-308)	0.84	0.46	0.85	(48 yrs.)	4.56
Perch (18-304)	0.91	1.05	0.76	(16 yrs.)	2.90
Portage (18-50)	0.88	0.58	0.94	(14 yrs.)	3.11
Rogers (18-184)	1.10	0.45	0.82	(17 yrs.)	2.30
Ross (18-165)	0.83	0.59	1.36	(21 yrs.)	3.05
Ruth (18-212)	1.09	0.82	0.86	(38 yrs.)	6.31
Shaffer (18-348)	1.03	1.07	0.78	(17 yrs.)	3.28
Sorenson (18-323)	0.92	0.73	0.94	(16 yrs.)	3.17
South Long (18-136)	1.68	1.02	1.19	(39 yrs.)	3.24
Stevens (18-325)	0.90	0.60	0.83	(8 yrs.)	2.00
Upper South Long (18-96)	1.84	0.73	1.20	(35 yrs.)	4.13
Whitefish (18-1)	1.38	0.68	1.26	(13 yrs.)	3.92
Young (18-252)	0.72	0.77	0.79	(16 yrs.)	2.74
DAKOTA COUNTY					
Byllesby (19-6)	4.16	4.78	5.21	(24 yrs.)	28.20
Marion (19-26)	2.20	0.64	2.08	(46 yrs.)	13.22
Orchard (19-31)	1.10	0.89	0.84	(13 yrs.)	1.69
Sunfish (19-50)	1.14	0.80	1.03	(14 yrs.)	3.42
Wood Park (19-24)	1.00	1.60	1.10	(7 yrs.)	1.83
DOUGLAS COUNTY					
Aaron (21-242)	1.16	0.52	0.84	(10 yrs.)	2.60
Andrew (21-85)	2.06	0.48	1.02	(13 yrs.)	4.37
Burgen (21-49)	2.06	0.70	0.92	(12 yrs.)	3.38
Chippewa (21-145)	1.37	0.96	1.23	(21 yrs.)	3.81
Devils (21-213)	0.72	0.62	0.94	(9 yrs.)	2.77
Geneva (21-52)	2.04	0.44	1.07	(11 yrs.)	2.79

Annual Lake Level Fluctuation (feet)

(Douglas County continued)

Lake Name	WY03	WY04	WYAv.	#Yrs.	Range
Ida (21-123)	1.04	0.52	1.05	(22 yrs.)	7.94
Latoka (21-106)	1.07	0.48	0.63	(12 yrs.)	6.15
Le Homme Dieu (21-56)	1.66	0.32	1.01	(14 yrs.)	2.28
Little Chippewa (21-212)	0.90	0.70	1.37	(19 yrs.)	9.09
Lobster (21-144)	2.01	1.05	1.23	(32 yrs.)	11.25
Louise (21-94)	2.55	0.88	1.60	(18 yrs.)	5.94
Mary (21-92)	2.00	0.45	1.41	(14 yrs.)	5.31
Miltona (21-83)	1.12	0.68	1.08	(29 yrs.)	4.77
Moon (21-226)	1.10	0.86	1.25	(20 yrs.)	10.59
Pocket (21-140)	2.34	1.23	1.13	(8 yrs.)	3.15
Red Rock (21-291)	1.67	0.62	1.40	(14 yrs.)	4.21
Union (21-41)	1.28	0.61	0.84	(7 yrs.)	1.44
Vermont (21-73)	1.28	1.01	1.12	(8 yrs.)	2.98
Victoria (21-54)	1.81	0.48	1.18	(23 yrs.)	4.16
Winona (21-81)	1.68	0.56	0.81	(11 yrs.)	2.00

GRANT COUNTY

Lake Name	WY03	WY04	WYAv.	#Yrs.	Range
Elk (26-40)	1.27	0.91	0.95	(10 yrs.)	3.85
Pomme de Terre (26-97)	0.92	1.28	1.09	(16 yrs.)	3.20

HENNEPIN COUNTY

Lake Name	WY03	WY04	WYAv.	#Yrs.	Range
Calhoun (27-31)	2.21	1.66	1.88	(77 yrs.)	6.36
Cedar Island (27-119)	1.51	1.52	1.21	(18 yrs.)	6.50
Christmas (27-137)	1.28	1.35	1.12	(6 yrs.)	3.10
Eagle/Pike (27-111)	1.65	1.30	1.11	(18 yrs.)	3.27
Edward (27-121)	1.63	1.13	1.06	(17 yrs.)	3.75
Fish (27-118)	1.64	1.81	1.55	(17 yrs.)	2.87
Galpin (27-144)	1.58	2.18	1.64	(7 yrs.)	2.75
Gleason (27-95)	1.52	1.94	1.73	(16 yrs.)	5.14
Harriet (27-16)	1.75	1.15	1.23	(74 yrs.)	4.90
Hiawatha (27-18)	3.04	3.23	2.84	(38 yrs.)	12.00
Holy Name (27-158)	0.85	1.72	1.17	(7 yrs.)	2.13
Independence (27-176)	1.68	1.98	1.68	(24 yrs.)	7.88
Indianhead (27-44)	1.51	1.88	1.41	(12 yrs.)	3.19
Long (27-160)	1.65	3.79	1.52	(19 yrs.)	4.15
Loring (27-655)	0.75	0.66	0.91	(22 yrs.)	3.57
Lydiard (27-159)	0.75	1.25	0.99	(7 yrs.)	3.33
Magda (27-65)	1.34	1.37	1.26	(6 yrs.)	2.16
Medicine (27-104)	2.30	2.18	1.60	(32 yrs.)	5.08
Minnetoga (27-88)	0.96	0.64	1.00	(31 yrs.)	3.00
Minnetonka (27-133)	1.81	2.18	1.46	(99 yrs.)	8.74
Mooney (27-134)	1.82	0.33	1.48	(11 yrs.)	7.40
Nokomis (27-19)	2.25	0.88	2.05	(55 yrs.)	8.76
Ox Yoke (27-178)	4.60	6.54	3.96	(9 yrs.)	7.23
Parkers (27-107)	3.70	2.34	2.58	(32 yrs.)	11.65
Rice (27-116)	6.37	2.06	2.08	(17 yrs.)	10.94
Sarah (27-191)	2.48	1.77	1.96	(13 yrs.)	4.60
Snyder (27-108)	1.58	2.24	2.00	(7 yrs.)	4.43
Twin (27-42)	3.30	1.82	1.46	(14 yrs.)	4.68
Weaver (27-117)	1.14	1.40	0.99	(17 yrs.)	3.19
Wirth (27-37)	2.24	0.38	1.56	(50 yrs.)	5.86

HUBBARD COUNTY

Lake Name	WY03	WY04	WYAv.	#Yrs.	Range
Bad Axe (29-208)	0.92	1.36	0.65	(9 yrs.)	2.42
Belle Taine (29-146)	1.53	1.29	1.35	(51 yrs.)	14.36
Big Sand (29-185)	0.86	0.53	0.83	(14 yrs.)	2.91
Big Stony (29-143)	1.08	0.68	0.79	(11 yrs.)	3.26
Blue (29-184)	0.70	0.74	0.62	(10 yrs.)	1.16
Eagle (29-256)	1.45	1.72	1.62	(14 yrs.)	2.78
East Crooked (29-101)	0.76	0.62	0.78	(11 yrs.)	3.69
Eighth Crow Wing (29-72)	1.02	0.84	0.55	(9 yrs.)	1.12
Eleventh Crow Wing (29-36)	0.43	0.22	0.29	(8 yrs.)	0.58
Fifth Crow Wing (29-92)	0.56	0.76	0.71	(11 yrs.)	1.39

(Hubbard County continued)

Lake Name	WY03	WY04	WYAv.	#Yrs.	Range
First Crow Wing (29-86)	0.31	0.60	0.57	(7 yrs.)	2.02
Fish Hook (29-242)	0.70	0.77	0.97	(14 yrs.)	2.12
Garfield (29-61)	0.66	0.67	0.58	(7 yrs.)	1.05
Gilmore (29-188)	0.51	0.60	0.56	(11 yrs.)	1.66
Grace (29-71)	0.83	0.54	0.73	(14 yrs.)	2.75
Island (29-88)	0.78	0.56	0.97	(6 yrs.)	2.35
Island (29-254)	1.32	1.16	1.99	(14 yrs.)	3.92
Kabekona (29-75)	1.05	1.58	1.22	(9 yrs.)	3.05
Little Mantrap (29-313)	1.15	0.88	0.96	(8 yrs.)	2.53
Little Sand (29-150)	0.80	0.52	0.71	(31 yrs.)	3.48
Long (29-161)	0.43	0.47	0.49	(18 yrs.)	1.18
Mantrap (29-151)	0.42	0.27	0.42	(10 yrs.)	1.08
Palmer (29-87)	1.20	0.64	0.85	(14 yrs.)	2.91
Plantagenet (29-156)	1.36	1.48	1.45	(23 yrs.)	3.47
Potato (29-243)	0.89	1.00	0.81	(13 yrs.)	1.71
Potato (HW at outlet dam)(29-243)	0.89	0.70	0.72	(25 yrs.)	1.72
Potato (TW at outlet dam) (29-243)	0.59	0.92	1.19	(14 yrs.)	2.78
Third Crow Wing (29-77)	1.24	1.52	1.11	(8 yrs.)	2.13
West Crooked (29-101)	0.88	0.83	0.73	(11 yrs.)	2.02

ISANTI COUNTY

Lake Name	WY03	WY04	WYAv.	#Yrs.	Range
Green (30-136)	1.56	0.22	1.51	(22 yrs.)	4.93
Long (30-72)	0.44	0.34	0.51	(11 yrs.)	1.82
Skogman (30-22)	1.52	1.64	1.32	(26 yrs.)	4.29
Spectacle (30-135)	0.63	0.68	0.63	(12 yrs.)	3.15
Typo (30-9)	1.64	1.98	1.61	(15 yrs.)	3.57

ITASCA COUNTY

Lake Name	WY03	WY04	WYAv.	#Yrs.	Range
Balsam (31-259)	0.74	1.08	1.16	(22 yrs.)	3.26
Bass (31-576)	0.54	0.95	0.81	(25 yrs.)	2.47
Beatrice (31-58)	0.38	0.51	0.81	(13 yrs.)	2.03
Bello (31-726)	0.40	1.00	0.76	(10 yrs.)	1.87
Bowstring (31-813)	1.38	1.38	1.67	(26 yrs.)	4.40
Buck (31-69)	0.62	0.66	0.59	(20 yrs.)	1.38
Burnt Shanty (31-424)	0.63	0.46	0.66	(15 yrs.)	2.40
Burrows (31-413)	0.96	0.50	0.72	(15 yrs.)	2.20
Carlson (31-366)	0.40	0.92	0.74	(10 yrs.)	1.62
Chase (31-749)	1.05	0.56	0.97	(6 yrs.)	2.61
Clearwater (31-214)	0.59	1.06	0.97	(9 yrs.)	1.75
Crooked (31-193)	2.65	6.20	6.15	(12 yrs.)	10.78
Dixon (31-921)	2.52	1.80	2.74	(11 yrs.)	4.43
Dora (31-882)	1.44	2.26	2.02	(24 yrs.)	4.35
Grave (31-624)	0.65	0.88	0.72	(12 yrs.)	1.62
Hale (31-361)	1.17	1.26	1.13	(12 yrs.)	2.46
Hale (31-373)	0.64	0.87	0.83	(46 yrs.)	3.26
Island (31-913)	0.58	0.85	0.77	(9 yrs.)	2.00
Jessie (31-786)	1.98	1.97	1.39	(15 yrs.)	5.07
Johnson (31-586)	1.30	0.80	0.95	(15 yrs.)	3.05
Kelly (31-299)	0.89	0.73	0.91	(9 yrs.)	2.39
Lawrence (31-231)	2.50	3.54	5.06	(10 yrs.)	10.98
Link (31-304)	0.42	0.24	0.54	(9 yrs.)	2.31
Little Bowstring (31-758)	1.30	1.71	1.30	(11 yrs.)	2.56
Little Long (31-613)	1.46	0.41	0.82	(14 yrs.)	5.68
Little Wabana (31-399)	0.70	0.48	0.55	(6 yrs.)	1.92
Long (31-570)	0.59	0.34	0.83	(39 yrs.)	3.39
Loon (31-571)	0.58	0.72	1.01	(40 yrs.)	3.62
Lost Moose (31-432)	0.30	0.45	0.50	(10 yrs.)	1.69
McAvity (31-585)	1.09	1.06	0.96	(7 yrs.)	3.06
McGuire (31-78)	0.73	1.88	2.65	(13 yrs.)	4.99
Moose (31-722)	0.48	1.03	0.76	(16 yrs.)	1.77
Mud (31-206)	0.58	0.88	0.95	(7 yrs.)	1.68
Owen (31-292)	0.86	0.50	0.75	(15 yrs.)	2.32
Pigeon Dam (31-894)	1.77	1.92	1.37	(17 yrs.)	3.30

Annual Lake Level Fluctuation (feet)

Lake Name	WY03	WY04	WYAv.	#Yrs.	Range
(Itasca County continued)					
Prairie (31-384)	0.10	0.19	1.13	(6 yrs.)	3.79
Pughole (31-602)	1.16	0.62	0.93	(14 yrs.)	3.32
Ruby (31-422)	0.73	0.60	0.60	(15 yrs.)	2.21
Sand (31-438)	1.83	0.66	0.89	(13 yrs.)	3.39
Sand (31-826)	1.75	1.52	1.73	(22 yrs.)	4.40
Shallow (31-84)	0.90	0.21	0.61	(13 yrs.)	1.23
Shoal (31-141)	0.54	0.96	1.03	(11 yrs.)	2.27
Siseebakwet (31-554)	0.76	1.16	0.75	(56 yrs.)	2.19
Smith (31-650)	0.88	0.35	0.80	(15 yrs.)	3.17
Snaptail (31-255)	0.53	1.26	1.19	(13 yrs.)	3.08
Snowball (31-108)	0.27	0.66	0.97	(39 yrs.)	4.28
South Sturgeon (31-3)	0.95	1.48	1.43	(11 yrs.)	3.40
Spider (31-538)	0.82	0.46	0.78	(15 yrs.)	2.40
Split Hand (31-353)	0.73	1.30	1.48	(23 yrs.)	3.65
Swan (31-67)	0.57	0.87	1.51	(56 yrs.)	4.65
Three Island (31-542)	2.09	0.82	0.90	(6 yrs.)	3.87
Trout (31-216)	0.76	1.07	1.09	(44 yrs.)	6.09
Turtle (31-725)	0.74	1.15	0.70	(13 yrs.)	2.09
White Swan (31-260)	0.74	1.19	0.69	(15 yrs.)	3.44
JACKSON COUNTY					
Clear (32-22)	0.80	1.15	1.11	(11 yrs.)	4.88
Fish (32-18)	1.06	1.13	1.27	(16 yrs.)	7.45
Heron (Duck) (32-57)	1.30	0.82	1.59	(14 yrs.)	7.00
Heron (North Marsh) (32-57)	3.19	4.60	4.28	(28 yrs.)	10.33
Heron (South Heron) (32-57)	3.11	6.27	3.68	(35 yrs.)	8.94
Heron (TW) (32-57)	3.47	4.41	4.49	(14 yrs.)	9.90
Loon (32-20)	0.86	1.44	1.40	(19 yrs.)	4.58
Pearl (32-33)	1.18	1.94	1.67	(14 yrs.)	4.21
Round (32-69)	0.38	1.05	1.00	(8 yrs.)	2.86
KANABEC COUNTY					
Fish (33-36)	6.67	3.87	3.28	(13 yrs.)	8.26
Knife (33-28)	2.84	1.08	2.09	(37 yrs.)	11.99
KANDIYOHI COUNTY					
Andrew (34-206)	0.99	1.79	1.48	(38 yrs.)	13.60
Big Kandiyohi (34-86)	2.12	1.44	1.39	(40 yrs.)	5.81
Calhoun (34-62)	1.12	1.00	1.36	(33 yrs.)	3.85
Diamond (34-44)	1.48	1.25	1.09	(23 yrs.)	3.95
Eagle (34-171)	0.78	1.02	1.11	(35 yrs.)	5.22
Elizabeth (34-22)	2.07	1.14	1.24	(25 yrs.)	3.12
Elkhorn (34-119)	0.84	0.54	0.84	(23 yrs.)	11.65
Florida (34-217)	1.04	1.12	1.50	(24 yrs.)	5.22
Foot (34-181)	1.30	1.19	1.01	(21 yrs.)	3.41
Games (34-224)	0.35	1.08	1.01	(27 yrs.)	4.09
George (34-142)	0.86	0.93	1.06	(29 yrs.)	3.88
Green (34-79)	1.24	1.65	1.57	(49 yrs.)	4.91
Henderson (34-116)	0.96	0.70	1.08	(22 yrs.)	5.57
Long (34-66)	0.45	0.67	0.51	(22 yrs.)	1.69
Long (34-192)	1.82	0.80	1.15	(24 yrs.)	12.31
Mud (34-158)	1.02	0.69	1.31	(37 yrs.)	7.32
Nest (34-154)	1.88	2.23	1.30	(36 yrs.)	3.96
Norway (34-251)	1.78	1.15	1.32	(22 yrs.)	4.29
Point (34-193)	1.19	0.86	1.05	(17 yrs.)	11.23
Ringo (34-172)	1.00	0.90	1.14	(20 yrs.)	7.64
Skataas (34-196)	1.36	1.21	1.21	(17 yrs.)	4.81
Swenson (34-321)	1.22	0.88	1.14	(17 yrs.)	5.63
Unnamed (Golden Pond) (34-355)	1.00	0.50	0.83	(10 yrs.)	2.54
Wagonga (34-169)	2.50	2.19	1.78	(20 yrs.)	4.92
LAKE COUNTY					
Farm (38-779)	0.25	0.50	0.43	(12 yrs.)	0.96
Garden (38-782)	0.34	0.80	1.14	(13 yrs.)	3.24

