1996 Water Availability Assessment

September 1996

Department of
Natural Resources
Division of Waters

Minn. Stat. 103A.43

1996 Water Availability Assessment

St. Paul, MN

September 1996

Department of
Natural Resources
Division of Waters

This report was prepared by staff of the Department of Natural Resources, Division of Waters. It is intended to fulfill the requirement of MS 103A.43 for the Environmental Quality Board to report on the availability of water to meet needs and on trends in water supply. The cost to develop and duplicate this report was approximately $7,000.

For additional information or copies, contact:
DNR, Division of Waters
500 Lafayette Rd., St. Paul, MN 55155
(612)296-4800 Fax (612)296-0445

Upon request, "Water Availability Assessment, 1996" will be made available in alternate format.

This information is available in an alternative format upon request.

The DNR Information Center phone numbers:
Twin Cities: (612) 296-6157
MN Toll Free: 1-800-766-6000
Telecommunication Device for the Deaf:
(612) 296-5484
MN Toll Free: 1-800-657-3929

Department of
Natural Resources
Division of Waters

Printed on Recycled Paper

WATER AVAILABILITY ASSESSMENT
EXECUTIVE SUMMARY

The Legislature has required (MS 103A.43) that the Environmental Quality Board (EQB) assess the quantity of surface and ground water in the state and the availability of water to meet the state's needs. The Department of Natural Resources (DNR), the state agency responsible for water appropriations and management, has prepared this water availability report for the EQB.

Minnesota's water resources are facing increasing stress caused by economic development and changing patterns of water use. The public is demanding more water-based recreational opportunities requiring the protection and maintenance of high quality surface water bodies. The public's growing emphasis on the recreational and aesthetic value of our lakes, streams and wetlands combined with the increased demand for water is resulting in greater reliance on Minnesota's groundwater resources to supply these needs. However, groundwater availability is much less well known and the impacts of development have not been assessed for most aquifer systems. This water availability assessment report provides an overview of water use policy in Minnesota, a discussion of the main areas of conflict over water allocation, a review of the sources of information that are currently being used to assess water availability, and finally, a proposal for characterization of Minnesota's water resources designed to markedly improve the DNR's ability to assess the availability of water for use.

Many inventories, assessments and evaluations of Minnesota's water resources have been made by state, federal and local agencies during the last 40 years. These include the 1959 Hydrologic Atlas of Minnesota, watershed-based Hydrologic Investigations Atlases that were published in the 1960's and 1970's, regional aquifer studies carried out to assess the ability of these aquifers to provide long-term water supplies, county-based geologic atlases and regional hydrogeologic assessments that compile geologic and hydrogeologic information, and numerous limited area, site-specific hydrogeologic studies to assess local water use conflicts. These studies are valuable sources of information to those seeking knowledge about Minnesota's surface and groundwater resources, yet they are generally inadequate to address the types of water availability questions the DNR is increasingly facing.

The DNR collects and evaluates a variety of water-related data in its mission of developing and managing water resources. These data include water use reports prepared by holders of DNR-issued water appropriations permits, streamflow data gathered through cooperative efforts of several state and federal agencies, precipitation and lake level data measured by volunteers, and ground water levels for several aquifers measured by Soil and Water Conservation District (SWCD) observers.

To improve reliability in estimating available water supply, the DNR is proposing a program of expanded data collection and analysis to better characterize Minnesota's ground water and surface water resources. The main needs are:

- Drilling and aquifer testing capability leading to detailed mapping of geology and aquifers;
- Stream gaging in additional watersheds;
- Quantification of ground water/surface water interactions; and research on methods to quantify recharge to aquifers;
- Capability to comprehensively evaluate water supply and evaluate trends.

This information is needed to address the State of Minnesota's goal of lasting, sustainable development and wise use of its water resources.

WATER AVAILABILITY ASSESSMENT

INTRODUCTION

The Legislature has required (MS 103A.43) that the Environmental Quality Board (EQB) assess the quantity of surface and ground water in the state and determine the availability of water to meet the state's needs. The Department of Natural Resources (DNR), the state agency responsible for water allocation and management, has prepared this water availability assessment report for the EQB.

Previous water availability assessment reports prepared by the DNR have focused on the variability of water use and the changes in water levels during the reporting period. In this 1996 report, the DNR has chosen to respond more directly to the Legislature's request for information concerning the availability of water in Minnesota. Several water use conflicts have developed in the state in recent years including major concerns in the Cities of Marshall and Moorhead, in the Red River and Straight River basins and in the Lincoln-Pipestone Rural Water District. These situations are prime examples of why, even in the land of ten thousand lakes, it cannot be assumed that water supplies are adequate to meet demands. Water development in many parts of the state has reached a point where a new proactive management approach is needed that can guide water withdrawal to minimize potential conflicts.

To enable the DNR to provide more detailed estimates of water availability to decision-makers and citizens of Minnesota, the DNR is seeking legislative support for additional funding to characterize and assess the state's ground and surface water resources. Currently the DNR must quantify these resources using limited data and broad assumptions, without sufficient staffing to look beyond current conflicts. It is clear that to achieve the state's goal of sustainable development and wise use of water resources, it is necessary to improve both the base of information and the level of effort applied to evaluating Minnesota's water resources.

This water availability assessment report provides an overview of water use policy in Minnesota, a discussion of the main areas of conflict over water allocation, a review of the sources of information that are currently being used to assess water availability and, finally, a proposal for characterization of Minnesota's water resources designed to markedly improve the DNR's ability to assess the availability of water for use.

WATER USE AND POLICY IN MINNESOTA

Minnesota has over 12,034 lakes and 92,000 miles of rivers and streams, and is at the headwaters of three major watersheds: the Great Lakes basin which flows to the Atlantic through the St. Lawrence seaway, the Souris-Red-Rainy Rivers basin which flow to Hudson Bay, and the Mississippi River basin , which flows to the Gulf of Mexico. It is no wonder that Minnesota is regarded as having an abundance of clean, usable water.

On the other hand, Minnesota's annual average precipitation varies greatly over the state. Southeast Minnesota receives an average of 32 inches per year, while northwest Minnesota receives an average of only 19 inches per year. Therefore, from a water supply standpoint, the state should be regarded as transitional between the humid east and the arid west.

