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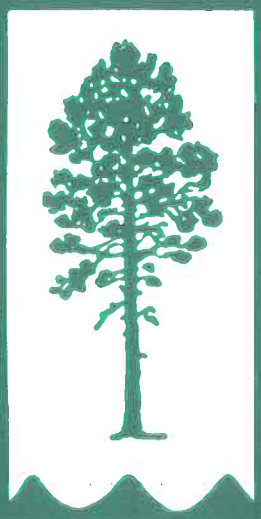

Assessment of Water Availability in Minnesota

December 1992

Pursuant to Minn. Stat. 103A.43

ENVIRONMENTAL QUALITY BOARD

MN PLANNING

The Minnesota Environmental Quality Board is an environmental policy forum. Its membership consists of the heads of nine state environmental agencies, five citizens and a representative of the governor serving as chair. The EQB Water Resources Committee coordinates and integrates water policy, planning and programs. **Minnesota Planning, charged with developing a long-range plan for Minnesota, provides staff to the Environmental Quality Board.**

The Environmental Quality Board has the charge to "assess the quantity of surface and ground water" in Minnesota and "the availability of water to meet the state's needs."

Assessment of Water Availability in Minnesota

Prepared by
EQB Water Resources Committee
Minnesota Environmental Quality Board
and
Minnesota Planning
December 1992

For copies of *Assessment of Water Availability in Minnesota* or other water plan reports contact:

The EQB Water Resources Committee
John R. Wells, Director
658 Cedar Street
St. Paul, MN 55155
612-296-3985

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This report was prepared by the EQB Water Resources Committee and the Water Resources Technical Advisory Committee, with Marilyn D. Lundberg the lead author. Nina Langoussis, Department of Natural Resources, provided significant contributions in analyzing 1980 and 1989 water use data. Suzanne Maeder, Land Management Information Center of the Department of Administration, provided special assistance with 1989 water use data. Additional contributions were made by: Sarah Tufford, Laurel Reeves, Jeanette Leete, James Japs, and numerous others from the Department of Natural Resources and Sheryl Corrigan, from the Metropolitan Council.

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SUMMARY

ALTHOUGH MINNESOTA is blessed with extensive amounts of water, various parts of the state may lack adequate supplies because of too much demand or poor quality, among other reasons. Good management is needed to minimize these problems.

Assessing whether there is an adequate supply to meet present and future needs in any given location is difficult. One must: 1) understand the quality and quantity of surface- and ground-water supplies and conditions that affect supplies; 2) have data on present and projected water use; and 3) relate existing and projected use to supplies. Information is lacking to make a thorough assessment.

This report contains information about water supplies, contrasts water use changes between 1980 and 1989, and projects future water use. It also offers recommendations to enhance the ability of the state to assess water availability. If carried out, these recommendations would enable state and local governments to better manage the state's water supply.

WATER SUPPLIES

Minnesota has a vast network of surface and ground water. The quantity of water in streams, lakes, and aquifers varies considerably across the state and throughout the year. Periods of drought stress usually plentiful supplies and endanger those systems that normally have less water.

State assessments, as well as the drought of the late 1980s, show that western and central Minnesota have a high concentration of watersheds with a potential for conflict over water uses. Other areas, such as southeast Minnesota, have plenty of water but may have supply problems because of pollution.

The volume of ground water is difficult to assess due to the complex geology of the state and the lack of information. The amount and type of aquifers vary throughout the state. Some, such as the bedrock aquifers underlying the southeastern part of the state, are highly productive. However, in other places, such as northeastern Minnesota, ground water is found in fractures and cracks of rocks that usually have poor yields.

While information about Minnesota's water supplies is improving, ground- and even surface-water information is not adequate for careful management.

WATER USE

Since the late 1960s, some types of water uses increased while other types decreased. Sources of supplies also have changed. A reduction by some large users, such as power plants, resulted in an overall decline in use. Specific reductions in use may affect particular supplies, such as the Mississippi River. However, increases in use are occurring mostly from ground-water sources throughout a large portion of Minnesota.