Lake Name	WY03	WY04	WYAv.	#Yrs.	Range
LE SUEUR COUNTY					
Frances (40-57)	1.32	1.76	1.05	(13 yrs.)	13.14
Jefferson (40-92)	1.24	2.02	1.25	(31 yrs.)	6.64
Tetonka (40-31)	1.80	3.85	1.84	(40 yrs.)	5.50
Volney (40-33)	1.38	1.87	1.39	(14 yrs.)	3.60
Washington (40-117)	1.08	2.42	1.51	(26 yrs.)	5.35
West Jefferson (40-92)	1.24	2.02	1.41	(30 yrs.)	6.92
LINCOLN COUNTY					
Benton (41-43)	1.14	0.84	1.52	(30 yrs.)	5.98
MCLEOD COUNTY					
Winsted (43-12)	1.30	1.86	1.66	(14 yrs.)	3.54
MAHNOMEN COUNTY					
Tulaby (44-3)	0.90	0.90	1.06	(12 yrs.)	2.44
MARTIN COUNTY					
Amber (46-34)	1.20	2.50	1.52	(12 yrs.)	3.91
Budd (46-30)	1.28	3.96	1.78	(11 yrs.)	5.32
George (46-24)	1.26	2.62	1.49	(12 yrs.)	8.84
South Silver (46-20)	1.04	1.06	1.28	(7 yrs.)	2.62
MEEKER COUNTY					
Belle (47-49)	1.13	0.85	1.34	(13 yrs.)	11.69
Big Swan (47-38)	4.58	4.55	5.30	(10 yrs.)	9.86
Clear (47-95)	1.90	1.08	1.37	(15 yrs.)	4.21
Dunns (47-82)	1.62	1.25	1.56	(9 yrs.)	2.94
Francis (47-2)	1.71	0.61	0.93	(22 yrs.)	4.95
Long (47-177)	2.90	2.11	2.10	(8 yrs.)	4.05
Manuella (47-50)	2.60	1.56	1.50	(14 yrs.)	4.47
Minnie-Belle (47-119)	1.38	1.06	1.33	(16 yrs.)	5.92
Richardson (47-88)	1.46	1.16	1.26	(9 yrs.)	2.59
Ripley (47-134)	0.24	0.87	0.96	(12 yrs.)	9.61
Spring (47-32)	1.53	1.26	1.04	(10 yrs.)	2.57
Stella (47-68)	1.40	1.10	1.13	(16 yrs.)	2.55
MILLE LACS COUNTY					
Mille Lacs (48-2)	1.43	0.64	1.35	(74 yrs.)	7.69
Onamia (48-9)	0.94	0.48	1.57	(39 yrs.)	6.12
Onamia (TW) (48-9)	0.88	0.56	1.87	(20 yrs.)	5.77
MORRISON COUNTY					
Fish Trap (49-137)	1.21	1.06	1.08	(22 yrs.)	4.36
Green Prairie Fish (49-35)	2.15	0.86	1.27	(9 yrs.)	2.68
Long (49-15)	1.30	0.54	0.73	(8 yrs.)	1.73
Pierz (49-24)	0.56	0.18	0.30	(7 yrs.)	0.60
Round (49-56)	1.16	0.60	0.89	(10 yrs.)	1.75
Shamineau (49-127)	0.69	0.47	0.87	(11 yrs.)	5.39
Sullivan (49-16)	2.37	0.90	1.42	(26 yrs.)	4.19
MURRAY COUNTY					
Sarah (51-63)	1.26	1.96	1.37	(10 yrs.)	4.46
Second Fulda (51-20)	3.76	2.79	1.96	(6 yrs.)	4.37
Shetek (51-46)	2.14	3.04	2.02	(55 yrs.)	7.67
Wilson (51-81)	0.84	1.00	0.76	(8 yrs.)	8.92
NOBLES COUNTY					
Bella (53-45)	0.90	2.08	2.23	(15 yrs.)	9.68
Indian (53-7)	1.60	1.24	1.67	(17 yrs.)	4.48
Ocheda (53-24)	1.58	1.76	1.43	(37 yrs.)	5.42
OTTER TAIL COUNTY					
Big McDonald (56-386)	1.11	1.09	0.92	(10 yrs.)	1.83
Blanche (56-240)	0.59	0.40	0.60	(13 yrs.)	1.94
Clitherall (56-238)	1.10	1.01	0.79	(11 yrs.)	2.11

Annual Lake Level Fluctuation (feet)

Lake Name	WY03	WY04	WYAv.	#Yrs.	Range
(Otter Tail County continued)					
Dead (56-383)	0.85	1.05	0.82	(9 yrs.)	2.88
Deer (56-298)	2.02	0.84	1.61	(8 yrs.)	3.22
Eagle (56-253)	0.82	0.89	0.87	(9 yrs.)	9.43
East Battle (56-138)	1.20	1.25	1.13	(18 yrs.)	4.21
East Leaf (56-116)	1.53	1.72	1.92	(10 yrs.)	3.32
East Loon (56-523)	1.10	0.82	0.89	(6 yrs.)	1.87
East Lost (56-378)	2.29	2.00	2.04	(12 yrs.)	3.97
East Spirit (56-501)	1.14	0.25	0.69	(6 yrs.)	6.22
Leek (Trowbridge) (56-532)	1.18	1.26	0.94	(6 yrs.)	1.38
Lida (56-747)	1.09	1.79	0.93	(10 yrs.)	2.82
Little McDonald (56-328)	1.10	0.45	1.01	(13 yrs.)	4.55
Little Pine (56-142)	0.81	0.75	1.05	(40 yrs.)	3.30
Lizzie (56-760)	0.92	1.55	1.18	(57 yrs.)	4.56
Long (56-388)	1.15	0.70	0.81	(12 yrs.)	2.08
Long (56-784)	1.20	1.22	1.19	(13 yrs.)	2.08
Middle Leaf (56-116)	1.74	1.24	1.75	(10 yrs.)	3.61
Otter Tail (56-242)	1.37	1.48	1.42	(75 yrs.)	4.63
Otter Tail (TW) (56-242)	1.98	0.85	1.71	(15 yrs.)	3.78
Pelican (56-786)	1.02	1.24	1.27	(31 yrs.)	4.94
Pickerel (56-204)	1.64	1.14	1.20	(11 yrs.)	3.42
Pickerel (56-475)	0.34	0.55	0.67	(26 yrs.)	3.03
Prairie (56-915)	0.50	0.66	0.78	(24 yrs.)	4.70
Round (56-297)	1.00	0.86	0.80	(7 yrs.)	2.13
Rush (56-141)	1.24	1.40	1.55	(65 yrs.)	3.87
Silver (56-302)	1.03	0.43	0.92	(8 yrs.)	3.10
Six (56-369)	0.82	0.50	0.51	(8 yrs.)	1.53
South Turtle (56-377)	1.46	0.89	0.98	(8 yrs.)	4.43
Star (56-385)	0.94	1.00	1.01	(28 yrs.)	3.79
Stuart (56-191)	1.00	0.70	1.18	(9 yrs.)	6.26
Swan (56-781)	0.91	1.34	1.01	(13 yrs.)	3.63
Sybil (56-387)	1.05	0.90	0.78	(9 yrs.)	3.04
Ten Mile (56-613)	0.81	0.93	1.15	(13 yrs.)	2.69
Wall (56-658)	0.43	0.90	0.41	(13 yrs.)	0.90
West Battle (56-239)	1.32	0.92	1.11	(32 yrs.)	8.42
West McDonald (56-386)	1.32	0.86	0.91	(11 yrs.)	2.25
PINE COUNTY					
Grindstone (58-123)	2.65	1.53	1.17	(28 yrs.)	3.21
Island (58-62)	1.54	1.13	1.47	(24 yrs.)	3.15
Pokegama (58-142)	4.62	3.38	3.76	(25 yrs.)	8.20
Sand (58-81)	0.24	0.60	1.40	(30 yrs.)	5.99
Sturgeon (58-67)	0.60	0.36	0.90	(28 yrs.)	4.04
Upper Pine (58-130)	1.52	0.46	0.80	(12 yrs.)	2.03
POLK COUNTY					
Cable (60-293)	1.17	1.44	0.98	(13 yrs.)	7.90
Oak (60-185)	0.68	0.52	1.11	(6 yrs.)	2.28
Sarah (60-202)	1.91	1.29	2.75	(16 yrs.)	14.89
Union (60-217)	0.76	0.56	1.50	(19 yrs.)	8.55
POPE COUNTY					
Gilchrist (61-72)	2.58	1.65	2.39	(14 yrs.)	5.50
Leven (61-66)	2.46	1.08	1.86	(11 yrs.)	3.38
Linka (61-37)	1.48	0.40	0.93	(11 yrs.)	2.07
Marlu (61-60)	1.30	0.57	1.11	(11 yrs.)	2.70
Pelican (61-111)	2.68	0.80	1.46	(12 yrs.)	6.83
Signalness (61-149)	1.06	0.75	0.84	(8 yrs.)	2.16
Villard (61-67)	5.42	1.00	2.36	(11 yrs.)	6.51
RAMSEY COUNTY					
Bald Eagle (62-2)	1.05	1.33	1.25	(82 yrs.)	6.69
Beaver (62-16)	2.25	1.20	1.93	(50 yrs.)	7.10
Bennett (62-48)	2.21	2.38	2.73	(18 yrs.)	6.60
Birch (62-24)	1.09	1.44	1.33	(75 yrs.)	7.13
Como (62-55)	2.47	2.27	1.75	(27 yrs.)	4.19
Gervais (62-7)	2.20	1.03	2.12	(81 yrs.)	7.20

Lake Name	WY03	WY04	WYAv.	#Yrs.	Range
(Ramsey County continued)					
Grass (62-74)	3.11	2.73	3.52	(23 yrs.)	9.70
Island (62-75)	1.55	1.16	1.41	(59 yrs.)	9.32
Johanna (62-78)	1.36	1.64	1.97	(81 yrs.)	10.92
Josephine (62-57)	1.13	1.38	1.18	(81 yrs.)	4.20
Long (62-67)	2.25	2.13	1.75	(81 yrs.)	5.20
McCarron (62-54)	1.15	1.44	1.15	(81 yrs.)	4.45
Owasso (62-56)	1.14	1.42	1.17	(81 yrs.)	5.79
Phalen (62-13)	2.75	3.55	3.45	(81 yrs.)	12.32
Pike (62-69)	1.85	0.84	1.36	(36 yrs.)	4.57
Round (62-9)	1.40	1.79	2.01	(71 yrs.)	11.67
Silver (East) (62-1)	1.75	1.95	1.69	(80 yrs.)	10.05
Silver (West) (62-83)	1.62	1.63	1.70	(71 yrs.)	13.25
Snail (62-73)	1.48	1.96	1.62	(81 yrs.)	7.20
Teal Pond (North) (62-26)	1.31	1.81	1.54	(9 yrs.)	4.47
Turtle (62-61)	1.25	0.97	1.00	(82 yrs.)	4.40
Valentine (62-71)	3.40	1.76	1.84	(80 yrs.)	6.95
Wabasso (62-82)	1.79	2.32	1.47	(67 yrs.)	5.53
Wakefield (62-11)	1.55	1.07	2.24	(52 yrs.)	10.53
Willow (62-40)	1.37	0.82	1.02	(18 yrs.)	2.01
RENVILLE COUNTY					
Allie (65-6)	1.78	2.04	1.47	(15 yrs.)	8.56
Preston (65-2)	1.30	2.04	1.48	(12 yrs.)	3.74
RICE COUNTY					
Cedar (66-52)	1.08	1.34	1.12	(18 yrs.)	3.22
French (66-38)	1.33	1.34	1.14	(13 yrs.)	2.87
ST. LOUIS COUNTY					
Aerie (69-701)	0.45	1.04	0.73	(8 yrs.)	1.80
Beaver (69-501)	0.80	0.61	0.90	(16 yrs.)	3.38
Big Rice (69-669)	1.40	1.76	1.20	(15 yrs.)	2.43
Black Duck (69-842)	0.89	0.71	0.92	(6 yrs.)	2.28
Burntside (69-118)	0.58	0.90	0.95	(14 yrs.)	4.76
Comstock (69-412)	1.00	0.84	1.47	(11 yrs.)	2.64
Crooked (69-703)	1.16	1.63	1.01	(8 yrs.)	2.01
Dark (69-790)	0.50	1.40	1.45	(17 yrs.)	4.69
Eagles Nest #1 (69-285)	0.58	0.71	0.74	(12 yrs.)	3.10
Eagles Nest #3 (69-285)	0.55	1.52	0.94	(13 yrs.)	1.77
Eagles Nest No. Four (69-218)	0.41	0.34	0.40	(12 yrs.)	0.97
Ely (69-660)	0.50	0.56	0.80	(51 yrs.)	2.80
Embarrass (69-496)	1.50	0.72	2.27	(46 yrs.)	6.29
Esquagama (69-565)	0.85	0.90	2.29	(30 yrs.)	8.10
Fourteen (69-793)	0.29	0.65	0.55	(13 yrs.)	1.34
Horseshoe (69-232)	0.43	1.00	0.76	(8 yrs.)	1.91
Jacobs (69-231)	0.64	0.59	0.79	(14 yrs.)	2.31
Janette (69-887)	0.60	0.72	0.76	(12 yrs.)	2.37
Leora (69-521)	0.60	0.65	0.80	(8 yrs.)	1.56
Lieung (69-123)	1.40	1.54	1.13	(9 yrs.)	3.01
Little Stone (69-28)	0.50	1.22	0.96	(13 yrs.)	2.99
Long (69-495)	0.56	0.79	1.21	(7 yrs.)	2.06
Long (69-653)	0.44	1.10	0.79	(13 yrs.)	1.47
Maple Leaf (69-700)	0.60	1.07	0.89	(14 yrs.)	1.78
Merrill (69-891)	0.52	0.78	0.75	(12 yrs.)	1.55
Nichols (69-627)	0.79	0.56	0.72	(16 yrs.)	1.71
Pelican (69-841)	0.35	0.84	1.03	(23 yrs.)	2.88
Perch (69-932)	0.30	0.56	0.51	(14 yrs.)	2.91
Prairie (69-848)	1.18	2.29	1.29	(21 yrs.)	3.86
Sabin (69-434)	2.42	2.42	2.73	(9 yrs.)	5.68
Schubert (69-546)	0.38	0.80	1.08	(10 yrs.)	2.27
Snowshoe (69-900)	0.82	0.55	1.50	(35 yrs.)	4.50
St. Mary's (69-651)	1.04	0.78	1.20	(47 yrs.)	4.57
Stone (69-27)	3.44	1.08	1.02	(15 yrs.)	3.52
Stone (69-686)	1.11	1.37	1.14	(12 yrs.)	3.01
Sturgeon (69-939)	1.01	1.15	1.52	(21 yrs.)	3.00
Thirteen (69-794)	0.34	0.66	0.53	(8 yrs.)	1.71