Water is needed for use by people and industry as well as to support recreation, wildlife and aesthetics. Water can be diverted to meet these demands when it is present in reliable quantities that can be delivered at a useful rate. For surface water supplies this means rivers and streams with consistent flow and lakes with adequate volume relative to withdrawal rates. For ground water supplies this means aquifers of sufficient extent and thickness and suitable hydraulic characteristics.

Water Appropriation and Conservation Plans

Minnesota Statutes 103G.265 requires the DNR to manage water resources to assure an adequate supply to meet long-range seasonal requirements for domestic, municipal, industrial, agricultural, fish and wildlife, recreational, power, navigation and quality control purposes. The DNR is also required by Minnesota Statues 103G.101 to develop a water resources conservation program for the state. Water conservation plays an important part in balancing management objectives that include both development and protection of Minnesota's water resources.

Appropriations or uses of surface and ground waters in excess of 10,000 gallons per day or one million gallons per year require a permit from the DNR. Permit applications are evaluated to determine impacts on water resources, impacts on other water users and adequacy of conservation measures. Most of the approximately 6,500 active permits are issued for agricultural irrigation (4,100 permits) and public water supply (950 permits) purposes. The following items outline conservation measures that apply to these two categories of water users:

- Local soil and water conservation districts (SWCD) are sent copies of permit applications and can require applicants for agricultural irrigation permits to have an approved soil and water conservation plan for each field to be irrigated (M.S.

103G.295).

- Public water suppliers are required to implement demand reduction measures that include a public education program and an evaluation of conservation rate structures before obtaining approvals for new wells or increased water volumes (M.S. 103G.291).
- Public water suppliers serving more than 1,000 people must have an approved water emergency and conservation plan (M.S. 103G.291). There are 317 public water suppliers that are required to have plans and as of December 1996 232 communities have submitted plans to the DNR for approval.

Water resource management also may require restrictions or prohibitions on inefficient and low priority water resources for future domestic and economic purposes. Using ground water for augmenting surface water basins and supplying once-through heating and cooling systems are recent examples of uses that are now limited or prohibited by Minnesota Statutes. Limits on these water uses will save more than 100 billion gallons per year.

Water Use Priorities

State law includes the following system of priorities by type of use:

MS103G.261 Water Allocation Priorities

(a) The commissioner shall adopt rules for allocation of waters based on the following priorities for the consumptive appropriation and use of water:
(1) first priority, domestic water supply, excluding industrial and commercial uses of municipal water supply, and use for power production that meets the contingency planning provisions of section 103G.285, subdivision 6;
(2) second priority, the use of water that involves consumption of less than 10,000 gallons of water per day;
(3) third priority, agricultural irrigation, and processing of agricultural products involving consumption in excess of 10,000 gallons per day;
(4) fourth priority, power production in excess of the use provided for in the contingency plan developed under section 103G.285, subdivision 6;
(5) fifth priority, uses, other than agricultural irrigation, processing of agricultural products, and power production, involving consumption in excess of 10,000 gallons per day; and
(6) sixth priority; nonessential uses.

(b) For the purposes of this section, "consumption" means water withdrawn from a supply that is lost for immediate further use in the area.

(c) Appropriation and use of surface water from streams during periods of flood flows and high water levels must be encouraged subject to consideration of the purposes for use, quantities to be used, and the number of persons appropriating water.

(d) Appropriation and use of surface water from lakes of less than 500 acres in surface area must be discouraged.

(e) The treatment and reuse of water for nonconsumptive uses shall be encouraged.

(f) Diversions of water from the state for use in other states or regions of the United States or Canada must be discouraged.

The Minnesota Water Plan, 1991

This newest edition of the State Water Plan outlines the following goals for water resource management in the State of Minnesota:

I. To improve and maintain the high quality and availability of Minnesota's water for future generations and the long-term health of the environment.

II. To ensure that our uses of water are sustainable, and that in meeting our needs for water, we recognize its limits and interconnections, accept its changing and variable nature, and adjust our demands upon it when necessary to safeguard it for future needs.

Sustainability for water use purposes would logically be determined by the rate of replenishment or, in other words, the average annual volume supplied by precipitation, which gives rise to streamflow (runoff) and recharge to ground water. While precipitation records may be adequate to describe the variability of precipitation across the state, the stream gage network does not cover all 81 primary watersheds. Current knowledge about recharge to ground water units is very limited. Therefore, sustainability in our uses of water cannot be determined now and may not be able to be determined for some time to come.

SOURCES OF CONFLICT IN THE ALLOCATION OF WATER

Minnesota Rules 4070 provides for the allocation of water and resolution of disputes that arise over water availability. Several areas where conflicts over the use of water repeatedly occur are described in this section.

Maintenance of Surface Water Elevations

Appropriation of water from streams at low flows has impacts on navigation, recreation, and aesthetics as well as on habitat. State law requires protection of minimum instream flows to avoid destruction of instream resources. When flows drop below minimum flow levels, pumping for off-stream uses must cease to protect the resource. Surface water users are required to have a contingency plan for low flow periods or to agree to withstand the impacts of no appropriation. Current minimum flow levels may not be adequate to protect the resource and the department is collecting stream habitat data to determine flow levels required for protection of fish and wildlife.

Operation of dams on the Mississippi River during low flows has resulted in the past in extreme low flows at the intake for the Minneapolis water system. Planning is under way to avoid repetition of that circumstance and to coordinate dam operations.

Lakes, especially those less than 500 acres in size, are not considered to be a desirable source of water for withdrawal use. Not only is the demand for water at its greatest when lake levels have reached their lowest levels, but also the public responds negatively toward lowered lake levels in most cases. Therefore, state law severely limits the amount of water that can be withdrawn from lakes for water supply purposes.

The volumes of water in lakes fluctuate with the level of the surface of the lake. By law the amount of water available for use from lakes is limited to 0.5 feet of water depth and a protected lake level may be set for the basin below which no withdrawals will be allowed. The withdrawal of lake water for irrigation or other uses is, therefore, considered unreliable because of natural fluctuations of water levels.