Reported public supply use increased 228 percent between 1950 and 1989. This is eight times greater than the population growth. Since the late 1960s, ground water is increasingly the choice for public supplies and irrigation. Irrigation has proliferated dramatically with the use of ground water. The growth in ground-water use is a cause for concern, since it is the least understood system.

Power generation is the biggest water use. However, in contrast to irrigation or public supply, most of this water is returned to its source and available for other uses. Mining and paper production use large amounts of water in northeastern Minnesota. Irrigation and public supply are important uses across the state. Industrial use is declining. Some vital uses of water are not easily quantified, such as that needed for recreation and to sustain plant and animal life.

PROJECTED WATER USE

Continued increase in water use is predicted for most of the state. According to an Army Corps of Engineers model developed for this assessment, by the year 2000, increases are predicted as follows: 20 percent for residential; 6 percent for commercial/industrial; 18 percent for institutional; and 15 percent for miscellaneous use.

A Metropolitan Council projection of Twin Cities water demand to 2010 forecasts that residential demand will increase by 17 percent from 1988 levels and commercial use will rise 9 percent. Growth is now occurring in areas beyond the boundaries of the Prairie du Chien-Jordan aquifer. Much of the growth in the Twin Cities area relies on ground water.

MANAGEMENT

Minnesota state and local governments have a good framework for managing water supplies and demand. However, both levels need to improve their capability and cooperation and to manage use according to available supplies.

NEEDS

Many important efforts now underway need to continue. They include: improving understanding of the ground-water system; expanding the observation well and stream gage networks; improving data management through development of a ground-water clearinghouse; and protecting supplies through wellhead protection and a response plan for spills on the Mississippi River.

RECOMMENDATIONS

This report contains several recommendations relating to water availability needs. They focus on collecting more information and improving data management, fostering better water management by state and local government and in the metropolitan area, and revamping the water appropriation permit system. Their purpose is to strengthen the state and local ability to protect and sustain Minnesota's water resources.

ISSUES AND RECOMMENDATIONS

OBTAINING GROUND-WATER INFORMATION

Issue: The state does not have enough information about ground-water resources to adequately manage appropriations and protect water quality. Except for a few aquifers, the yield potential of most ground-water sources in the state is uncertain. Yields cannot be determined quickly enough to respond to emergencies. Information about buried aquifers is lacking. The state is accelerating the production of regional aquifer assessments and county geologic atlases.

Recommendation: Continue to accelerate the production of regional aquifer assessments and county geologic atlases. Begin a concerted effort to identify buried aquifers. Develop an ongoing program to analyze aquifers for safe yield. Expand the observation well network so it can serve as a management tool. Work toward developing Twin Cities and statewide ground-water models to aid water management efforts.

OBTAINING SURFACE-WATER INFORMATION

Issue: The state does not have enough information about surface-water resources to adequately manage use to protect stream flows. The stream gage network is limited. Ecological and recreational benefits of surface water are difficult to measure when allocating water among competing uses. Few protected flows are established for streams. Current protected flow designations are not adequately supported by research.

Recommendation: Expand the state's stream flow gaging stations to determine flow in the 81 watersheds with more certainty. Evaluate the watershed contributing to each gage when interpreting flow records. Document ecological and recreational benefits. Accelerate comprehensive program development and determination of protected flows. Relate observation wells and precipitation to watersheds to better understand ground- and surface-water interconnections.

ANALYZING AND REPORTING INFORMATION

Issue: The state's water use and supply data are not analyzed to discern trends. Information about specific aspects of water use is missing, such as the industrial use of public supplies. Consumptive use is not reported or routinely calculated. Neither local governments nor the state projects future water use. Management is a reactive process.

Recommendation: Gather, analyze, and report annual water use data for watersheds, aquifers, and counties by major use categories so trends can be readily determined. Develop consumption coefficients for major uses and estimate present and future consumption. Local governments and the state should project future water needs.