Annual Lake Level Fluctuation (feet)

(St. Louis County continued)

Lake Name	WY03	WY04	WYAv.	#Yrs.	Range
Thompson (69-241)	1.24	0.65	1.12	(7 yrs.)	2.19
Unnamed (Kumpala) (69-424)	0.91	1.30	1.44	(7 yrs.)	2.94
Vermilion (69-378)	0.67	1.52	1.58	(54 yrs.)	3.19

SCOTT COUNTY

Lake Name	WY03	WY04	WYAv.	#Yrs.	Range
Dean (70-74)	1.02	1.07	1.53	(6 yrs.)	4.92
Lower Prior (70-26)	1.86	2.35	2.34	(32 yrs.)	10.22
Spring (70-54)	2.52	1.74	1.68	(15 yrs.)	3.45
Upper Prior (70-72)	1.86	2.35	2.30	(33 yrs.)	12.20

SHERBURNE COUNTY

Lake Name	WY03	WY04	WYAv.	#Yrs.	Range
Elk (71-141)	4.57	2.65	2.17	(10 yrs.)	5.32
Long (71-159)	0.96	0.63	1.25	(13 yrs.)	9.04
Rush (71-147)	3.75	1.80	2.18	(15 yrs.)	6.50

SIBLEY COUNTY

Lake Name	WY03	WY04	WYAv.	#Yrs.	Range
Swan (72-93)	1.09	1.55	1.46	(7 yrs.)	4.62

STEARNS COUNTY

Lake Name	WY03	WY04	WYAv.	#Yrs.	Range
Bankers (73-286)	0.85	1.19	0.87	(6 yrs.)	1.86
Bear (73-190)	0.80	1.46	1.01	(6 yrs.)	1.88
Big (73-159)	1.42	1.27	1.44	(15 yrs.)	5.20
Big Fish (73-106)	0.89	1.03	1.02	(28 yrs.)	4.06
Carnelian (73-38)	0.21	1.15	1.38	(13 yrs.)	10.56
Eden (73-150)	4.22	1.88	2.69	(17 yrs.)	10.38
Grand (73-55)	0.87	0.87	1.04	(24 yrs.)	3.21
Knaus (73-86)	1.88	1.08	1.45	(10 yrs.)	4.66
Koronis (73-200)	1.50	1.53	2.02	(24 yrs.)	6.00
Kraemer (73-64)	1.20	0.99	1.25	(9 yrs.)	3.65
Kreigle (73-97)	0.66	0.66	0.98	(6 yrs.)	2.57
Long (73-4)	1.56	0.66	1.37	(12 yrs.)	3.38
Lower Spunk (73-123)	2.46	2.13	1.91	(8 yrs.)	3.07
Maria (73-215)	1.09	0.80	1.04	(7 yrs.)	3.76
Marie (73-14)	0.90	0.77	1.10	(6 yrs.)	1.95
North Brown's (73-147)	2.00	1.84	2.15	(13 yrs.)	4.93
Rossier (73-72)	1.43	1.44	1.25	(6 yrs.)	2.52
School Section (73-35)	1.10	0.17	1.34	(8 yrs.)	9.28
Two Rivers (73-138)	2.80	1.90	3.25	(21 yrs.)	7.51
Willow (73-34)	1.27	1.14	1.23	(8 yrs.)	2.65

SWIFT COUNTY

Lake Name	WY03	WY04	WYAv.	#Yrs.	Range
Camp (76-72)	1.80	0.86	1.68	(10 yrs.)	4.65

TODD COUNTY

Lake Name	WY03	WY04	WYAv.	#Yrs.	Range
Beauty (77-35)	1.67	1.47	0.93	(11 yrs.)	2.55
Big (77-63)	0.56	0.87	0.94	(12 yrs.)	2.19
Big Birch (77-84)	1.02	0.92	1.06	(28 yrs.)	3.23
Big Swan (77-23)	2.51	0.87	1.79	(7 yrs.)	4.11
Fairy (77-154)	1.58	1.44	1.39	(16 yrs.)	9.91
Latimer (77-105)	1.25	0.72	1.17	(7 yrs.)	2.56
Little Birch (77-89)	0.70	0.72	1.04	(25 yrs.)	3.42
Long (77-27)	1.52	0.76	0.89	(12 yrs.)	2.10
Long (77-149)	1.12	0.63	1.08	(8 yrs.)	6.83
Maple (77-181)	1.74	0.76	1.35	(16 yrs.)	3.08
Mound (77-7)	0.82	0.62	0.67	(12 yrs.)	1.65
Osakis (77-215)	3.15	0.68	1.62	(44 yrs.)	8.33
Pine Island (77-67)	0.94	0.44	0.93	(7 yrs.)	2.41
Sauk (77-150)	3.55	2.36	1.99	(22 yrs.)	5.47

WADENA COUNTY

Lake Name	WY03	WY04	WYAv.	#Yrs.	Range
Hazel (80-5)	0.90	0.46	0.91	(25 yrs.)	3.33
Spirit (80-39)	1.26	0.82	1.74	(6 yrs.)	6.07
Stocking (80-37)	0.52	0.68	0.58	(17 yrs.)	1.62

WASHINGTON COUNTY

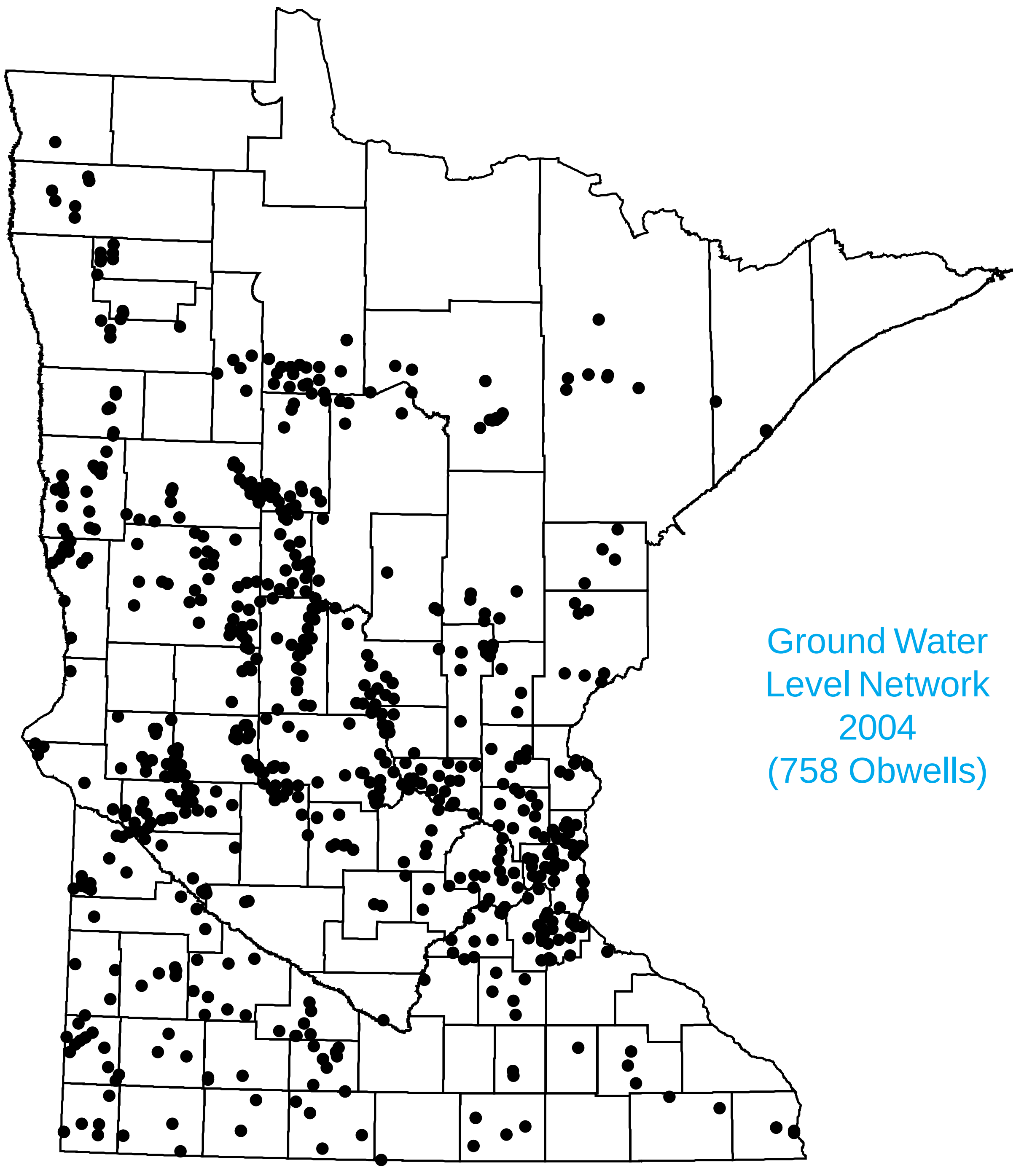
Lake Name	WY03	WY04	WYAv.	#Yrs.	Range
Armstrong-South Portion (82-116)	1.82	1.72	1.14	(6 yrs.)	1.82
Barker (82-76)	1.34	1.68	1.55	(8 yrs.)	4.71
Bass (82-35)	1.17	1.18	1.34	(10 yrs.)	3.75
Bass (82-123)	1.18	1.02	1.18	(8 yrs.)	8.50
Battle Creek (82-91)	2.03	0.68	1.27	(15 yrs.)	3.02
Benz (82-120)	1.50	1.26	1.14	(7 yrs.)	2.14
Big Carnelian (82-49)	1.06	1.05	1.25	(28 yrs.)	14.26
Big Marine (82-52)	1.02	1.48	1.06	(31 yrs.)	7.10
Carol (82-17)	1.15	0.88	1.14	(9 yrs.)	1.63
Carver (82-166)	1.26	0.23	1.28	(14 yrs.)	3.22
Cloverdale (82-9)	1.59	1.37	2.10	(11 yrs.)	9.21
Colby (82-94)	2.50	1.87	1.82	(6 yrs.)	2.96
DeMontreville (82-101)	0.93	1.52	1.45	(37 yrs.)	6.40
Downs (82-110)	2.13	1.58	2.54	(23 yrs.)	7.73
Eagle Point (82-109)	2.37	1.59	2.21	(30 yrs.)	7.40
Echo (82-129)	1.10	0.86	1.12	(7 yrs.)	2.02
Elmo (82-106)	0.50	0.47	1.17	(30 yrs.)	9.58
Fish (82-64)	3.17	1.24	1.46	(7 yrs.)	3.79
Forest (82-159)	1.06	1.07	0.77	(30 yrs.)	2.78
Goose (82-59)	2.38	1.22	1.87	(11 yrs.)	6.00
Halfbreed (82-80)	0.96	0.84	0.93	(15 yrs.)	3.48
Hay (82-65)	0.90	1.10	1.10	(7 yrs.)	2.41
Horseshoe (82-74)	1.12	1.03	1.62	(27 yrs.)	15.74
Jane (82-104)	0.82	0.62	1.50	(37 yrs.)	9.33
Lily (82-23)	2.61	3.11	1.93	(10 yrs.)	11.98
Little Carnelian (82-14)	1.70	1.29	3.27	(13 yrs.)	35.67
Long (82-21)	2.52	1.65	2.01	(9 yrs.)	3.19
Long (82-30)	1.20	1.30	0.98	(9 yrs.)	5.25
Long (82-68)	1.92	1.38	1.79	(7 yrs.)	5.40
Long (82-118)	3.22	2.88	3.33	(31 yrs.)	10.34
Long (82-130)	1.84	1.82	1.74	(8 yrs.)	2.97
Loon (82-15)	1.44	1.32	1.32	(9 yrs.)	3.10
Louise (82-25)	1.20	0.76	1.17	(9 yrs.)	3.24
Lynch (82-42)	1.20	0.84	1.16	(7 yrs.)	2.30
Markgrafs (82-89)	1.85	1.64	1.44	(7 yrs.)	2.81
Masterman (82-126)	1.38	0.78	1.04	(8 yrs.)	2.06
McDonald (82-10)	1.30	0.80	1.07	(11 yrs.)	3.92
McKusick (82-20)	3.49	1.32	1.40	(9 yrs.)	6.02
Mud (82-26)	0.86	0.47	0.50	(10 yrs.)	1.03
Mud-wetland so of Co.4 (82-26)	1.48	0.92	0.97	(11 yrs.)	1.73
North Twin (82-18)	1.07	0.66	0.90	(9 yrs.)	2.18
Oneka (82-140)	0.94	0.90	0.98	(26 yrs.)	4.13
Pat (82-125)	1.09	0.91	1.23	(8 yrs.)	4.28
Plaisted (82-148)	1.49	1.04	1.29	(7 yrs.)	4.73
Powers (82-92)	3.34	1.38	3.92	(8 yrs.)	23.10
Rice (82-146)	1.45	1.19	1.12	(7 yrs.)	2.04
Shields (82-162)	2.53	0.73	1.33	(9 yrs.)	2.71
Silver (82-16)	1.50	0.74	1.47	(9 yrs.)	3.12
South School Section (82-151)	0.69	1.00	1.38	(9 yrs.)	4.91
South Twin (82-19)	1.20	0.70	1.49	(9 yrs.)	4.71
Square (82-46)	0.33	0.34	0.67	(28 yrs.)	5.34
Staples (82-28)	1.06	1.06	1.08	(8 yrs.)	3.33
Sunfish (82-107)	0.80	1.01	1.49	(30 yrs.)	18.15
Sunnybrook (82-133)	2.86	1.40	2.10	(12 yrs.)	3.60
Sunset (82-153)	1.95	1.37	1.28	(11 yrs.)	3.47
Tanners (82-115)	1.35	0.35	1.17	(14 yrs.)	2.80
Terrapin (82-31)	0.10	0.72	1.07	(6 yrs.)	2.62
Turtle (82-36)	1.53	0.66	1.03	(11 yrs.)	3.52
Twin (82-48)	2.28	2.26	2.33	(8 yrs.)	3.84
Unnamed (82-87)	0.69	0.90	0.82	(6 yrs.)	1.56
Unnamed (82-128)	1.32	0.82	1.33	(7 yrs.)	3.39
Unnamed (82-303)	1.45	0.96	1.22	(7 yrs.)	3.08
Unnamed (82-349)	1.53	1.34	1.67	(7 yrs.)	4.67

Annual Lake Level Fluctuation (feet)