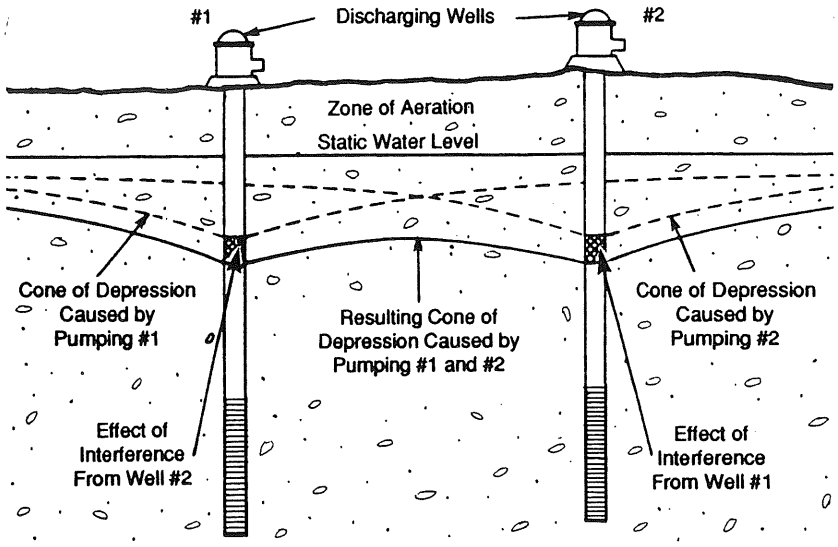
Agricultural Irrigation

Agricultural irrigation can greatly reduce the availability of surface and ground water during periods of low rainfall even when there is no drought. This impact results from consumptive use of water by the crops and high volumes of pumpage. Removal of water at times of limited rainfall adds to the natural lowering of water levels due to evapotranspiration.

Irrigation on coarse-textured soils increases the chance that fertilizers applied to the crops will wash away or leach into the soil before it can be tied up in the soil or utilized by the plants. Soil and water conservation plans and the use of crop-specific best management practices can minimize potential water quality problems.

Well Interferences

In instances where water levels near high capacity pumping wells are lowered enough to prevent adjacent wells from obtaining water, a well interference results and other users may be prevented from obtaining water, even when generally adequate supplies of ground water are available. In this local situation, one well cannot capture enough water because of the pumping effects from another.



Well Interference Between Two Installations

Minnesota law requires the DNR to evaluate well interferences and limit withdrawals by high capacity users if they directly lower water levels in a domestic well. If part of the problem is due to poor construction or maintenance of the domestic well, the owner may be obligated to make repairs.

Water Supply Conflicts

A water supply conflict can occur when the ground water resource is limited or inadequate. In a situation where the combined withdrawal demands of all water users exceed the supply, the conditions of Minnesota Rules, part 6115.0740 apply. Users in the same priority class share in the availability or lack of water in the aquifer on which they depend. Additionally, the users are subject to the requirements of Minnesota Rules, part 6115.0670, subpart 3, item C., governing the appropriation of ground water which reads in part:

> Approval of appropriation from ground water shall be further subject to the following:
> 1) The amounts and timing of water appropriated shall be limited to the safe yield of the aquifer to the maximum extent feasible and practical. (See Minn.R. 6115.0630 for definitions of safe yield under different conditions.)

Similar sharing in availability or lack of water applies to surface water users in the same priority class from the same stream. When a stream reaches a predetermined minimum flow, all water users are required to reduce or terminate withdrawals to protect the instream needs. Efforts are ongoing to better define the instream flow needs of Minnesota streams. Historic data on streamflows are limited in distribution; additional streamflow data are needed to obtain useful estimates of normal flow levels for Minnesota streams statewide.

Conflicts Resulting from Development Pressure

It is difficult to determine in advance when withdrawals from an aquifer will exceed safe yield. Where the extent and thickness of the aquifer is not known, little can be said about the volume of water the aquifer can supply. Water levels can fluctuate widely in response to changes in recharge, climate or nearby pumpage. Long term records of aquifer response to these changes are needed along with extent and thickness of the aquifer in order to evaluate the results of development pressure. Installation of observation wells outside the area of influence of pumping wells is particularly important so that direct local pumping effects do not mask real trends in water level caused by cumulative climatic and aquifer-wide pumping effects. The DNR observation well network is largely dependant on inactive wells drilled for other purposes. Therefore, wells in the network commonly do not meet this requirement.

Water demand can be influenced by informing the users of a need to change water use habits. Public water suppliers are required to adopt water conservation plans to reduce the need for new water supplies. It may be possible for a community to provide a new major user with adequate water merely by adopting water conservation measures that reduce or even out demand for water in their system. The level of awareness that develops during a series of drier years needs to be sustained after the rains resume.

Development of Rural Water Systems

Ground water resources of useable quality or adequate quantity are relatively scarce in the southwest corner of the state and in the Red River Valley. Many of the towns, rural water users and irrigators in these areas rely upon shallow wells in near-surface aquifers

of limited areal extent. These aquifers are susceptible to water level decline during drought, to contamination and to withdrawals in excess of recharge. Some of these rural communities and farms have experienced water supply and water quality problems enticing them to establish or connect to rural water systems. Others have connected to a system, not due to any problems with their own systems, but due to the availability and (subsidized) low cost of the rural water system.

Rural water systems pipe water over large distances to communities and to individual farmsteads. The justification for building such extensive systems is said to be the overall low availability of water and the poor quality of available water. Such systems may only be viable because of federal subsidies in the form of grants and loans. From the perspective of the individual customer, it is less risky to hook up to a subsidized water system than to rely on reconditioning an aging well or drilling a new well. In some cases, rural water supply systems have been funded and built without consideration for, or evaluation of, the impacts of the withdrawal in relation to the availability of water in the area in question.

Rural water systems free the landowner from concerns about his/her impact on water quality due to poor land use practices. Poor planning of feedlot facilities and poor management of fertilizers and pesticides will not affect the operator's own drinking water. Indeed, with the delivery of reliable water, larger crop and livestock operations are made possible. The greatly increased waster from these facilities may add to the water quality problems that already exist.

Use of a rural water supply system without adequate backup supplies and adequate wellhead protection makes a sizeable population vulnerable to supply restriction or contamination. The concentration of water withdrawal from all of these rural properties and communities into one well field concentrates the impacts of pumping and physically limits the total volume of water that can be pumped. The water supply that might be developed for these same users would be greater if the withdrawals were better distributed throughout the region.

EXISTING SOURCES OF INFORMATION TO ASSESS WATER AVAILABILITY

Existing sources of information include both published studies about or related to Minnesota's water resources and data that are presently being collected by, or on behalf of, the Minnesota DNR and other agencies. These are discussed by category in the sections that follow.