IMPROVING AND VERIFYING DATA

Issue: Relying only on information from state permits poses problems for estimating total water use. A permit is not required for those appropriating less than 10,000 gallons per day or 1 million gallons per year. In addition, the state has little idea of how many appropriators fail to apply for required permits. The completeness of the data has changed over time, and the lack of verification creates problems with accuracy.

Recommendation: Expand enforcement efforts to ensure that all those requiring a permit have one. See that permit holders follow requirements for reporting water pumped and have contingency and conservation plans. Work with the U.S.

Geological Survey and the U.S. Department of Agriculture to develop approaches for consistently estimating water use and consumption by nonpermitted users.

FUNDING MINNESOTA GEOLOGICAL SURVEY

Issue: The Minnesota Geological Survey provides vital information about the state's hydrogeology. Its mapping and technical assistance is crucial for many programs, such as county geologic atlases. MGS is not funded for fiscal year 1993, jeopardizing a great deal of geologic work now underway.

Recommendation: Fully fund the Minnesota Geological Survey in fiscal year 1993.

CORRECTING MULTIAQUIFER WELLS

Issue: The state has many multiaquifer wells. This type of well can provide a conduit for pollution from upper aquifers to deep aquifers. In southeast Minnesota, many multiaquifer wells extend to the deep, relatively pure Mount Simon-Hinckley aquifer. Multiaquifer wells provide the second largest amount of groundwater used in the Twin Cities. The state well code now prohibits their construction. However, the state does not require reconstruction unless a well proves to be a pollution hazard. Some factors hampering well sealing include the difficulty of identifying well owners and the refusal or inability of some owners to seal wells.

Recommendation: Promote sealing abandoned multiaquifer wells. To accelerate this effort, create a revolving fund to pay for the sealing of abandoned wells where the current owner is not known or refuses to act. Make the Mount Simon-Hinckley aquifer the initial priority for this fund, with a five-year target for sealing all its multiaquifer wells.

The Department of Health, in cooperation with the Board of Water and Soil Resources, should develop a plan for the timely assessment of operating multiaquifer wells. Owners of multiaquifer wells vulnerable to contamination must immediately take corrective action to prohibit the introduction or spread of contamination. Other owners should propose within two years of notification by MDH how and when any multiaquifer wells will meet well code requirements. After the two-year deadline, the state may require monitoring of multiaquifer wells at the owner's expense as a condition of continued well operation.

LOCAL PLANNING FOR SUPPLY AND DEMAND

Issue: Local governments have land use and growth management authority. Some cities are expecting to double or triple current water use but give little consideration to the overall effect increased demand may have on watersheds and aquifers. Comprehensive water plans, prepared by counties in Greater Minnesota, can address water supply and use issues. The state water appropriation program is reactive to many local decisions. The state, under M.R. 6115.0810, has the authority to work with local government to develop water appropriation and use management plans.

Recommendation: Strengthen comprehensive local water plans in Greater Minnesota so they specifically address: water use anticipated for growth; the effect of growth on demand; demand management; and related water quality issues. Plans should coordinate supply management and use with other affected counties.

Recommendation: Establish a local-state pilot program for several counties experiencing growth pressures. For this program, the state would develop a water appropriation and use management plan, working with comprehensive local water planning. The state would promote cooperation among water suppliers.

TWIN CITIES PLANNING FOR SUPPLY AND DEMAND

Issue: In the Twin Cities, there is no regional framework for water supply for the over 2.2 million people, 130 municipalities, and 1,300 water appropriators. This has engendered a fragmented approach to surface- and ground-water management.

Local governments in the metropolitan area have comprehensive plans to manage growth. The plans contain land use and public facilities components. The Metropolitan Council provides a regional framework for growth management. It is also responsible for developing a long-term water supply plan for the region. A Metropolitan Council plan can guide water supply use, conjunctive use, demand management, and supply sharing in the Twin Cities.