Lake Name	WY03	WY04	WYAv.	#Yrs.	Range
(Washington County continued)					
Unnamed (Bailey) (82-456)	6.68	4.79	4.63	(6 yrs.)	7.22
Unnamed (Goetschel) (82-313)	1.08	0.91	1.11	(6 yrs.)	3.66
Unnamed (Goggins) (82-77)	1.12	0.96	1.63	(7 yrs.)	4.10
Unnamed (Jackson WMA) (82-305)	3.10	2.78	2.31	(8 yrs.)	3.54
Unnamed (July Ave.) (82-318)	2.91	1.72	3.13	(8 yrs.)	6.63
Unnamed (Maple Marsh) (82-38)	1.56	0.94	1.35	(8 yrs.)	2.61
Unnamed (May Ave. Wetland) (82-296)	1.20	1.34	0.99	(11 yrs.)	2.36
Unnamed (Vandeberg) (82-84)	2.22	1.14	1.42	(6 yrs.)	4.41
Unnamed (Kismet Basin) (82-334)	1.35	0.85	1.31	(9 yrs.)	4.82
Unnamed (Perro Pond) (82-310)	2.16	0.98	2.74	(7 yrs.)	6.49
West Boot (82-44)	0.81	0.60	0.77	(10 yrs.)	2.13
White Bear (82-167)	1.13	1.03	1.20	(81 yrs.)	6.81
Wilmes (82-90)	3.55	3.05	2.76	(6 yrs.)	4.65
Wood Pile (82-132)	1.36	0.78	1.28	(8 yrs.)	4.18
WATONWAN COUNTY					
Kansas (83-36)	1.53	2.41	1.54	(11 yrs.)	5.01
Long (83-40)	0.57	8.97	1.81	(20 yrs.)	16.17
St. James (83-43)	1.20	1.74	1.53	(13 yrs.)	6.20
WRIGHT COUNTY					
Ann (86-190)	3.22	2.81	3.59	(9 yrs.)	7.33
Augusta (86-284)	1.26	0.90	1.12	(11 yrs.)	2.97
Bass (86-234)	0.88	0.73	1.37	(6 yrs.)	4.60
Birch (86-66)	1.42	0.90	1.26	(12 yrs.)	6.19
Charlotte (86-11)	2.07	1.28	1.51	(20 yrs.)	8.68
Collinwood (86-293)	1.30	1.00	1.16	(10 yrs.)	3.88
Emma (86-188)	2.60	1.81	2.59	(6 yrs.)	6.20
Howard (86-199)	1.90	0.84	1.18	(6 yrs.)	2.51
Ida (86-146)	0.84	0.48	0.61	(9 yrs.)	3.59
Indian (86-223)	0.40	0.92	1.42	(19 yrs.)	9.76
Little Waverly (86-106)	1.50	1.30	1.39	(15 yrs.)	6.82
Maple (86-134)	1.66	0.78	1.27	(19 yrs.)	5.34
Mary (86-193)	1.38	1.07	1.21	(8 yrs.)	2.85
Pulaski (86-53)	3.13	1.13	1.58	(29 yrs.)	17.69
Sugar (86-233)	1.28	0.82	0.82	(28 yrs.)	4.43
West Lake Sylvia (86-279)	1.67	0.74	0.94	(26 yrs.)	4.03

chapter three

ground water

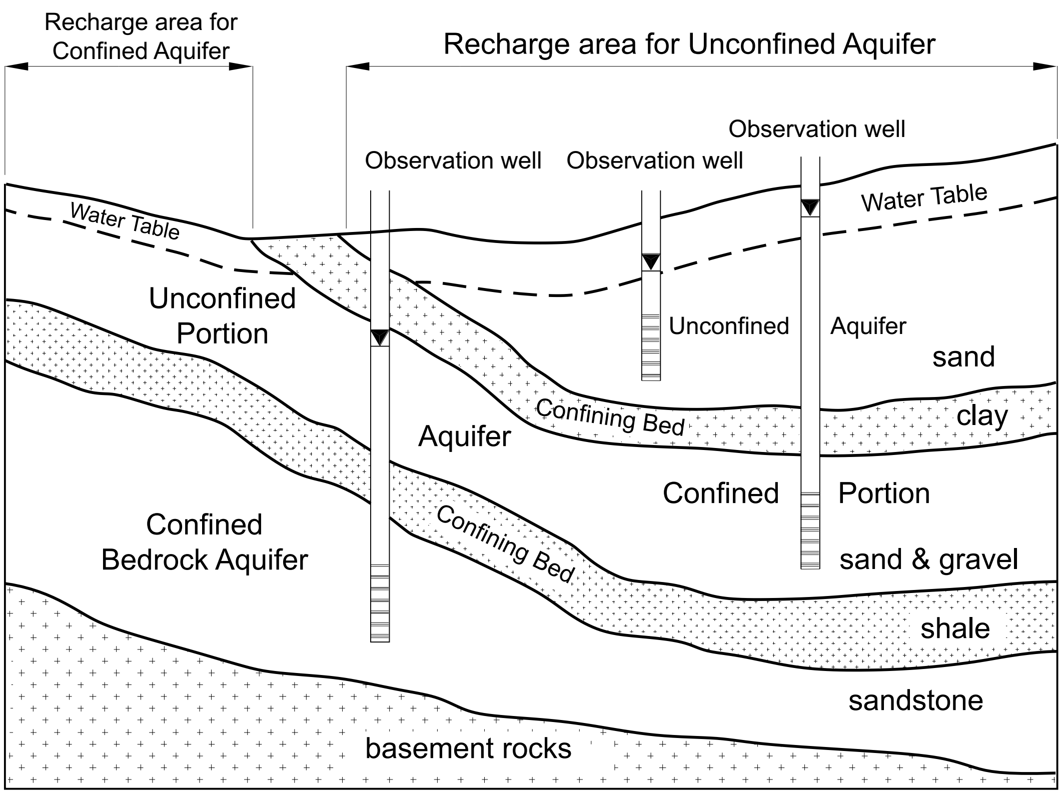


Introduction

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). The number of observation wells (obwells) has remained constant at approximately 750 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) and other cooperators, under agreements with DNR Waters, measure the wells periodically and report the readings to DNR Waters as part of the Ground Water Level Program. Readings are also obtained from volunteers and electronically 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 greater pressure than atmosphere, 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.

Statewide Summary

The remainder of this chapter discusses the ground water levels in unconfined and confined aquifers during Water Years 2003 (WY03) and 2004 (WY04). This discussion focuses on a comparison of water levels in WY03 and WY04 to the water levels over the period of record for the ground water level monitoring wells (obwells) analyzed in this report. Hydrographs of representative obwells illustrate the analysis. 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 10 to 40 years.

During these water years, the DNR monitored water levels in approximately 750 wells throughout the state. Water levels are usually recorded monthly from March through November. Figures 2, 5 and 7 show the locations of these wells, identifying those that were placed in unconfined (water table) aquifers, in buried drift aquifers and in bedrock aquifers.

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 3. The wells identified by number are also the subject wells in Figure 4. Figure 4A shows the standard hydrographs for these wells over the entire period of record. Figure 4B shows hydrographs for the two-year period under discussion. Also shown on Figure 4B is the monthly precipitation recorded at a station near each well.

The representative unconfined obwells reflect the precipitation patterns throughout the state overlaid on the normal seasonal fluctuations. In WY04, the response of unconfined aquifer water levels to high precipitation in late summer was not consistent statewide.

Figure 2

Unconfined Observation Wells

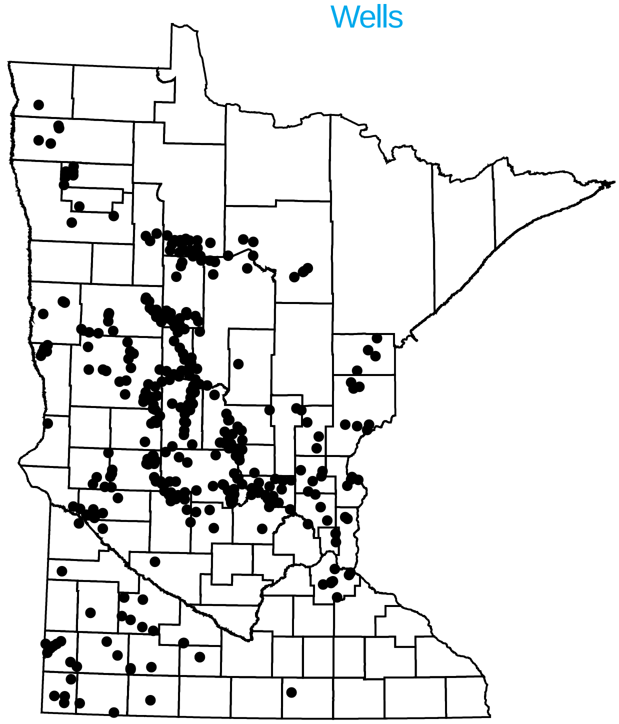


Figure 3

Location of Representative Unconfined and Buried Drift Wells

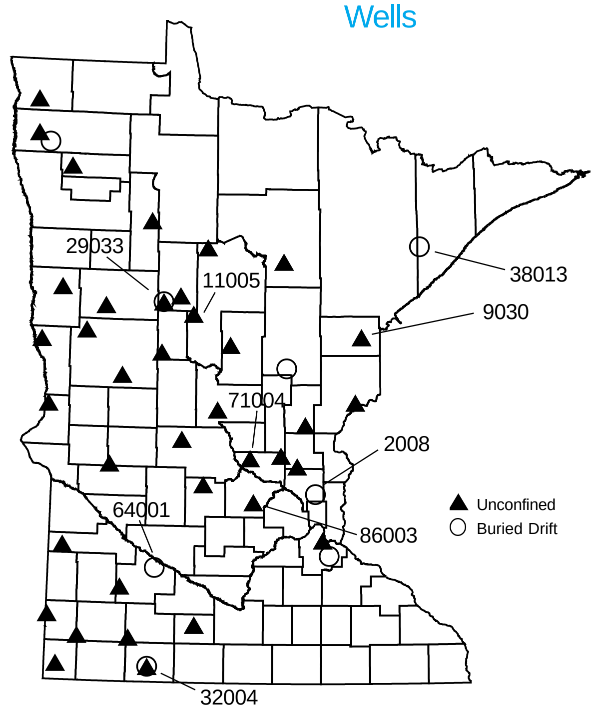
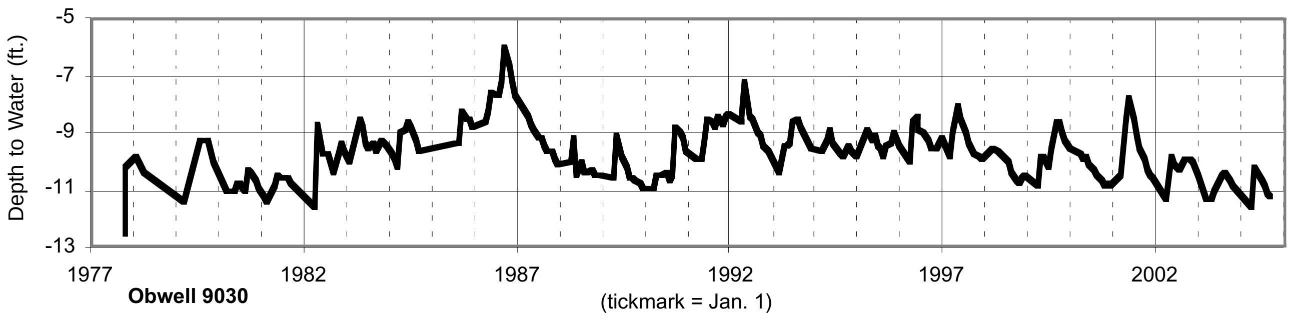
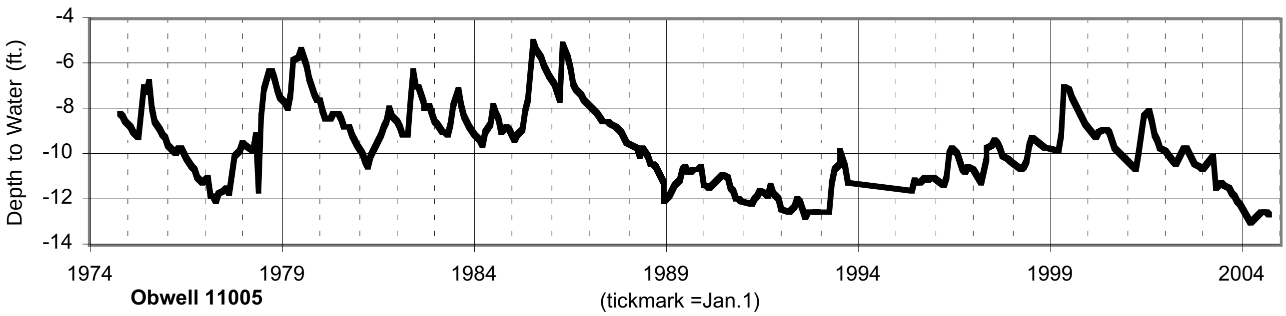