Published Inventories, Assessments and Evaluations

Many inventories, assessments and evaluations of Minnesota's water resources have been completed over the past 40 years. The purpose and scale of the reports vary and each contributes to knowledge about availability of water in different ways. The most widely used types of reports are summarized below. A more complete reference to studies involving ground water resources in Minnesota has been compiled in the "Minnesota Ground Water Bibliography" (Armstrong and McAdams, 1990).

Hydrologic Atlas of Minnesota

The Hydrologic Atlas of Minnesota (1959) is a summary of ground and surface water resources as known at the time. The report divides the state into four ground water regions and thirty-nine major watersheds.

Inventory of Lakes in Minnesota

Minnesota's lakes are listed in DNR Bulletin 25 and in the state's Public Waters Inventory. Bathymetric maps of most of the major lakes of the state have been completed, thus the volume of water in storage in the state's lakes can be calculated.

Minnesota Water and Related Land Resources Plan

The 1970 report "Minnesota Water and Related Land Resources", funded by the Federal Water Resources Council under the Water Resources Planning Act of 1965, examined water use and supply, economic and population growth, water quality, recreation, fish and wildlife, floods, drainage, irrigation and water-borne transportation.

Hydrologic Investigations Atlases

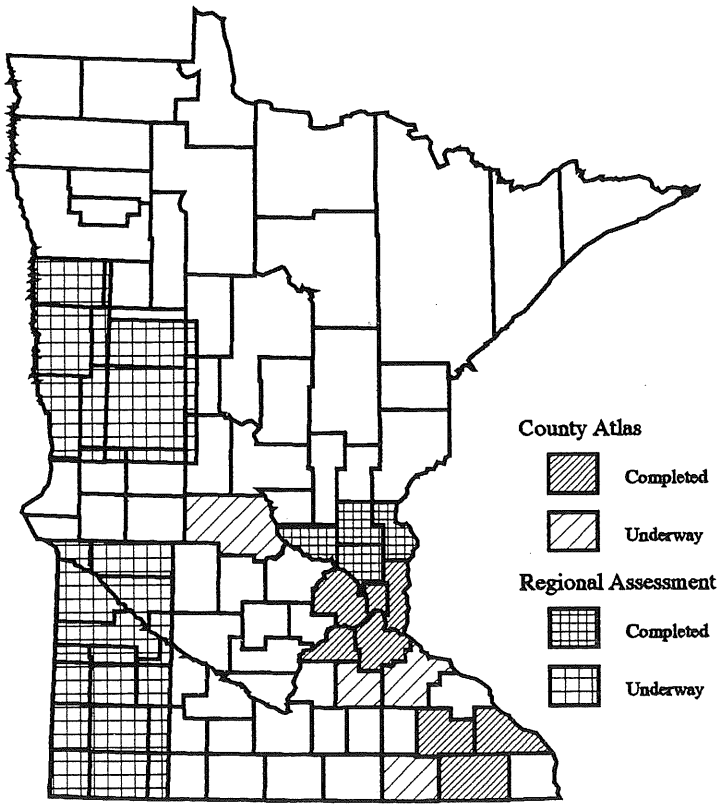
During the 1960's and 1970's a major program of Water Resources Investigations was undertaken in Minnesota by the DNR Division of Waters in cooperation with the United States Geological Survey (USGS). Hydrologic Investigations Atlases were produced for each of the state's 39 major watersheds. These atlases expanded upon the 1959 Statewide Atlas and provided more detailed watershed mapping and evaluations of ground water supplies, water use, streamflow, and water quality. The ground water information in these reports was compiled by the DNR into a summary publication: "Ground Water Resources in Minnesota".

Regional Aquifer Studies

The hydrologic investigations atlases were not detailed enough to provide users with

quantitative estimates of potential yield. Consequently, specific studies designed to estimate the long term capability of an aquifer to support withdrawal use were initiated in areas where more detailed water availability information was needed. One example is the 1987 report "Evaluation of Availability of Water from Drift Aquifers near the Pomme de Terre and Chippewa Rivers, Western Minnesota", (USGS WRI 86-4098), which describes the hydrogeology of these aquifers and provides estimates of water yield. This level of water resource information is suitable as a starting point for regional planning and management.

Where specific aquifers have experienced development pressure and the need for detailed information was critical, quantitative estimates of water availability have been made using ground water flow models. An example of a quantitative regional appraisal is the 1980 cooperative study "Ground-Water Appraisal of Sand Plains in Benton, Sherburne, Stearns, and Wright Counties, Central Minnesota". This study evaluated the effect of projected irrigation pumpage from a 960 square mile surficial sand aquifer on ground water levels and surface water features like wetlands and streams. This type of quantitative study can be used by planners, developers and water users as a guide for developing ground water resources.



County Geologic Atlas and Regional Hydrogeologic Assessment Program

County Geologic Atlases

In the 1980's, the Minnesota Geological Survey (MGS) in cooperation with counties began producing county-scale geologic and ground water resource maps. The DNR has been a partner with the MGS in producing these maps since the early 1990's. The atlases include maps of the geology, hydrogeology and ground water geochemistry, evaluations of the sensitivity of ground water resources to contamination as required by M.S.103H.101, and various specialized maps relevant to each county that may include mineral resources and ground water basin delineation. The atlas maps show where aquifers are present and how thick and extensive they are, indicate ground water flow directions and provide estimates of well yields. The atlases are ideal for local planning and decision-making, and provide the geologic and hydrogeologic data needed to make quantitative calculations of ground water availability. The participating counties contribute funds for preparation of the atlases.