Recommendation: The Metropolitan Council should provide a framework for managing water supplies, demand, and conservation in the Twin Cities. Local comprehensive plans should specifically address expected water use, conservation, and demand management and conform to the regional framework.

IMPROVING WATER SUPPLY AND DEMAND MANAGEMENT

Issue: The permit system does not foster good water management. The Department of Health regulates well construction. It either permits or gets a notification of planned well construction. The Department of Natural Resources regulates water appropriation and requires a permit for larger-volume users. However, the law allows well construction to proceed before an appropriation permit is sought. This makes the appropriation permit process reactive.

Restricting ground-water use is difficult in times of drought. The DNR must verify that the use will draw down surface-water supplies, but the lack of ground-water data makes this hard. The law, however, restricts surface-water appropriators during droughts. Thus, where ground and surface water are directly connected, surface-water users face restrictions while ground-water users do not.

Surface-water users must prepare contingency plans, but ground-water users need not. Most water utilities profit from increased water use. Thus, there is little incentive to promote conservation or share supplies. Only new or amended permits need conservation plans. There are no state standards or teeth in conservation planning and little planning to manage demand.

From 150 to 600 high-capacity wells are constructed each year. High-capacity wells create a large cone of depression. When a well is sited, the appropriator and the state need to consider the closeness of other wells, the impact of additional pumping, and whether surface water or better demand management might be preferred.

Recommendation: Enact legislation to restructure the process for regulating water supply development according to the following three points. This includes legislation to require obtaining an appropriation permit, a permit amendment, or conditional approval before constructing a well. (If an appropriation permit is not required, the process for well construction does not change.)

1) An applicant for a water appropriation permit or permit amendment should be required to complete a "certificate of need," which must include documentation that:

   - The need is legitimate and consistent with the local water plan and that demand is properly managed;
   - An acceptable contingency plan and conservation measures are proposed; and
   - Conjunctive use between surface and ground water has been appropriately considered.

2) The DNR, in conjunction with state agencies concerned with water quality and supply management, should conduct a resource assessment that includes:

   - Verifying the consistency of the proposed water use and source with water use recommendations contained in the local water plan and in any water appropriation and use management plans under M.R. 6115.0810;
   - Determining the appropriate water supply (surface, ground, conjunctive, or reuse);
   - Evaluating the proper placement of high capacity wells;
   - Determining appropriate permit conditions to safeguard environmental quality (e.g., incorporation of best management practices, water resources protection requirements, or minimization of soil erosion);
   - Determining appropriate permit conditions for ground-water users to protect instream flow conditions; and
   - Providing conditional approval for ground-water use until an appropriator submits a well record and any required pumping test.

3) The DNR should develop a plan for the timely review of existing appropriation permits so that: a) all appropriators meet requirements specified above, and b) all permits should be reviewed within five-year periods.

WATER RESOURCES OF MINNESOTA

MINNESOTA HAS abundant water. However, it is not always available when and where it is needed or for the use desired. At certain times and places, demand for water exceeds supplies or contamination bars some uses. Water supply problems exist now in various parts of the state. Without proper management, more problems will occur in the future.

Variability in supplies, precipitation, water use and water quality are the main factors that affect the amount of water available in any given place or for any given use. The quantity of surface water and ground water varies considerably throughout Minnesota.

UNDERSTANDING WATER SUPPLIES

The state does not have enough information to manage water use to protect some stream flows. Federal funding for stream flow gaging dropped markedly in the last decade. This loss, plus increased operating costs, resulted in the drop of stream flow gages from about 150 in the 1970s to about 95 in 1988. Only 43 of the 81 major watersheds have continuous recording gages. Of those, dams affect stream flows at 18 gaging sites.

Insufficient information about ground-water resources hinders water appropriation management and quality protection. The yield potential of most ground-water sources in the state is uncertain and is not quickly determined. Bedrock aquifers are relatively well mapped and somewhat characterized as to their water capacity. So are the surficial sand aquifers, which occur near the land surface. However, a great deal is still unknown about these aquifers.