Figure 4A

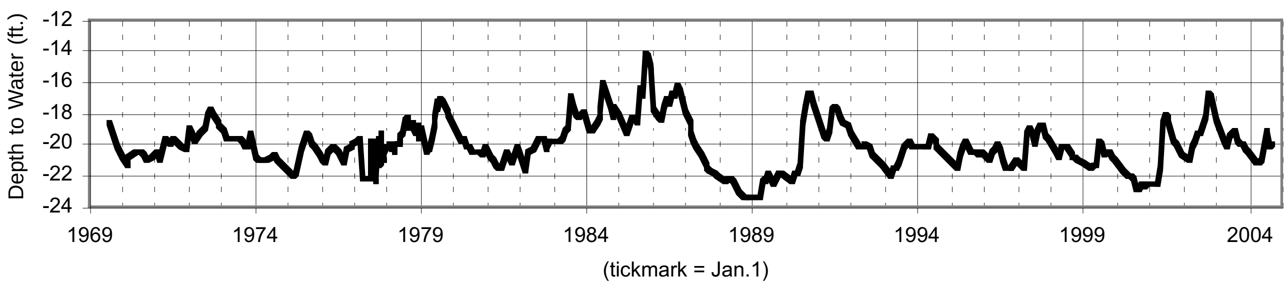
Unconfined (Water Table) Obwells



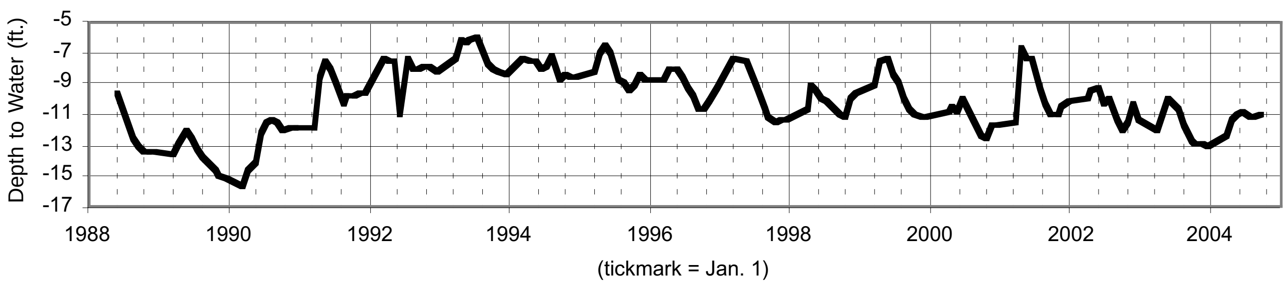
Obwell 9030



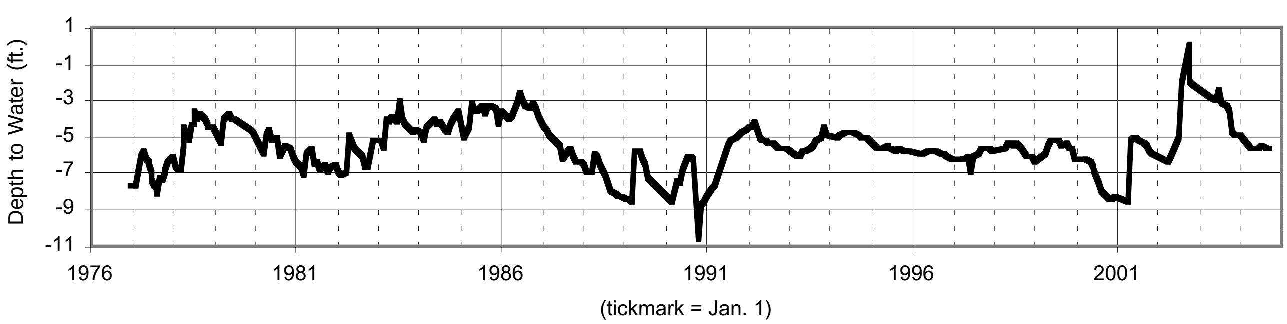
Obwell 11005



Obwell 71004



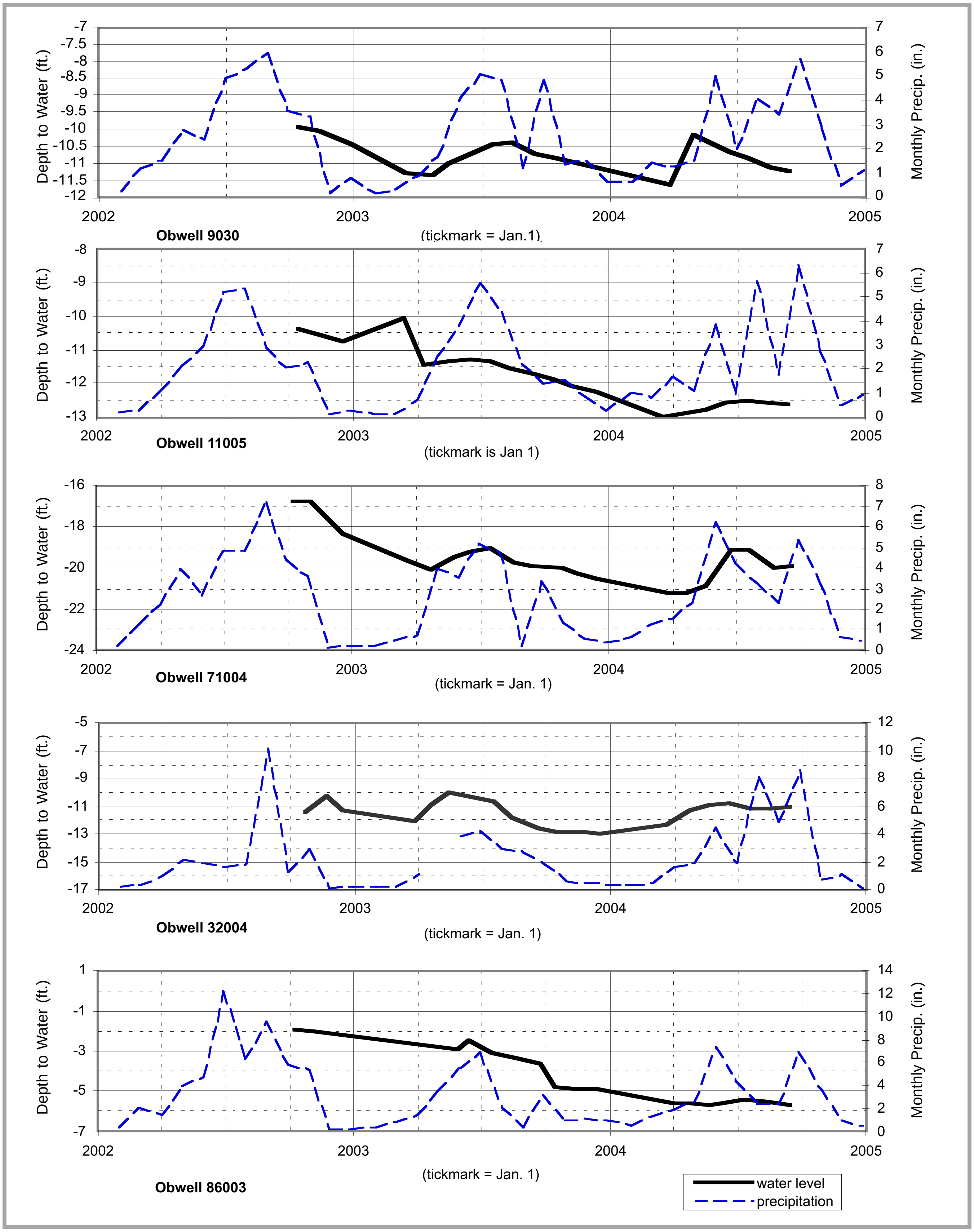
Obwell 32004



Obwell 86003

Figure 4B

Unconfined (Water Table) Obwells



Confined Aquifers

Changes in precipitation patterns are usually 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 amounts. Observation wells in the confined aquifers reflect that general rule.

Buried Drift Aquifers

Under confined conditions, these aquifers generally respond more slowly to seasonal inputs from snow melt 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 without additional data.

The approximate location of the buried drift wells selected for analysis are among the numbered wells shown in Figure 3. The hydrographs for these wells for the entire period of record are shown in Figure 6.

In the northern portion of the state, buried drift water levels continue the downward trend established in the previous water years. In central Minnesota a slight downward trend is also noticeable. In the southern portion of the state no trend is discernable, but fewer extremes, high and low, are evident.

Buried drift levels in the Twin Cities Metro area are muddled by induced recharge to the bedrock system. That is, most public supply is pumped from the underlying bedrock aquifers, which causes a downward draw on buried drift water levels and an enhanced leakage to the bedrock.

Figure 5

Buried Drift Observation Wells

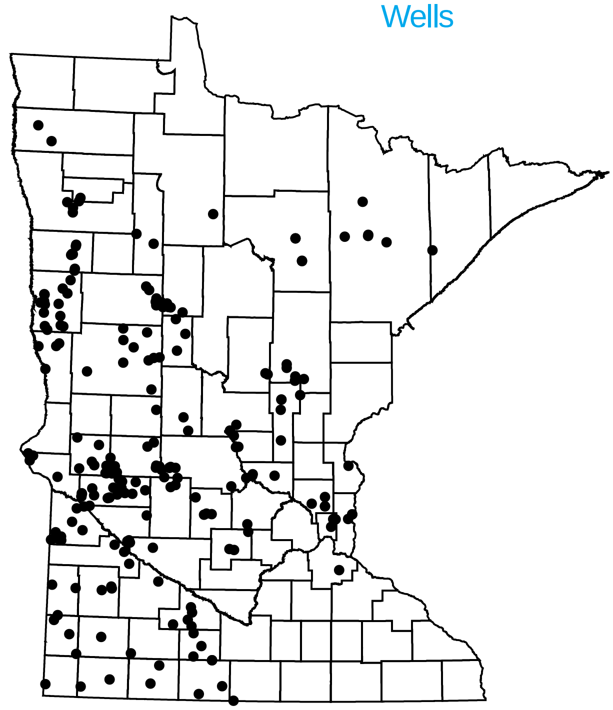
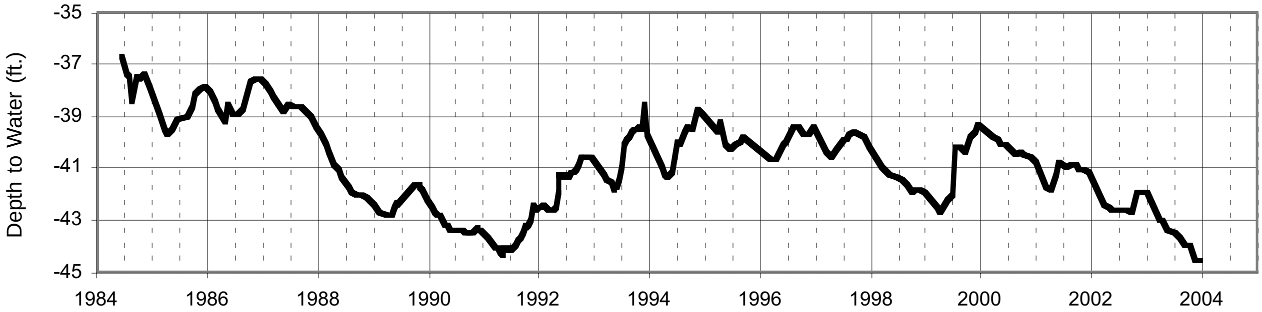


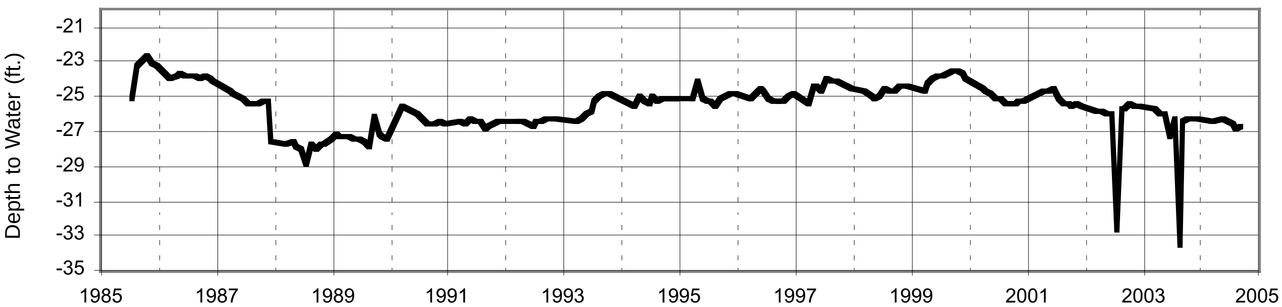
Figure 6

Buried Drift (Confined) Obwells



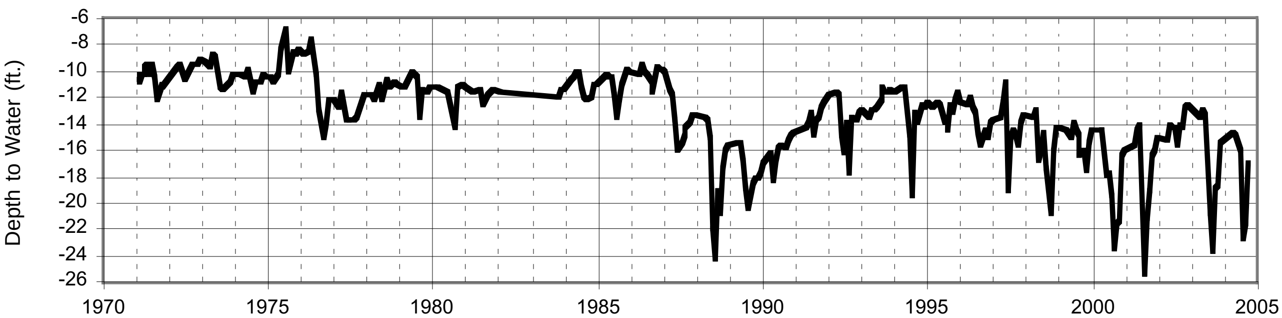
Obwell 38013

(tickmark = Jan. 1)



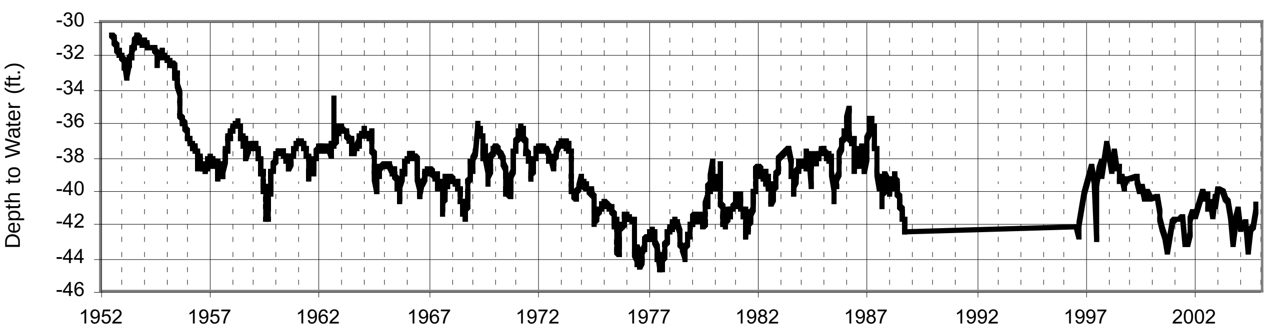
(tickmark = Jan. 1)

Obwell 29033



(tickmark = Jan. 1)

Obwell 2008



(tickmark = Jan. 1)

Obwell 64001

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 in situations where the aquifer is adjacent to unconfined materials; for example, 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 selected for this report are shown in Figure 8. Wells identified by number are those wells for which hydrographs are shown in Figure 9. Prairie du Chien-Jordan water levels reflect the intensity of human use for water supply. In areas of higher use, Prairie du Chien-Jordan wells show a gradual decline in water levels. Annual pumping cycles are clearly visible in these hydrographs.

Figure 8

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

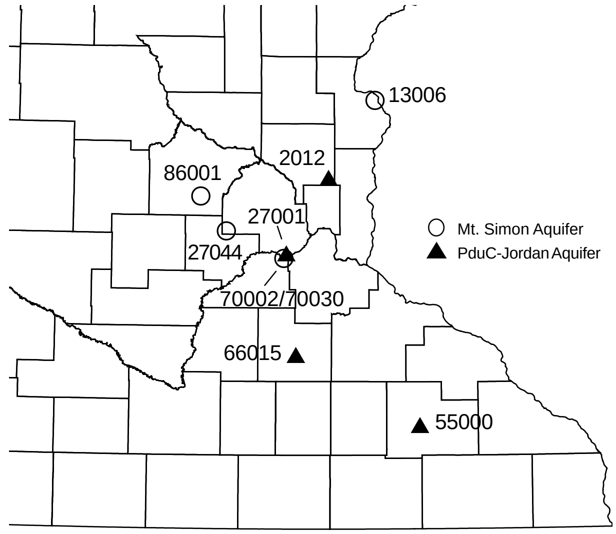
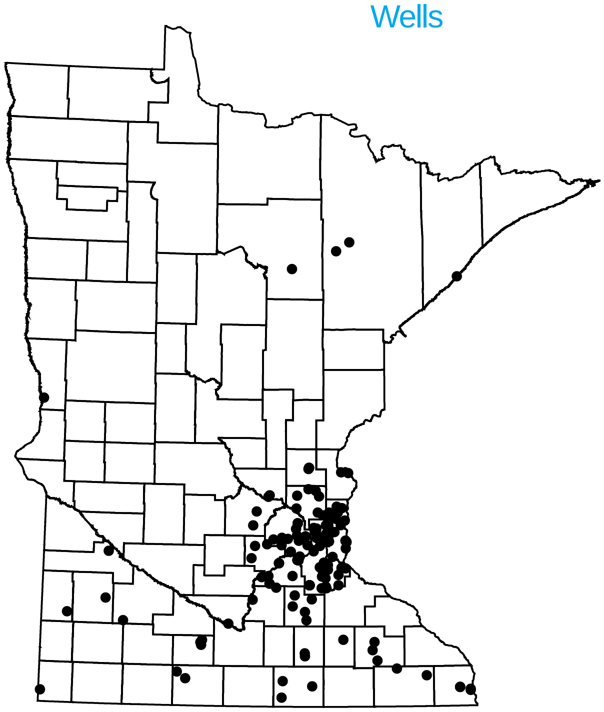


Figure 7

Bedrock Observation 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 wells whose hydrographs appear in Figure 10. Figure 10 shows the standard hydrographs for these selected wells over their entire period of record. The trace of Obwell 70002/70030 shows the impacts of human use on this aquifer in an area where, during the period of this report, water withdrawal from this aquifer increased in order to protect surface water features. This hydrograph illustrates the local result of that increased use. The impact of water withdrawal from the Mt. Simon over the entire basin has been to reduce levels on the outer edge of the basin by approximately 40' since predevelopment. This drop does not necessarily imply that the Mt. Simon aquifer is being depleted, but rather it illustrates that this aquifer is vulnerable to overuse.