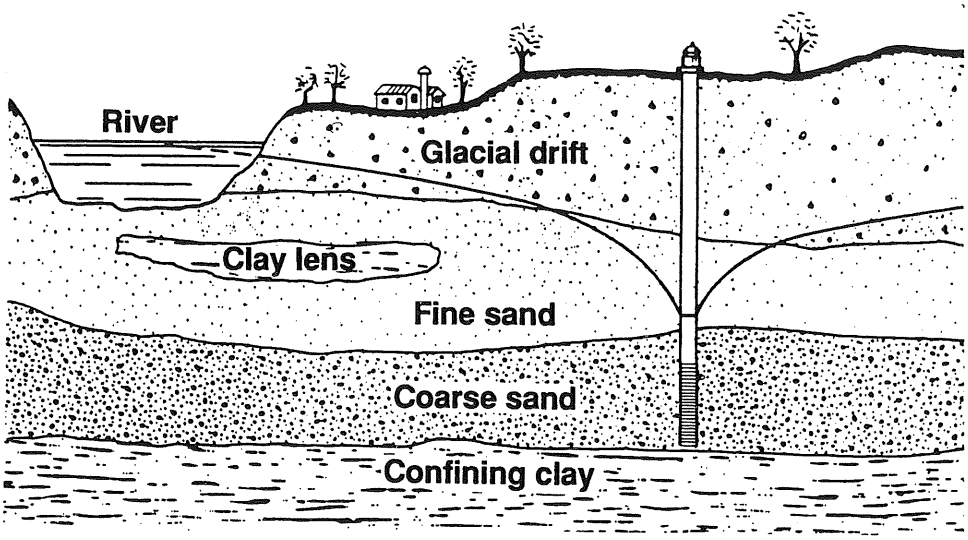
Regional Hydrogeologic Assessments

The DNR, again in partnership with the MGS, began developing Regional Hydrogeologic Assessments for multi-county areas of the state in 1991. These assessments were undertaken to complete evaluation of the sensitivity of ground water resources to contamination more quickly than could be accomplished through the County Geologic Atlas program. The Regional Hydrogeologic Assessments consist of compilations of existing information on the near surface geology and ground water resources. Limited field work and drilling are included to define glacial stratigraphy. The main products are maps of the uppermost aquifer units and an assessment of the sensitivity of the uppermost aquifer to contamination. A regional hydrogeologic assessment is not a substitute for a county atlas.

Hydrologic/Hydrogeologic Modeling Studies

These aquifer specific, or watershed-specific, studies are the most detailed and yield the most complete understanding of hydrologic conditions and water availability for a location. Hydrologic models of stream flows and levels are used to assess effects of urbanization, drainage, water control structures and water withdrawal or diversion, and can be used to forecast future watershed yields. Hydrogeologic modeling is undertaken to determine whether pumpage causes water level decline in other wells or in surface features of concern such as trout streams, calcareous fens, wetlands or small lakes.

These investigations are site specific or limited in area. The results provide information for resolution of well interferences or water use conflicts or guide the resolution of conflicts among users of a resource.



Cross section illustrating the relationship between a well and a surface feature.

Water Allocation and Management Study: 1985-87

This LCMR-supported project included an analysis of ground and surface water availability by major watershed for three scenarios: a drought year, a normal year, and a wet year, for the purpose of determining the degree to which water is a constraint to economic pursuits. That report concluded that at current rates of withdrawal, water supply is a constraint only during drought periods at the watershed scale of analysis in Minnesota. The study results apply only regionally and do not mean that site specific limitations will not exist even in normal or wet years.

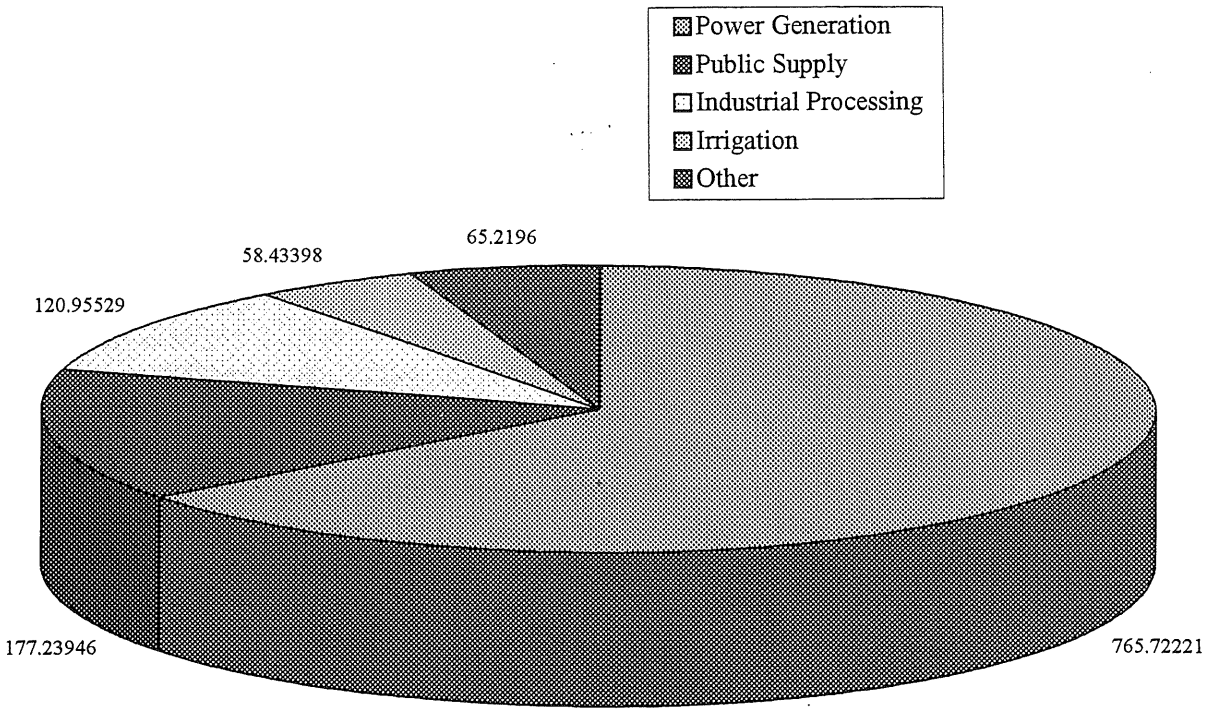
Data Collected By or Reported to the Department of Natural Resources

Data currently being collected by, or reported to, the DNR that are relevant to the evaluation of water availability are described below.

Water Use Data

Permit holders are required to measure and report their use of water to the DNR each year. The reported water use is required to be accurate to within 10 percent. DNR staff compile these data to evaluate conflicts or proposed developments where there may be seasonal or long-term impacts resulting from the permitted withdrawals.

In past reports on water availability, changes in pumpage aggregated by various sectors, combined with changes in water levels or flows, have been used as indicators of changes in water availability. As a measure of water availability, these data are of limited value without additional information to relate the changes to the overall supply in a aquifer or basin.