Many buried aquifers exist, but their boundaries and yields are unknown, and many more are thought to exist but have not been investigated. The mechanics of ground-water recharge are largely unknown, which inhibits efforts to prevent ground-water pollution.

Minnesota has 650 observation wells to monitor ground-water levels throughout the state and its complex aquifer systems. Some aquifers do not have observation wells, and some aquifers have only a few in scattered locations. In contrast, North Dakota, which has less ground water than Minnesota, has about 3,000 active observation wells. Figure 1 depicts Minnesota's observation well network.

In the late 1970s, the Water Planning Board developed estimates of surface- and ground-water supplies for 39 watersheds in the state. It then compared water supplies with demands. Due to lack of data and limitations of assumptions, it found that it could not demonstrate where shortages exist or may exist in the near future.

The Water Allocation and Management project, funded by the Legislative Commission on Minnesota Resources in 1985, was a cooperative effort of several agencies and researchers. Again, however, the lack of data made it difficult to make assumptions for the various studies included in the project.

Computer models have been used to assess water availability for the Twin Cities and for other places in the state. Usually, these models are used for one project and are not maintained for future use. The cost of upkeep hinders ongoing model development.

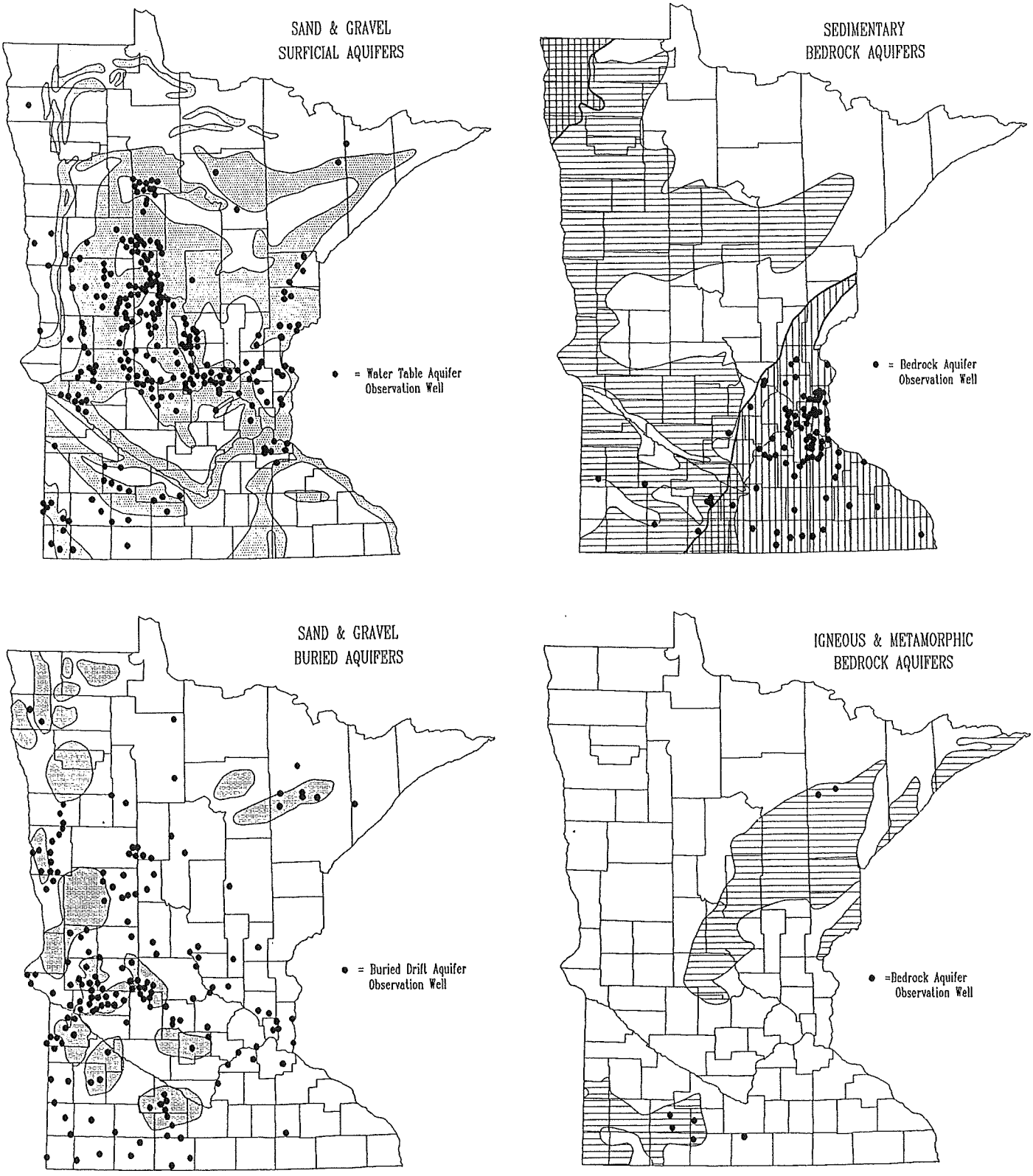

Figure 1. Observation Well Network

Department of Natural Resources Maps

SURFACE-WATER SYSTEM