Figure 9

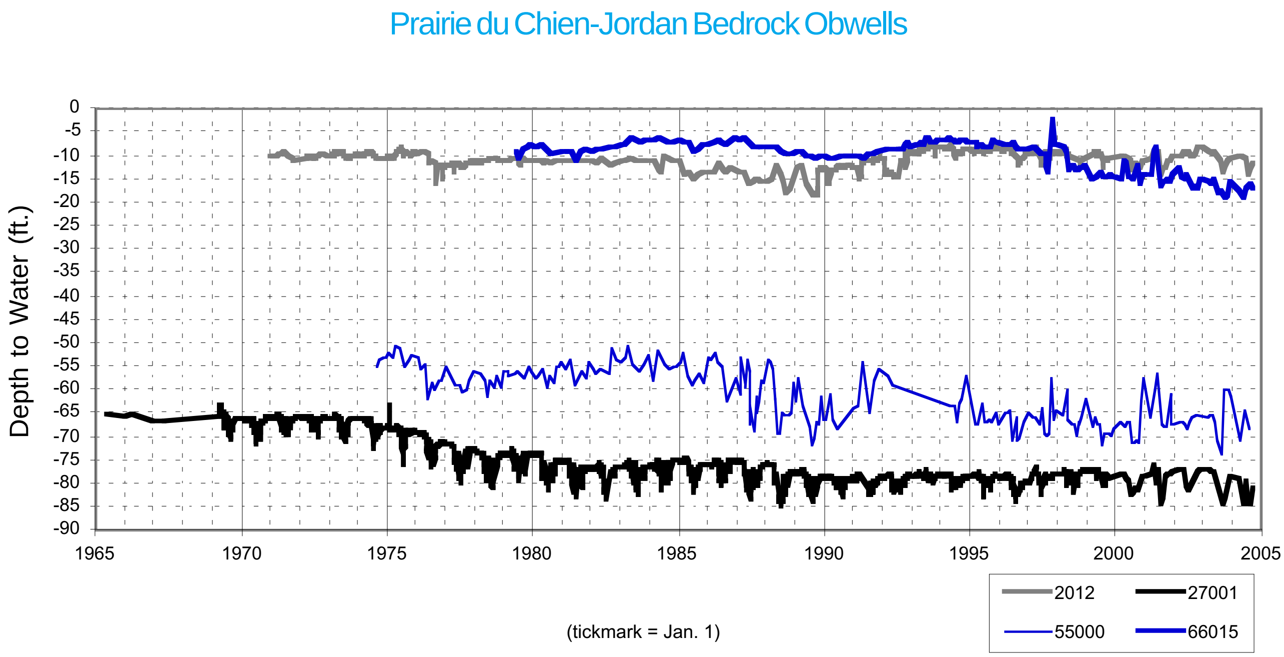
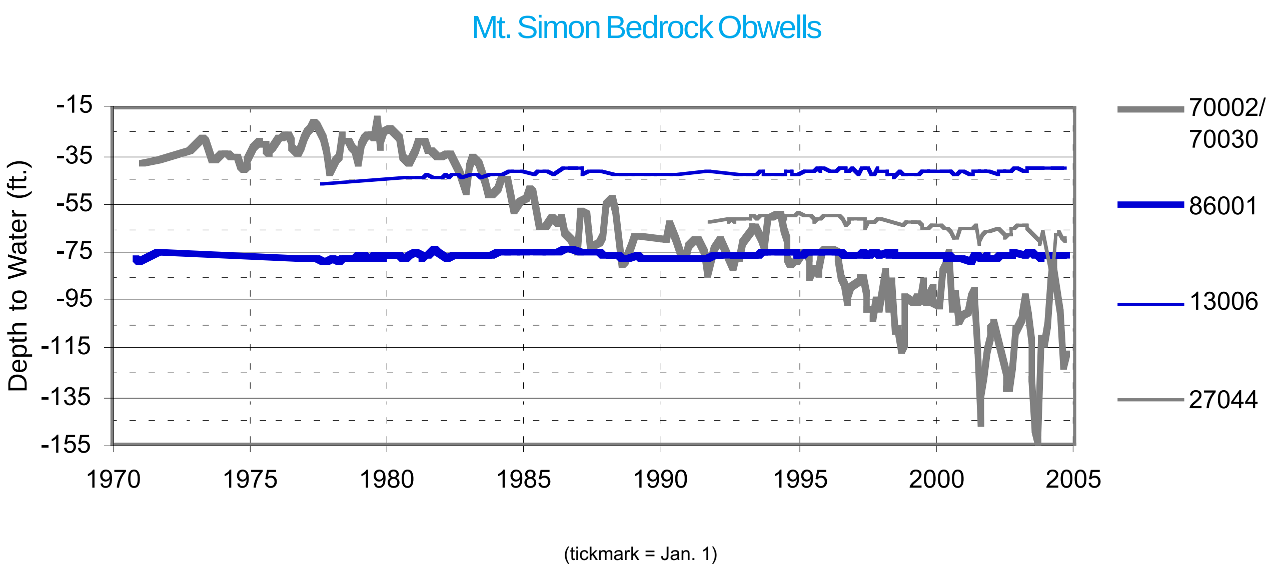


Figure 10



Network Improvement

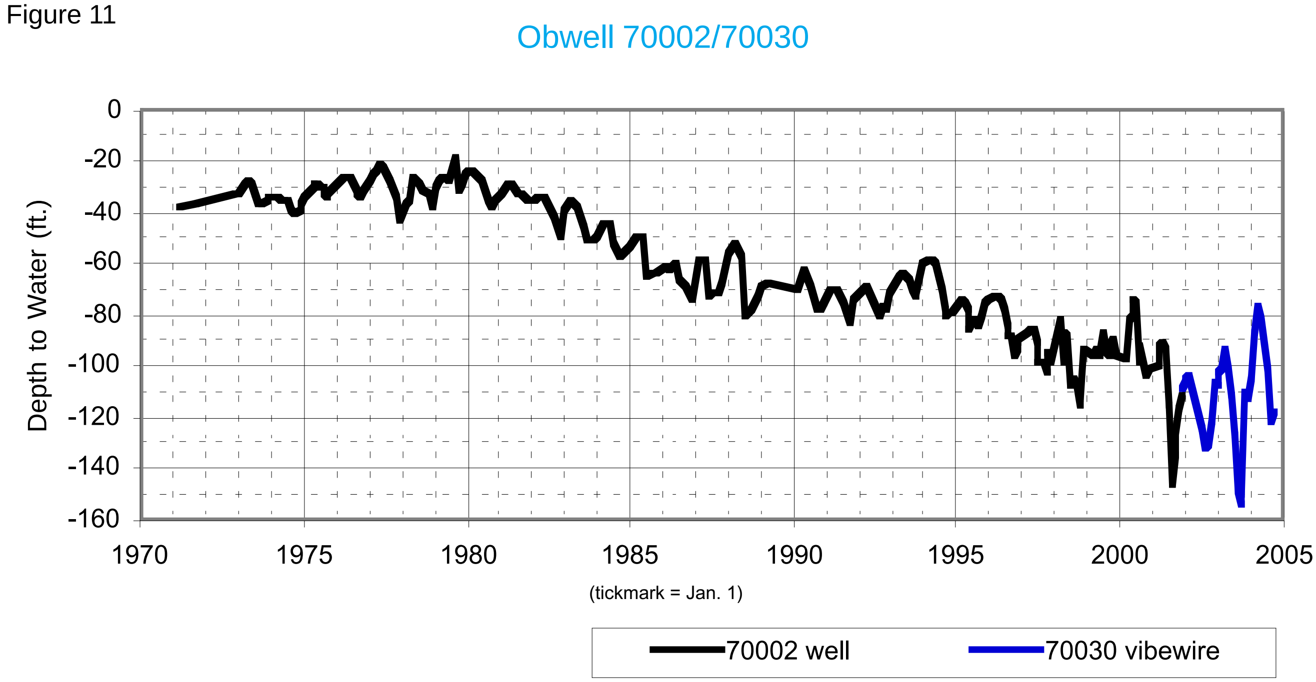
A systematic review of each obwell continues. During this review, each obwell will be visited by DNR hydrogeologists. When feasible, physical tests such as slug tests, gamma logging, and video logging will be performed on the obwell in order to confirm the quality and usefulness of the obwell within the network. Although approximately 750 obwells are actively monitored, the ground water level database contains some water levels for nearly twice that many wells that are not being monitered (inactive). The fate of the inactive wells 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.

DNR Waters' program of exploratory drilling and observation well installation continued on a limited basis. A few shallow obwells were replaced that were no longer functioning properly or that were lost due to a variety of circumstances such as inadvertent sealing, road construction, or well owners' decisions to eliminate the wells from their property.

The multi-aquifer monitoring point in southern Dakota County is now monitored in real-time using equipment provided and maintained by the US Geological Survey. Piezometers at this site are located in each aquifer and confining layer from the Shakopee Formation down into the Mt. Simon aquifer. This equipment will allow the data to be accessed though a webpage.

The vibrating wire piezometer, a technology used in civil engineering, has been adapted to monitor ground water levels. The piezometer is placed at the desired depth in a borehole or well and may be sealed in place. Measurements are 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. The technique has now been used at many locations throughout the state. For instance, Obwell 70002 had a long period of record in a significant aquifer. It was important to maintain that monitoring location if possible, however, the property owner needed to use the well location for another purpose. A vibrating wire piezometer was installed in the well as the well was sealed. The hydrograph of Obwell 70002/70030 shown in Figure 11 illustrates that this transition occurred seamlessly.

Figure 11



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 constuction -

Materials: Water quality is affected by well construction. PVC, which is used for most new obwells, cannot 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. The number of wells from which water quality samples can be taken in a day is considerably lower, so several days would be needed in order to visit each well for both purposes.

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.

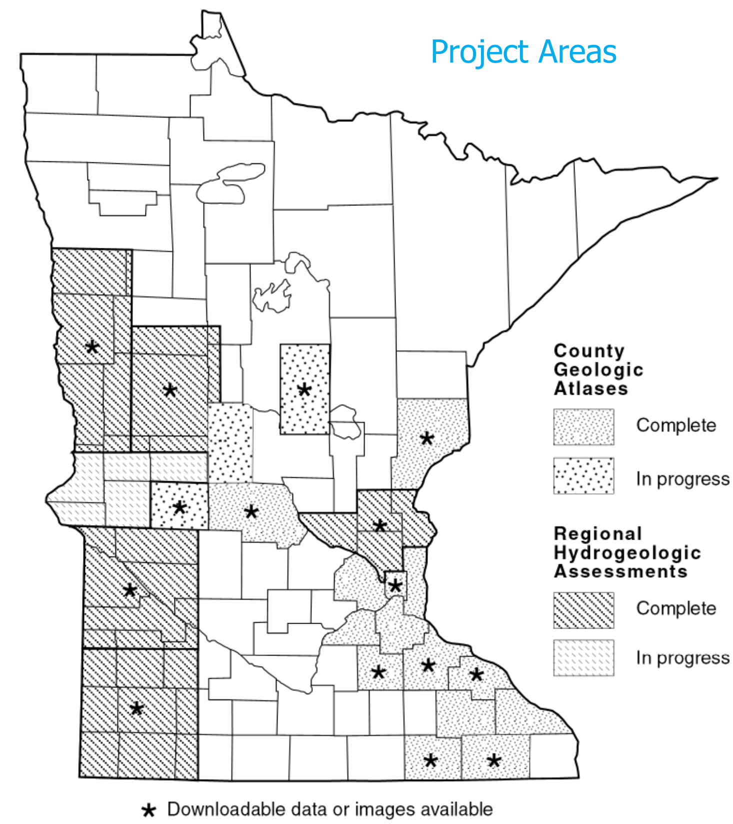
County Geologic Atlas and Regional Hydrogeologic Assessment Program

Ground Water Data

DNR Waters and the Minnesota Geological Survey (MGS) collaborate preparing the maps and reports of the County Geologic Atlases and Regional Hydrogeologic Assessments. The geologic data collection, mapping, and interpretation of the rock and sediment beneath the earth's surface by the MGS provide the framework for ground water studies by DNR Waters of how water moves through those materials and interacts with water at the land's surface.

DNR Waters project staff measure water levels in wells and collect water samples for chemical and isotopic analysis. Project staff also use ground water level monitoring data, climatology records, water use permits, and geophysical study reports.

Atlases and assessments are used in planning, environmental protection, and education. A better understanding of the physical environment and ground water systems enables better environmental decision-making.



Data Available Online

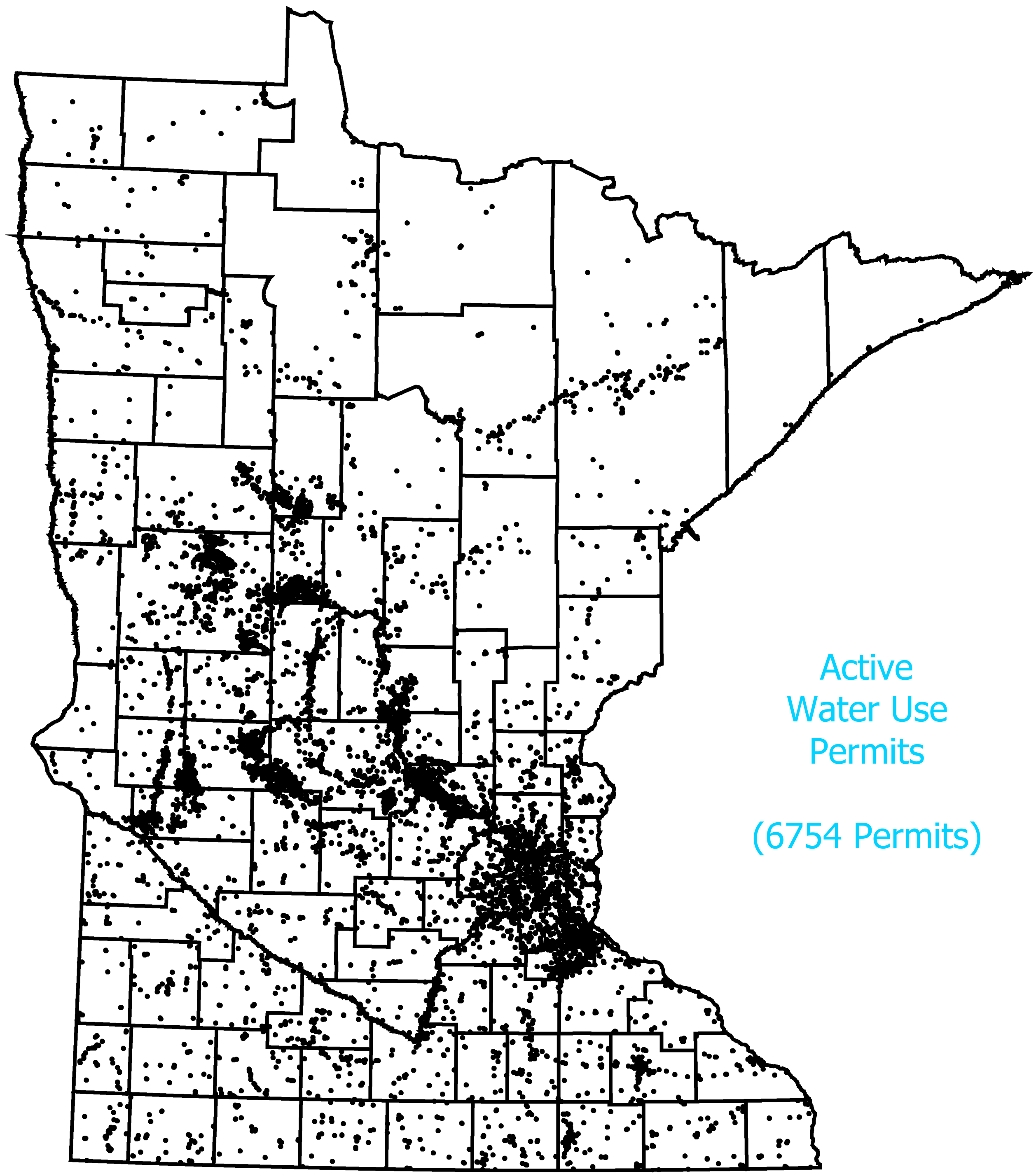
Digital data for many Atlas and Assessment projects, including geographical information systems (GIS) and related resource data, can be downloaded over the internet. Some map plate images and documents are also available as portable document format (PDF) files. GIS files have detailed data descriptions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

Digital data for many projects can be downloaded for use in GIS programs such as ArcView, ArcGIS, and EPPL7. 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 accessed on the DNR Waters website at
http://www.dnr.state.mn.us/waters/
Links to MGS project data on their ftp site are also on the DNR Waters website.
For more information on MGS project data see the MGS website at
http://www.geo.umn.edu/mgs/.

chapter four

water use



Active
Water Use
Permits

(6754 Permits)

Introduction

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

All permittees must use a flow meter or other approved method of measurement to determine the volume of water withdrawn and must submit an annual report of water use. Reported water use data are 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 (CY) 2002 and 2003.

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 upon 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.

Comparison of 2002 and 2003 Statewide Water Use

Water use in 2003 was 1374.0 billion gallons (BG) and was the highest use ever reported. 2002 reported use was 6% less than the 2003 total and is nearly the same as the value reported in 1999. Figure 1 is a comparison of 2002 and 2003 showing use by major category, and the volume and percent change between the years. The largest change in the two-year period was for irrigation, increasing by 35 BG or 50%. The smallest change in use was for the category "other," increasing by 1 BG or 2%. No category reported a decrease in usage, reflecting the fact that 2003 was climatologically the driest year in more than a decade.

Figure 2 graphically shows the changes in use patterns for four main use categories (excluding power generation) from 1985 to 2003. Water use in 2003 for irrigation and public supply was the highest since the drought year 1988 and the large uses reported in 2001. The pattern seen in irrigation reflects low use in times of high precipitation and large use in times of lower precipitation. Industrial processing use is influenced by economic vitality. Industrial water use rebounded to past levels, after a notable decline in 2001, mainly due to a resumption in mine processing and pit dewatering for hard rock mining.