Minnesota Water Use 1994
in Billions of Gallons

Climate Information

The State Climatology Office, part of the DNR's Division of Waters, is a repository for Minnesota climatological data. These records include current and historical temperature and precipitation records. Volunteer observers provide readings of rainfall amounts or snow depth which are combined with data from professional observers to cover the state with a network of over 1,000 stations. More than 150 stations have over 40 years of readings. The data are used to develop hydrologic models and to monitor extreme conditions (flood and drought) in a historical context.

The water in lakes, streams and aquifers comes from precipitation. Snow melt in spring and soaking rains throughout the growing season contribute to the water resources which are available for our use as streamflow or ground water recharge. Water availability assessments must include analysis of rainfall distribution in relation to streamflow and ground water levels to estimate sustainable water supply.

Streamflow Monitoring

Stream gages have been installed by the U.S. Geological Survey to continuously measure flows at 96 sites on Minnesota streams and rivers. Streamflow measurements collected over time and over changing climate conditions allow statistical analysis of high and low flows. The staff of the DNR use these measurements to produce weekly streamflow summary maps which are available to interested clients.

The current stream gage network is not adequate for assessment of many permit issues because most permit holders are located on the smaller tributary streams while the gages are on the main rivers in downstream locations. Most new gages installed in recent years have been temporary installations at project sites. The Straight River Watershed Study is an example of a project where stream gaging is an integral part of the data collection effort. In this study, pumpage adjacent to the stream is thought to impact flow and temperature in the channel, possibly causing harm to the trout fishery. The impacts of ground water withdrawals on the stream are being evaluated and a management plan is being developed.

Sustainable surface water availability can be defined as the amount of streamflow above the amount needed to satisfy instream water use. This volume of water is highly variable depending on precipitation and runoff. The use of watercourses for purposes such as irrigation is problematic because demands for irrigation water are typically highest when flows are at low levels due to lack of precipitation. During a drought period in 1988 and 1989, over two hundred water appropriation permits were suspended to maintain minimum flow levels and protect instream uses.

Lake Level Monitoring

Water levels on about 700 lakes are measured by volunteers and reported to the DNR on a periodic basis. The lake gages are reset each spring so that the levels are referenced to a surveyed datum. The volumes of water in lakes fluctuate with the level or depth of the lake. By law, the amount of water available for appropriation from lakes is limited to 0.5 feet of water depth and a protected lake level may be set for the basin below which no withdrawals will be allowed.

Lake level manipulation is not encouraged in Minnesota, but where lake level manipulation is deemed necessary, the starting point for controls is the ordinary high water mark. Field surveys are used to identify the marks that the lake has left upon its basin. Once determined, this ordinary high water mark provides the starting elevation from which lake levels are measured.

The withdrawal of lake water for irrigation or other uses is usually not permitted

because of the limited volumes of water in storage and the likelihood that the lake will be at its lowest during a drought, exactly when the demand for water is greatest. Additional lowering of lake levels by pumping is generally not favored by the public or lakeshore residents.

Watershed Delineation

The variability of surface water levels at any location can be affected by activities within the watershed upstream of that location. The DNR makes use of this relationship by suspending surface water appropriation permits within the watershed where stream flows fall below protected values.

Ground water basin delineation also is needed to effectively manage the spread of contaminants or the impacts of pumpage in the subsurface. The accurate delineation of basin boundaries will require a great deal more information than is currently available for most of the state.

Wetland Data

Wetlands were inventoried as part of the Public Waters Inventory and as part of the National Wetlands Inventory. Use of water from wetlands has been authorized for emergency purposes in the past. The volume available from an individual wetland is limited. Water in wetlands generally cannot be considered to be available for use particularly in view of the protection policy adopted by the state in the Wetlands Conservation Act

Water levels in many wetlands and lakes are an indication of the elevation of the water table. Water levels in wetlands are, therefore, representations of the water levels in the surficial aquifers. Pumpage from an aquifer will impact the water level in wetlands near the pumping site. Water levels are monitored in only a few wetlands in the state which makes it difficult to interpret observed changes in water levels.

Geophysical Investigations

The DNR uses geophysics to assess the properties of the earth's materials and to indirectly determine the location of potential aquifers or the water table without having to drill wells. The geophysics staff use several techniques to measure those properties in order to assist in mapping subsurface geologic units, evaluate mineral resources, estimate ground water supplies, locate buried wastes and trace contaminant plumes. These techniques allow units in the subsurface to be traced between drill holes with greater certainty than is possible without these data.

Water Well Drillers' Logs

Data are available from drillers' logs as development takes place. Since they are only available where use is already occurring, they are not adequate for the assessment of statewide water availability. These data are considered to be a poor quality data source because they are not distributed throughout the area of interest, the drill holes do not fully penetrate the subsurface units of interest and the logs may not include detailed observations necessary to interpret stratigraphic relationships. Well locations frequently are not adequately described for scientific work.

Exploratory Drilling

Drilling and sampling of subsurface units is the only reliable way to evaluate ground water supplies in any detail. The DNR has undertaken a cooperative drilling effort, referred to as the "grid drilling" program, financed through a one-time appropriation from the legislature and matched by local governments, in order to locate aquifers in the southwestern part of the state. Water sources are scarce in that part of the state and demand for water is increasing. Potential aquifers, which have been located through this effort, now need to be test pumped and evaluated hydrologically.

Water Level Observation Wells

The DNR observation well network has been developed to record water levels in areas of present or expected ground water use. These data are used to assess response of ground water supplies to pumping and climate and to evaluate local water complaints. Observation wells provide an early warning that pumpage is exceeding recharge if declines are observed over time. The network is composed of over 700 wells throughout the state. The network includes aquifers in common use and is expanded when funding and opportunity allows.

Most wells added to the network are unused existing wells. The capability to select sites for installation of new observation wells would greatly enhance the network in the future. Needs are urgent in areas of the state where water supplies are limited in quantity or quality such as in the southwest and northwest.

To be able to assess ground water availability, the network needs to be expanded with a systematic drilling program done in conjunction with aquifer mapping and assessment. The density of wells needed for these assessments of Minnesota aquifers, and thus to determine the amount of water in storage in those aquifers, may be as high as one per township. Where a township is underlain by more than one aquifer, more than one observation well would be needed in that township. The accuracy and detail of the resulting analysis are determined by the density of information available.