Minnesota is at the headwaters of three major North American watersheds: the Great Lakes basin to the east, the Souris-Red-Rainy Rivers basin to the north, and the Mississippi River basin to the south. The state has 81 major watersheds with over 90,000 miles of rivers, 12,000 lakes covering 3.4 million acres, and 5 million acres of wetlands.

In 1987, as part of the Water Allocation and Management project, the DNR compared surface-water supplies with demands. The results provide a comparison of water availability around the state and a preliminary basis for determining problem areas.

The study had major drawbacks due to lack of data. For many watersheds, estimates of water supplies were used, rather than actual figures, because only 20 of the 39 watersheds had continuous gaging stations providing reliable data. It is summarized here since it is the most recent statewide watershed assessment.

Figure 2 shows the study results. Watersheds are portrayed as having a positive, neutral, or negative water balance. Two water balance ratios were estimated to identify where water shortages were likely to occur. Ratios show the availability and use of water under normal and under dry conditions.

Calculations were based on annual averages of water supply and demand. Thus, the positive water balance ratios, shown for some watersheds, do not reflect the considerable daily, seasonal, and annual fluctuations. Flows of streams within a watershed also were averaged. This, then, does not reflect problems with specific stream reaches. Figure 3 shows the many problem areas that resulted in suspended appropriation permits during the drought of 1988.

Northeast Minnesota shows a potential for conflict over water availability, even though