Figure 1

Comparison of Water Use by Major Category: 2002 & 2003 (Billions of Gallons)

	Water Use 2002		Water Use 2003		Change from 2002 to 2003	
Use Category	**BG**	**% of Total**	**BG**	**% of Total**	**BG Change**	**% Change**
Power Generation	814.4	63%	824.7	60%	10	1%
Public Supply	198.9	15%	221.9	16%	23	12%
Industrial Processing	162.4	13%	168.7	12%	6	4%
Irrigation	70.0	5%	104.7	8%	35	50%
Other	53.1	4%	54.1	4%	1	2%
Totals	**1,298.8**	**100%**	**1,374.0**	**100%**	**+75**	**5.8%**

column totals may not sum due to independent rounding

A comparison of surface water versus ground water use for 2003 (Figure 3) shows that the majority of appropriations are from surface water sources. However, if the non-consumptive water use for power generation is removed, uses of ground water and surface water are more even (non-consumptive use means water that is immediately returned to its source after use). In 2003, 80% of total use in Minnesota was from surface water sources, however, 60% of the total was for power plant cooling, a relatively non-consumptive use.

Surface water use increased from 2001 to 2003 due to demands for power generation and industrial processing, while ground water use increased due to demands for irrigation by agriculture and by public water suppliers.

Figure 2

Minnesota Water Use - 1985 to 2003
(Billions of Gallons)

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Power Generation	508	539	637	663	664	698	694	679	722	765	748	710	701	785	812	829	798	814	825
Public Supply	171	170	192	203	174	164	170	175	164	178	180	189	185	192	184	197	211	199	222
Industrial Processing	109	76	69	94	120	102	115	158	127	120	160	147	159	169	166	173	110	162	169
Irrigation	49	30	67	103	86	71	60	63	30	56	62	80	58	77	72	83	96	70	105
Other	49	42	38	42	48	53	52	58	63	64	60	57	63	58	65	59	58	53	54
Total	**886**	**857**	**1003**	**1105**	**1092**	**1088**	**1091**	**1133**	**1106**	**1183**	**1210**	**1183**	**1166**	**1281**	**1299**	**1341**	**1273**	**1299**	**1374**

column totals may not sum due to independent rounding

Minnesota Water Use
(excluding Power Generation)
in Billions of Gallons

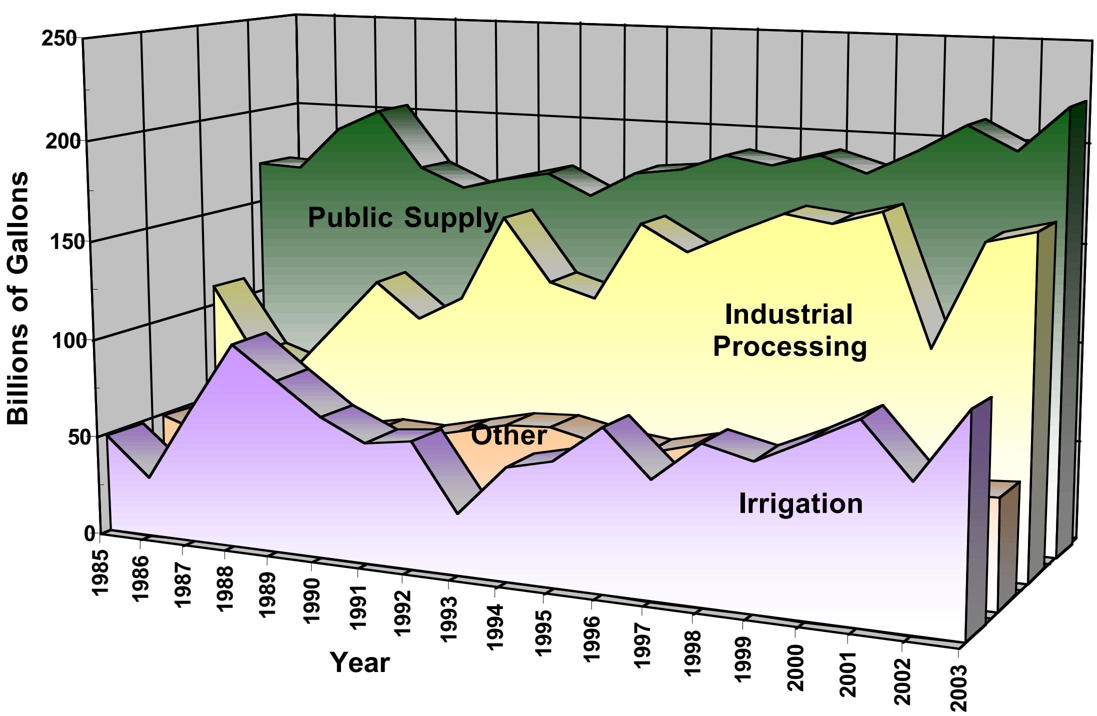
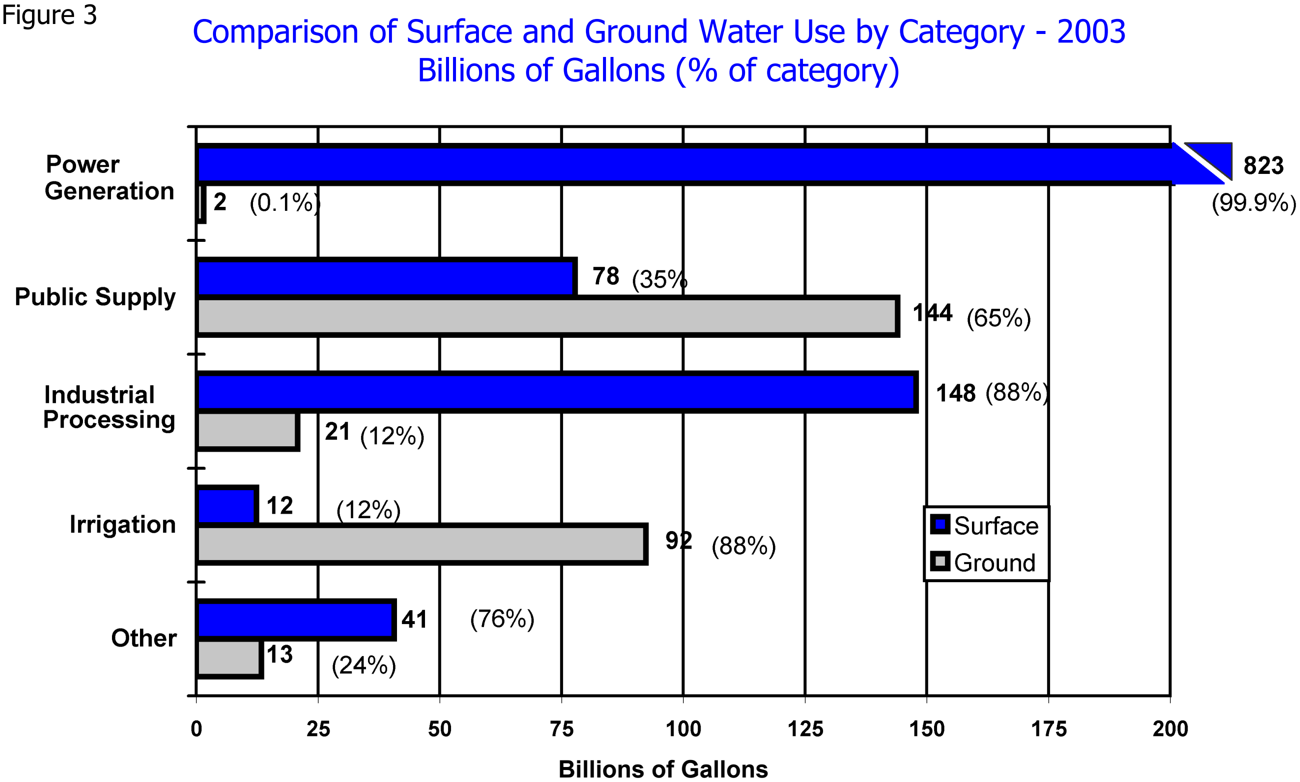


Figure 3



Power Generation

Figure 4 shows that power generation (nuclear power cooling and steam power cooling) was the primary use in eight of the 11 counties with the highest total use in 2003. Goodhue and Wright Counties alone accounted for 24% of reported use in 2003, largely due to nuclear power plant cooling. Surface water sources supply nearly all water used for power plant cooling, most of which is returned to the surface water source.

Public Water Supply

Public supply gradually increased from 1990 to 1999 due to population increases, higher use for lawn watering and demands by industrial customers. However, public supply increased at a faster pace from 2000 to 2003 (Figure 5). Reported water use for 2001 and 2003 was 211 BG and 222 BG respectively. 65% of public water supply came from ground water in 2003, compared to 37% nationally (USGS, *Estimated Use of Water in the United States in 2000*).

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 implement demand management measures before requesting approvals 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 2003
Billions of Gallons

	County	Surface Water	Ground Water	Total	Primary Use
1)	Goodhue	208.7	2.4	211.1	Nuclear Power Cooling
2)	Wright	116.3	3.7	120.0	Nuclear Power Cooling
3)	Washington	103.3	13.6	116.9	Steam Power Cooling
4)	Dakota	87.7	29.9	117.6	Steam Power Cooling
5)	Hennepin	77.5	39.6	117.1	Steam Power Cooling
6)	Cook	68.3	0.0	68.3	Mine Processing
7)	Itasca	68.2	1.0	69.2	Steam Power Cooling
8)	St. Louis	87.4	2.1	89.5	Steam Power Cooling
9)	Ramsey	69.6	12.5	82.1	Steam Power Cooling
10)	Lake	48.9	0.0	48.9	Mine Processing
11)	Anoka	37.8	12.5	50.3	Municipal Waterworks
	Total	**973.7**	**117.3**	**1091.0**	
		88% of SW Use	*43% of* GW Use	*79% of* Total Use	

Irrigation

Annual variations in the amount and distribution of rainfall greatly affect the demand for irrigation water. Combined irrigation use for calendar years 2002-2003 was 3% lower compared to the previous two-year period. However, 2003 had the highest irrigation use of the 4-year period with 105 billion gallons.

Irrigation accounts for only a small amount (8%) 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 (88% in 2003). The timing of irrigation water use can be significant when evaluating regional water supplies and the potential for well interferences. Almost all irrigation water use is compacted into the five-month period from May to September of each year.

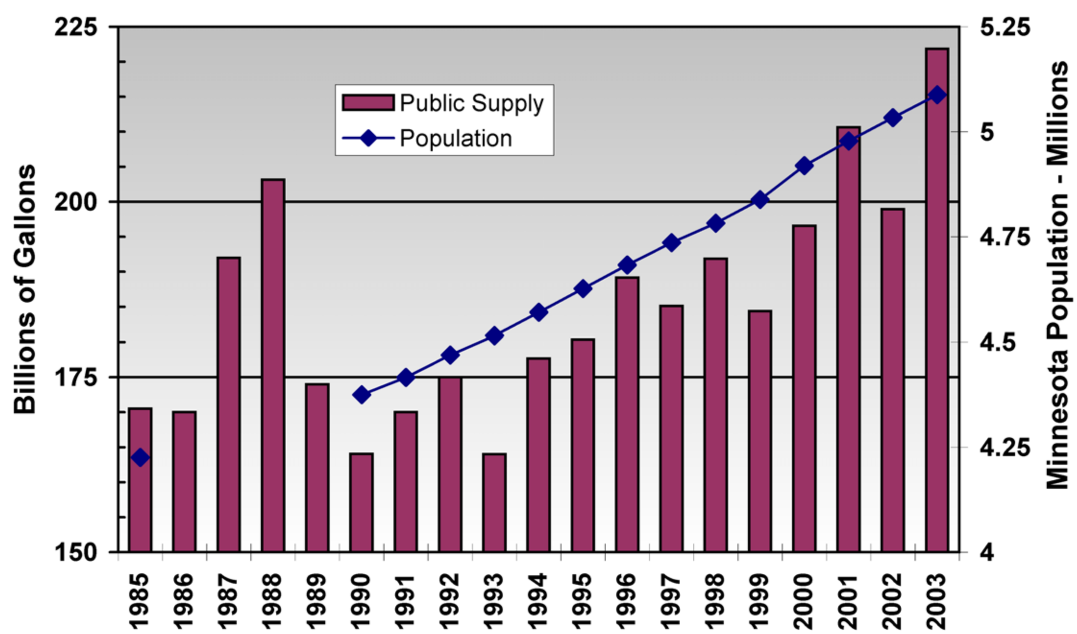
Otter Tail and Sherburne Counties reported the highest appropriations for irrigation in 2003, using 14.5 BG and 9.1 BG respectively. Roseau, Sibley, Traverse and Winona Counties reported only golf course irrigation under the irrigation category.

Industrial Processing

Industrial processing use decreased from an average of 170 BG to 110 BG in 2001 due to a reduction in demand for mine processing and pit dewatering. Mine processing use decreased by 50%, accounting for most of the decline. In 2002 and 2003, overall industrial processing use was back to pre-2001 levels due to the resumption of mining activities. Pulp and paper processing, and agricultural processing, accounted for 15% and 6%, respectively, of the total use reported.

Figure 5

Minnesota Public Water Supply Use and Minnesota Population



Other Uses

Other uses include air conditioning, water level maintenance, fisheries operations, temporary construction dewatering, pollution confinement, snow making and other specialty uses that represent about 4% of Minnesota's total water use.

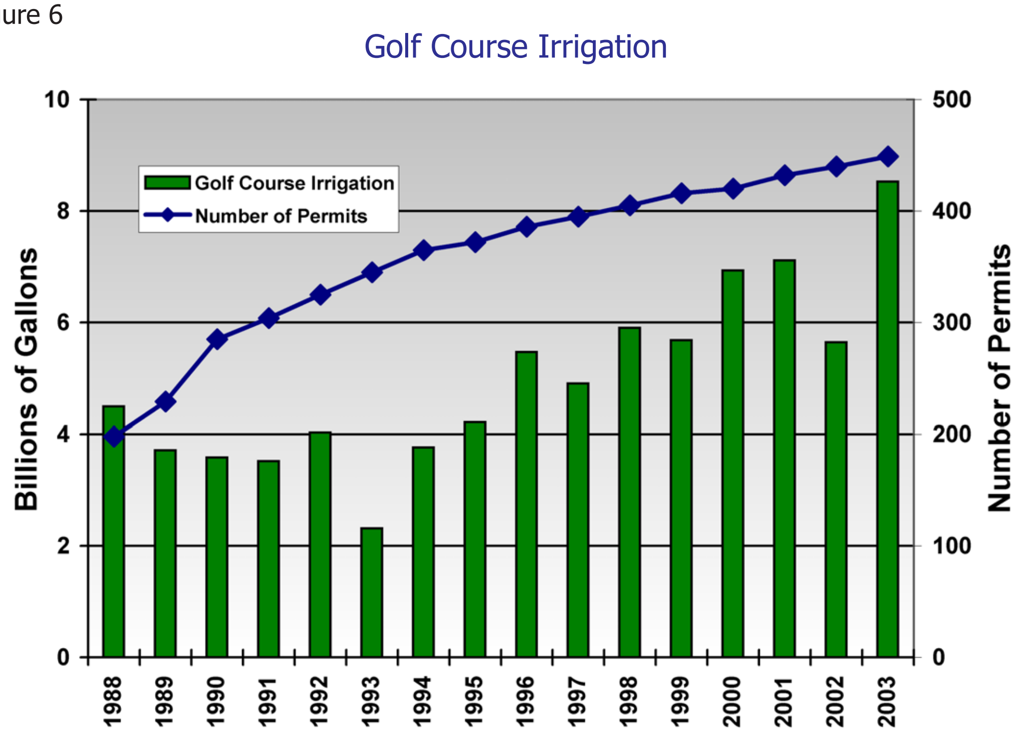
Golf Course Irrigation

As the number of golf courses has increased in Minnesota, so has the associated water use (Figure 6). Over the last 15 years the number of golf course permits has more than doubled, as has the water use, depending upon the relative dryness of a given year.

Summary

Total water use in 2003 increased to a new high of 1374 billion gallons. Power generation continues to account for the majority of use, totaling 824.7 BG (or 60%) in 2003. Surface water accounts for 80% of all appropriations.