Aquifer Tests

Aquifer tests are carried out by pumping a well under controlled conditions and measuring the resulting water level changes in neighboring wells. When a test is being conducted because of a known problem, it is usually adequate to measure only existing wells since they are the sites of interest. However, when the goal is to evaluate the resource, it is more desirable to drill and accurately log new observation wells for the purpose of having known conditions. A new well constructed specifically for taking scientific measurements would not be affected by lack of maintenance and would be drilled to an ideal depth for the intended purpose.

The DNR conducts aquifer tests to address conflicts over water between two well owners or to describe the water supply locally in support of the water appropriation permit program. In the case of an aquifer test conducted as part of an investigation for an agricultural irrigation permit, the length of the test is limited by statute (103G.295 Sub 4. (5)) to 72 hours for water table conditions or 24 hours for artesian conditions. This results in the termination of many tests before the water level declines stabilize and before the extent of the aquifer can be detected. This statutory limit needs to be changed to allow the DNR to continue any aquifer test until water levels stabilize so that maximum information is gathered on the aquifer with each test conducted.

DATA REQUIREMENTS TO IMPROVE ESTIMATES OF WATER AVAILABILITY

To address the desire for greater reliability in estimating available water supply, the DNR is proposing a program of expanded data collection and analysis to better characterize Minnesota's ground water and surface water resources in three general areas:

1) a focused drilling and testing program to improve mapping and knowledge of the hydraulic characteristics of the state's aquifers;

2) additional streamflow monitoring to characterize surface water availability and surface water-ground water interactions that effect availability; and

3) evaluation of water use trends in the context of overall resource availability and valued surface water features.

Ground Water Characterization

Aquifers are rocks or sediments that store water and are sufficiently permeable to transmit water to wells at useful rates. To estimate ground water availability, it is necessary to know both the amount of water in storage in the aquifer and the rate at which it can be removed. To estimate the amount of water that can be removed continuously

without mining the aquifer (the sustainable rate of withdrawal), the rate of recharge to the aquifer must be known.

The amount of water contained within an aquifer can be estimated if the aquifer's areal extent and saturated thickness are known. Geologic maps typically define the areal extent of geologic units and thus are a good starting point for estimating the volume of stored water in an aquifer. However, the rate at which ground water can be withdrawn is more difficult to determine.

Aquifer tests or pumping tests are typically used to estimate an aquifer's permeability (the primary characteristic that affects the rate of water movement through an aquifer), but these tests are expensive to perform and are strictly applicable only to the portion of the aquifer in the immediate vicinity of the pumped well. A less precise but still valuable indication of an aquifer's permeability can be obtained by observation and test pumping of water wells as they are installed. The State of Minnesota has required since 1952 that well drillers submit water well records that detail observations about the geologic materials they encounter, the presence of ground water, and the results of test pumping conducted for each well they drill. Hydrogeologic data from these water well records is much more widely available than data from pumping tests, and has been used heavily by those preparing the hydrogeologic studies reviewed in the previous section of this report.

The value of water well records is dependent upon the well drillers' ability and interest in classifying the geologic and hydrogeologic data they encounter, which varies widely. Also, most water well records are from wells drilled for domestic or agricultural use which tend to be relatively shallow wells clustered in areas of development. Thus, water well records tend to provide little information about deeper aquifers or aquifers in sparsely populated areas of the state.

Several improvements are recommended to make the water well records more useful for scientific interpretation. First, a systematic, statewide effort should be undertaken to verify the recorded data and add it to the Ground Water Clearinghouse GIS system (location, unique number, aquifer code, depth, etc.). The MGS does this work in areas where it is cooperating with DNR to produce a county geologic atlas or regional assessment.

This kind of data verification is a critical first step since errors in well location, site elevation, geologic interpretation , etc. on the water well logs are common and greatly affect the resulting geologic and hydrogeologic interpretations. From the verified set of water well records, wells can be selected for geophysical logging to provide a means to objectively compare the geologic characteristics of an aquifer and assess its variability.

Second, building on the water well records, DNR proposes to fill gaps in the

availability of well data by drilling test holes and installing observation wells in selected areas where water is in short supply and the information is not available from other sources. Test drilling will be undertaken to delineate and map potential aquifers identified from existing information. Observation wells will be installed at a limited number of sites in aquifers located during the drilling effort. At a few sites, aquifer tests will be conducted to establish the amount of water in storage and determine the capability of the aquifer to sustain pumpage. Ground water levels and samples for water chemistry and isotope analysis will be collected.

Seismic surveys may be used to extend the information gained from existing or newly-installed wells. The newly obtained information will then be compiled into a subsurface map showing thickness and extent of subsurface units/potential aquifers, and the flow rates and directions of flow in those determined to be aquifers.

Because of the high cost of subsurface exploration, it will be necessary to perform this work sequentially on a priority basis in different areas of the state. For example, water supplies are a high priority concern in the western third and southwestern quarter of the state. A limited extent exploratory drilling program was funded for the 1995-97 biennium and has yielded information about several potential aquifers. These units still need to be characterized hydrologically, and many other areas would benefit from similar exploratory drilling.

In order to fully describe the availability of water in these areas, existing water use needs to be documented. Also surface water features need to be mapped in detail and their relationship to the maintenance of ground water levels needs to be documented.

Surface Water Characterization

Surface water characterization is needed to determine the capability of lakes and streams to provide a reliable source of water for consumptive use. In the case of rivers and streams, the characteristics of the watershed and the climate, especially precipitation and the relationship to ground water resources, determine the volume and consistency of flow. The probability that flow will be above a certain value for a defined period of time can be estimated from curves developed from long term streamflow monitoring data.