Figure 6



Reported Water Use by County 2002 - 2003 (Millions of Gallons)

Reported Water Use

	County	2002 Surface	2002 Ground	2002 Total	2003 Surface	2003 Ground	2003 Total	Primary Use	% of 2003 Total
1	Aitkin	1,234.3	101.0	1,335.3	1,018.4	114.3	1,132.7	Wild Rice Irrigation	86
2	Anoka	35,722.9	10,511.7	46,234.6	37,769.8	12,509.9	50,279.7	Municipal Waterworks	95
3	Becker	13.0	2,513.9	2,526.9	13.8	3,420.2	3,434.0	Major Crop Irrigation	71
4	Beltrami	1,368.1	729.7	2,097.8	630.3	763.4	1,393.7	Municipal Waterworks	45
5	Benton	3,613.7	2,492.8	6,106.5	3,854.8	4,096.4	7,951.2	Industrial Processing	47
6	Big Stone	25.3	446.0	471.3	14.3	545.6	559.9	Major Crop Irrigation	53
7	Blue Earth	7,518.9	3,724.4	11,243.3	8,056.7	3,946.2	12,002.9	Steam Power Cooling	66
8	Brown	120.1	982.9	1,103.0	126.7	1,023.5	1,150.2	Major Crop Irrigation	45
9	Carlton	2,305.4	660.5	2,965.9	1,988.1	717.3	2,705.4	Pulp/Paper Processing	72
10	Carver	23.0	2,854.9	2,877.9	35.7	3,605.4	3,641.1	Municipal Waterworks	82
11	Cass	34.8	1,133.5	1,168.3	21.7	1,301.1	1,322.8	Major Crop Irrigation	38
12	Chippewa	25.5	531.8	557.3	75.0	605.4	680.4	Municipal Waterworks	71
13	Chisago	156.9	962.1	1,119.0	102.9	1,262.1	1,365.0	Municipal Waterworks	56
14	Clay	1,700.6	832.6	2,533.2	1,837.5	1,024.4	2,861.9	Municipal Waterworks	70
15	Clearwater	3,366.6	107.4	3,474.0	3,637.7	127.7	3,765.4	Wild Rice Irrigation	96
16	Cook	53,511.2	13.6	53,524.8	68,272.2	7.9	68,280.1	Mine Processing	99
17	Cottonwood	461.0	1,162.6	1,623.6	129.1	1,222.6	1,351.7	Municipal Waterworks	40
18	Crow Wing	489.6	1,766.4	2,256.0	546.9	2,129.0	2,675.9	Municipal Waterworks	45
19	Dakota	68,024.2	21,826.6	89,850.8	87,736.5	29,945.7	117,682.2	Steam Power Cooling	71
20	Dodge	68.9	580.8	649.7	15.6	564.6	580.2	Municipal Waterworks	62
21	Douglas	91.3	1,453.1	1,544.4	119.2	1,793.8	1,913.0	Major Crop Irrigation	39
22	Faribault	0.0	808.0	808.0	0.0	839.4	839.4	Municipal Waterworks	61
23	Fillmore	3,532.8	662.8	4,195.6	3,354.1	647.9	4,002.0	Hatcheries & Fisheries	83
24	Freeborn	12.6	1,624.5	1,637.1	47.0	1,685.6	1,732.6	Municipal Waterworks	74
25	Goodhue	216,262.0	2,061.3	218,323.3	208,719.3	2,352.0	211,071.3	Nuclear Power Cooling	91
26	Grant	0.0	628.0	628.0	0.0	855.5	855.5	Major Crop Irrigation	79
27	Hennepin	76,098.8	33,821.3	109,920.1	77,480.2	39,575.5	117,055.7	Steam Power Cooling	66
28	Houston	9.0	533.4	542.4	27.6	558.6	586.2	Municipal Waterworks	73
29	Hubbard	26.0	4,470.2	4,496.2	22.1	5,213.2	5,235.3	Major Crop Irrigation	79
30	Isanti	3.6	626.9	630.5	3.3	807.3	810.6	Municipal Waterworks	46
31	Itasca	68,606.6	1,007.8	69,614.4	68,231.0	1,017.8	69,248.8	Steam Power Cooling	84
32	Jackson	165.8	296.7	462.5	149.5	297.0	446.5	Municipal Waterworks	59
33	Kanabec	10.3	163.0	173.3	18.3	210.2	228.5	Municipal Waterworks	69
34	Kandiyohi	570.5	2,335.5	2,906.0	447.2	3,521.4	3,968.6	Municipal Waterworks	47
35	Kittson	77.4	351.7	429.1	137.9	427.7	565.6	Major Crop Irrigation	46
36	Koochiching	18,750.4	46.3	18,796.7	16,285.8	46.6	16,332.4	Pulp/Paper Processing	97
37	Lac Qui Parle	33.5	1,296.7	1,330.2	68.0	1,510.0	1,578.0	Agricultural Processing	45
38	Lake	47,649.6	0.6	47,650.2	48,889.1	0.3	48,889.4	Mine Processing	99
39	Lake of the Woods	274.7	67.4	342.1	270.5	68.9	339.4	Wild Rice Irrigation	78
40	Le Sueur	4,422.2	1,251.4	5,673.6	4,209.4	1,370.6	5,580.0	Quarry/Mine Dewatering	60
41	Lincoln	6.4	482.1	488.5	8.3	1,394.4	1,402.7	Municipal Waterworks	62
42	Lyon	144.1	1,437.8	1,581.9	117.7	1,554.2	1,671.9	Municipal Waterworks	63
43	McLeod	71.2	1,848.1	1,919.3	421.1	1,950.8	2,371.9	Municipal Waterworks	51
44	Mahnomen	0.0	84.9	84.9	0.0	85.2	85.2	Municipal Waterworks	95

Reported Water Use by County
2002 - 2003 (Millions of Gallons)

Reported Water Use

	County	2002 Surface	2002 Ground	2002 Total	2003 Surface	2003 Ground	2003 Total	Primary Use	% of 2003 Total
45	Marshall	143.7	226.3	370.0	143.7	227.6	371.3	Municipal Waterworks	30
46	Martin	7,564.7	414.8	7,979.5	8,712.2	398.8	9,111.0	Steam Power Cooling	89
47	Meeker	13.9	776.6	790.5	22.8	1,760.0	1,782.8	Major Crop Irrigation	59
48	Mille Lacs	24.8	454.0	478.8	37.8	565.4	603.2	Municipal Waterworks	67
49	Morrison	59.8	3,447.3	3,507.1	144.3	4,623.2	4,767.5	Major Crop Irrigation	77
50	Mower	35.2	2,618.3	2,653.5	42.1	2,767.7	2,809.8	Municipal Waterworks	44
51	Murray	48.2	225.6	273.8	85.4	234.9	320.3	Municipal Waterworks	70
52	Nicollet	78.8	1,806.1	1,884.9	104.8	1,982.7	2,087.5	Municipal Waterworks	84
53	Nobles	60.9	1,163.3	1,224.2	59.6	1,149.8	1,209.4	Municipal Waterworks	93
54	Norman	0.4	136.0	136.4	0.0	145.9	145.9	Municipal Waterworks	90
55	Olmsted	5,624.1	6,230.0	11,854.1	10,512.2	5,726.8	16,239.0	Steam Power Cooling	65
56	Otter Tail	26,204.2	12,457.9	38,662.1	24,457.5	15,170.6	39,628.1	Steam Power Cooling	60
57	Pennington	748.7	26.7	775.4	723.8	26.5	750.3	Municipal Waterworks	56
58	Pine	17.8	481.3	499.1	88.3	557.7	646.0	Municipal Waterworks	52
59	Pipestone	40.1	997.8	1,037.9	54.6	967.1	1,021.7	Rural Waterworks	45
60	Polk	4,141.6	478.5	4,620.1	4,688.1	653.9	5,342.0	Municipal Waterworks	65
61	Pope	48.9	4,125.7	4,174.6	55.6	8,955.8	9,011.4	Major Crop Irrigation	95
62	Ramsey	65,896.7	12,080.1	77,976.8	69,590.7	12,510.6	82,101.3	Steam Power Cooling	63
63	Red Lake	527.5	341.9	869.4	308.4	355.2	663.6	Municipal Waterworks	53
64	Redwood	125.7	435.4	561.1	66.9	485.1	552.0	Municipal Waterworks	74
65	Renville	97.1	776.6	873.7	59.1	783.8	842.9	Municipal Waterworks	56
66	Rice	86.4	2,632.7	2,719.1	79.3	2,781.5	2,860.8	Municipal Waterworks	81
67	Rock	34.4	634.4	668.8	50.6	605.5	656.1	Municipal Waterworks	59
68	Roseau	0.2	322.3	322.5	0.0	338.5	338.5	Municipal Waterworks	91
69	St. Louis	96,064.4	2,083.7	98,148.1	87,382.6	2,073.0	89,455.6	Steam Power Cooling	60
70	Scott	175.2	4,662.0	4,837.2	178.4	5,791.0	5,969.4	Municipal Waterworks	68
71	Sherburne	19,917.9	8,442.6	28,360.5	22,441.3	11,328.2	33,769.5	Steam Power Cooling	38
72	Sibley	9.7	728.9	738.6	3.2	687.1	690.3	Municipal Waterworks	82
73	Stearns	3,317.5	6,880.0	10,197.5	3,468.2	10,553.0	14,021.2	Major Crop Irrigation	50
74	Steele	1,430.1	1,751.8	3,181.9	1,424.0	1,918.6	3,342.6	Municipal Waterworks	54
75	Stevens	56.4	1,592.0	1,648.4	80.0	2,607.6	2,687.6	Major Crop Irrigation	80
76	Swift	28.7	3,904.5	3,933.2	34.1	5,875.8	5,909.9	Major Crop Irrigation	91
77	Todd	143.2	2,551.1	2,694.3	236.9	3,142.9	3,379.8	Major Crop Irrigation	74
78	Traverse	3.3	102.9	106.2	2.8	101.2	104.0	Municipal Waterworks	97
79	Wabasha	0.9	1,039.4	1,040.3	10.5	1,097.6	1,108.1	Municipal Waterworks	79
80	Wadena	494.5	3,078.8	3,573.3	730.4	3,781.3	4,511.7	Major Crop Irrigation	90
81	Waseca	29.0	744.4	773.4	27.6	779.8	807.4	Municipal Waterworks	89
82	Washington	102,216.1	10,879.3	113,095.4	103,343.4	13,553.6	116,897.0	Steam Power Cooling	86
83	Watonwan	51.7	1,098.7	1,150.4	25.5	1,174.2	1,199.7	Municipal Waterworks	59
84	Wilkin	50.6	154.8	205.4	73.1	213.7	286.8	Municipal Waterworks	49
85	Winona	1,017.9	2,273.4	3,291.3	984.4	2,462.7	3,447.1	Municipal Waterworks	45
86	Wright	125,144.8	2,974.4	128,119.2	116,343.8	3,742.4	120,086.2	Nuclear Power Cooling	97
87	Yellow Medicine	60.4	870.8	931.2	74.2	774.6	848.8	Rural Waterworks	47
	Totals			**1,298,837**			**1,374,012**		

Minnesota Reported Water Use

Category	2002	2003
Power Generation	(Millions of Gallons)	
Nuclear Power		
surface	325,423.0	309,011.0
ground	13.1	14.8
Steam Power Cooling		
surface	385,286.9	409,473.4
ground	452.0	644.0
Other Power		
surface	102,315.7	104,686.5
ground	904.7	869.9
Subtotal	**814,395.4**	**824,699.6**
Percent of Total	**63%**	**60%**
surface	813,025.6	823,170.9
ground	1,369.8	1,528.7
Public Supply		
Municipal Water Works		
surface	72,979.1	77,803.9
ground	121,689.7	140,013.1
Private Water Works		
surface	10.6	10.6
ground	710.0	736.7
Commercial & Institutional		
surface	0.0	0.0
ground	1,436.5	1,315.9
Cooperative Water Works		
surface	0.0	0.0
ground	1.6	1.9
Fire Protection		
surface	0.0	0.0
ground	17.4	17.4
State Parks, Waysides, Rest Areas		
surface	0.0	0.0
ground	42.9	45.0
Rural Water Districts		
surface	0.0	0.0
ground	2,032.3	1,914.2
Subtotal	**198,920.1**	**221,858.7**
Percent of Total	**15%**	**16%**
surface	72,989.7	77,814.5
ground	125,930.4	144,044.2

Minnesota Reported Water Use

Category	2002	2003
Irrigation		
Golf Course		
surface	1,276.0	1,710.4
ground	4,366.9	6,818.3
Cemetery		
surface	0.0	3.2
ground	32.4	63.7
Landscaping		
surface	40.8	63.6
ground	498.0	647.4
Sod		
surface	65.2	138.7
ground	39.2	234.5
Nursery		
surface	119.0	180.2
ground	328.5	552.8
Orchard		
surface	1.6	2.8
ground	1.7	10.3
Non Crop		
surface	2.8	9.1
ground	25.2	20.9
Temporary		
surface	0.0	0.0
ground	11.0	50.9
Major Crop		
surface	1,794.6	2,714.7
ground	52,935.8	83,827.9
Wild Rice		
surface	8,363.7	7,540.1
ground	83.8	133.8
Subtotal	**69,986.2**	**104,723.3**
Percent of Total	**5%**	**8%**
surface	11,663.7	12,362.8
ground	58,322.5	92,360.5

Minnesota Reported Water Use

Category	2002	2003
Industrial Processing		
Agricultural		
surface	172.9	68.7
ground	10,038.7	9,673.8
Pulp and Paper		
surface	28,453.4	25,024.7
ground	1,031.9	868.0
Mine		
surface	109,747.8	119,521.4
ground	61.5	137.6
Sand and Gravel Washing		
surface	2,876.1	2,760.5
ground	1,033.1	1,168.6
Industrial Process Cooling Once-Through		
surface	164.8	216.8
ground	1,661.4	1,656.6
Petroleum or Chemical		
surface	182.0	259.6
ground	3,661.0	4,224.8
Metal		
surface	0.0	0.0
ground	1,434.4	1,442.4
Non-Metal		
surface	0.5	0.4
ground	1,523.7	1,248.1
Other		
surface	0.0	0.0
ground	365.3	385.6
Subtotal	**162,408.5**	**168,657.6**
Percent of Total	**13%**	**12%**
surface	141,597.5	147,852.1
ground	20,811.0	20,805.5

Category	2002	2003
Other		
Air Conditioning		
Commercial & Institutional Building AC		
surface	274.1	282.8
ground	159.2	134.6

Minnesota Reported Water Use

Category	2002	2003
Heat Pumps & Coolant Pumps		
surface	82.2	105.3
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	2,341.9	1,900.7
Other AC		
surface	0.0	0.0
ground	0.0	0.0
Temporary		
Temporary Construction Non-Dewatering		
surface	11.2	7.6
ground	4.7	4.2
Temporary Construction Dewatering		
surface	81.5	8.7
ground	1,943.9	2,247.0
Temporary Pipeline and Tank Testing		
surface	0.0	2.6
ground	0.0	0.0
Other Temporary		
surface	56.0	131.1
ground	0.0	0.0
Water Level Maintenance		
Basin (Lake) Level Maintenance		
surface	856.1	2,479.2
ground	189.9	348.6
Mine Dewatering		
surface	19,653.4	21,078.4
ground	26.7	7.3
Quarry Dewatering		
surface	11,967.2	10,661.0
ground	0.0	0.0
Sand/Gravel Pit Dewatering		
surface	402.3	491.4
ground	17.7	44.6

Minnesota Reported Water Use

Category	2002	2003
Tile Drainage & Pumped Sumps		
surface	35.2	30.5
ground	315.2	140.6
Other Water Level Maintenance		
surface	27.9	44.0
ground	1,200.3	1,220.8
Special Categories		
Pollution Confinement		
surface	0.0	0.0
ground	4,468.4	4,323.2
Hatcheries & Fisheries		
surface	5,474.0	5,091.2
ground	658.0	586.0
Snow Making		
surface	212.8	172.5
ground	303.6	314.1
Peat Fire Control		
surface	0.0	0.0
ground	0.0	0.0
Livestock Watering		
surface	0.0	0.0
ground	925.5	680.3
Other Special Categories		
surface	28.3	78.7
ground	1,409.6	1,455.9
Subtotal	**53,126.8**	**54,072.9**
Percent of Total	**4%**	**4%**
surface	39,162.2	40,665.0
ground	13,964.6	13,407.9
Grand Total (Millions of Gallons)	**1,298,837**	**1,374,012**
surface	**1,078,439**	**1,101,865**
ground	**220,398**	**272,147**

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