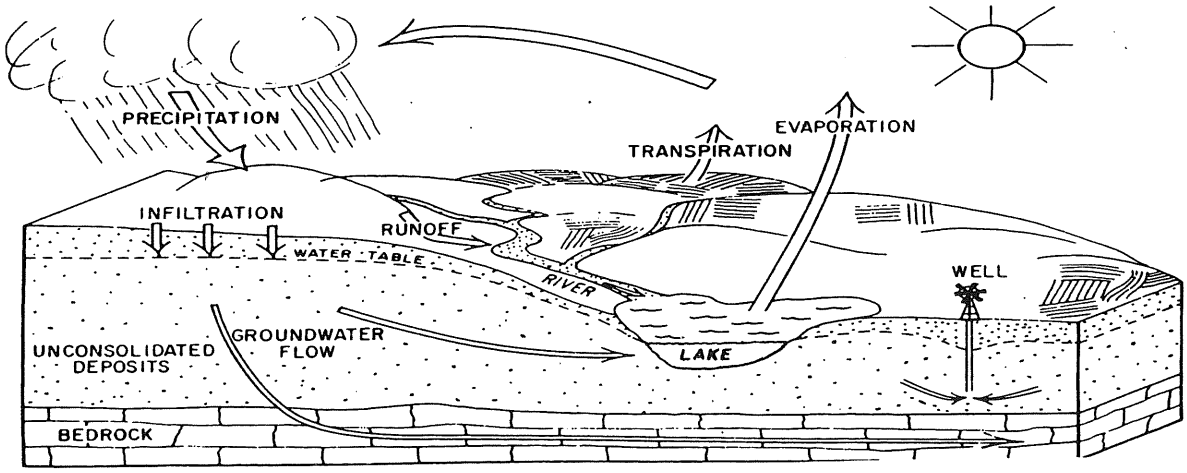
Surface water characterization is also very important in assessing overall water availability since surface water bodies are usually directly connected to the underlying ground water. Withdrawal of water from either source directly affects the other. For example, pumping ground water from a well located near a river will result in lowering of the river, since pumping will depress the surface of the water table which in this case extends into the river. Knowledge of surface water-ground water interactions, especially in cases where surface water bodies are highly valued for recreational or aesthetic

purposes, is critical to the proper management of our water resources.

Consistent, long term collection of streamflow and precipitation data enable hydrologists to develop curves that can be used to characterize streamflow under different conditions. The curves can be used to identify the individual contributions of ground water, surface runoff, and precipitation to streamflow making it possible to assess the importance of ground water to maintain streamflow. In addition, an estimate of recharge to ground water can be derived from the information obtained from the curves.

The distribution and number of stream gages on Minnesota rivers is inadequate to address water availability issues. The DNR proposes to expand the current streamflow monitoring network by selecting new monitoring locations based on potential surface water availability and constraints due to surface water - ground water interaction. The department also proposes to add staff to the Climatology office in the Division of Waters to compile precipitation data across the state in order to obtain better estimates of recharge to ground water and runoff to streams.

Minnesota law does not adequately address impacts of ground water pumpage on streamflow or on levels in lakes and wetlands. A clear statement in the statutes recognizing that surface waters may be impacted by ground water pumping is needed in order to protect high value surface water bodies. Examples of situations where this relationship is significant include the Straight River near Park Rapids and several calcareous fens and trout streams in the Twin Cities Metropolitan area.



The Hydrologic Cycle

Evaluation of Water Use Trends and Availability

The ground and surface water data collection and analysis capability at the DNR is

limited and, therefore, most current efforts are responsive to conflicts or to natural extremes such as droughts or floods. To make better use of data currently being collected and evaluate the additional data proposed for collection above, additional technical staff are needed.

A key task of the additional staff would be to analyze the quantitative distribution of precipitation across the state and through time in conjunction with streamflow monitoring data. Through this analysis an estimate of ground water recharge can be derived and quantified in conjunction with ground water level monitoring data. These analyses must be carried out for each aquifer or watershed to evaluate the level of water use that is sustainable without resulting in adverse impacts on surface features.

Recharge, or the rate of replenishment of ground water, has traditionally been one of the least known quantities in hydrology. New techniques are becoming available to assess the rate of recharge for a given aquifer. One of these techniques, chlorofluorocarbon dating, allows hydrologists to track the movement of ground water downward over time. The DNR is proposing to begin systematic dating of shallow ground waters throughout the state in cooperation with the USGS. If funds are provided for this work, regular compilations of all known information about the availability of water from each significant aquifer in the state will be prepared and published.

The department recognizes a need for reports interpreting the trends in water use and the capability of the streams and aquifers to sustain current plus additional development. If additional resources are obtained, the DNR will be able to provide this kind of information to decision makers and the public before development decisions are made. The additional data will provide for a greater degree of accuracy in the estimates of water available for use, and the DNR will be able to carry out water availability assessments comparing actual use to the resource potential and documenting impacts more precisely than is possible with current efforts.

SUMMARY AND CONCLUSION

It is no longer sufficient to wait for someone to drill a well before testing and evaluating aquifers, or to wait for a major industrial appropriation to be undertaken before determining streamflow capabilities to support both natural ecosystems and consumptive use. The State of Minnesota desires lasting, sustainable development and wise use of its water resources. To achieve this goal, it is necessary to improve both the base of information and level of effort applied to evaluating Minnesota's water resources.

REFERENCES

Armstrong, Dave and Toby V. McAdams, 1990 Minnesota Ground Water Bibliography, 2nd Edition.

Lindholm, G.F. 1980. Ground-Water Appraisal of Sand Plains in Benton, Sherburne, Stearns, and Wright Counties, Central Minnesota, U.S. Geological Survey Water Resources Investigations Open-File Report 80-1285. 103p.

Minnesota Department of Conservation, 1959. Hydrologic Atlas of Minnesota Bulletin No. 10. 182p.

Minnesota Department of Conservation, 1968. An Inventory of Minnesota Lakes, Bulletin No. 25.

Minnesota Department of Natural Resources, 1994. Assessment of Water Use and Ground Water Availability. A report to the Legislature in compliance with MS 103A.43, Section 11.

Minnesota Department of Natural Resources - Division of Waters, 1976. Ground Water Resources in Minnesota - A review of general availability, quality, distribution, use and problems, Bulletin 27. 62p.

Minnesota Department of Natural Resources - Division of Waters, 1977. Geology and Water-Supply Potential of the Anoka Sand-Plain Aquifer, Minnesota. Technical Paper No. 6. 17p.

Minnesota Environmental Quality Board - Water Resources Committee, 1991. Minnesota Water Plan. 44p.

Water Resource Coordinating Committee, State Planning Agency, 1970. Minnesota Water and Related Land Resources. First Assessment. 396p.

Young, P.G. and S. Woods. 1987. Water Use in Minnesota Agriculture. Minnesota Department of Natural Resources, Division of Waters. A report submitted to the Legislative Commission on Minnesota Resources. 46p.