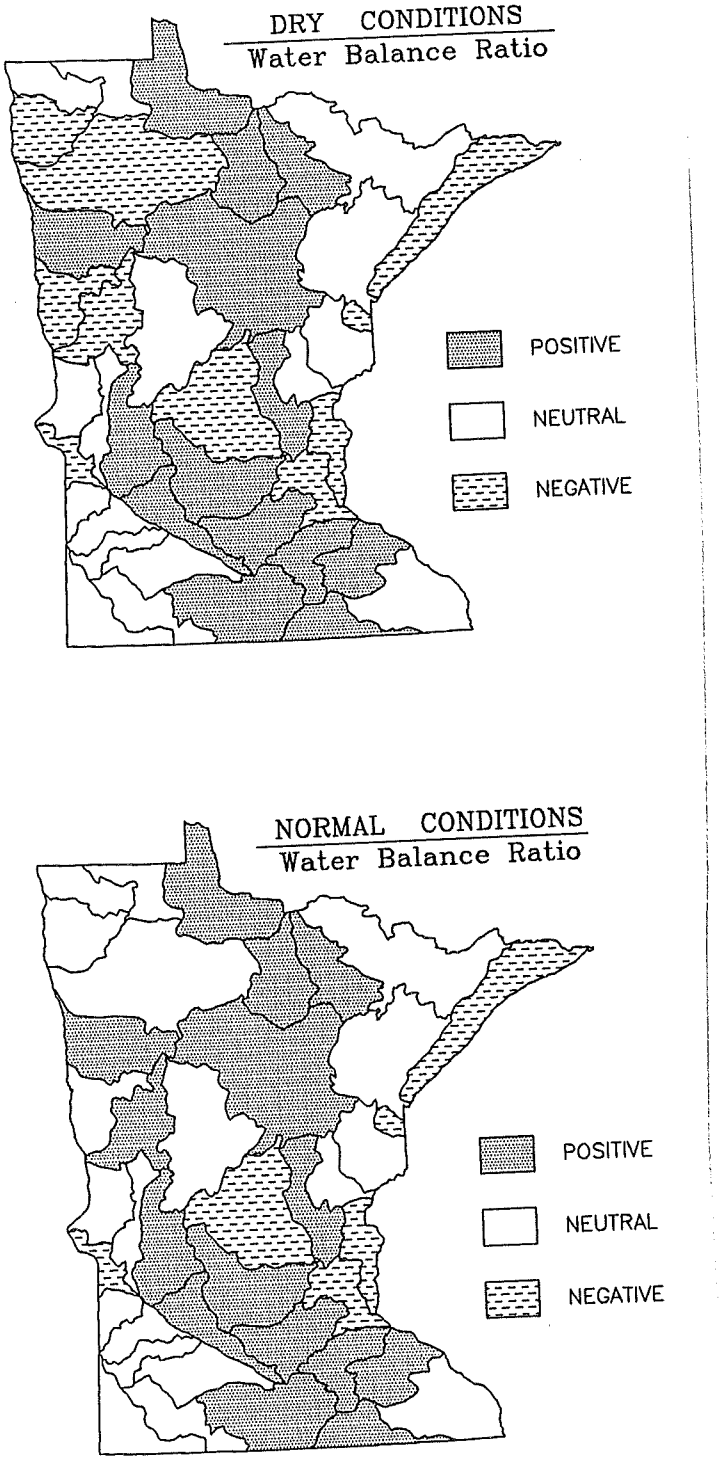

Figure 2. Water Balance Results
Department of Natural Resources Maps

water withdrawals are low. In large part, water variability and low flows are not a problem. However, trout streams drain about 45 percent of the region. The state allows only temporary water appropriations from trout streams, which could constrain certain water uses.

Western Minnesota has the highest concentration of watersheds with negative and neutral water balance ratios. Stream fluctuations are large, ranging from floods to no flow. Most of the available water occurs during spring floods. Many localized conflicts occur over surface-water and ground-water use. Problems include periodic fish kills due to low flows or water quality on the Buffalo, Wild Rice, Pelican, and Des Moines rivers.

Central Minnesota is another area with neutral or negative water balances. The drought in the late 1980s severely hit central and west central Minnesota. Some problem watersheds include the Long Prairie, Sauk, Straight, and Elk rivers. The drought heightened concern about ground-water appropriation and its effect on water quantity and temperature of nearby streams in this region. The state restricted surface-water permits in 1988 but did not restrict ground-water permits. Since ground-water appropriations may deplete a stream, this puts a surface-water user in an inequitable position compared to a well user.

The Twin Cities area shows a large negative ratio during both normal and dry conditions. However, the considerable flow into the region, from the Mississippi, Minnesota, and St. Croix rivers, was not considered. Problems occurred with municipal water supplies during droughts in the 1970s and 1980s. The report *Twin Cities Metropolitan Area Water Supply: A Plan for Action* prepared by the Metropolitan Council in 1992 provides a comprehensive examination of water supply issues in this region.

Southeast Minnesota appears to have little potential for conflict over water quantity.

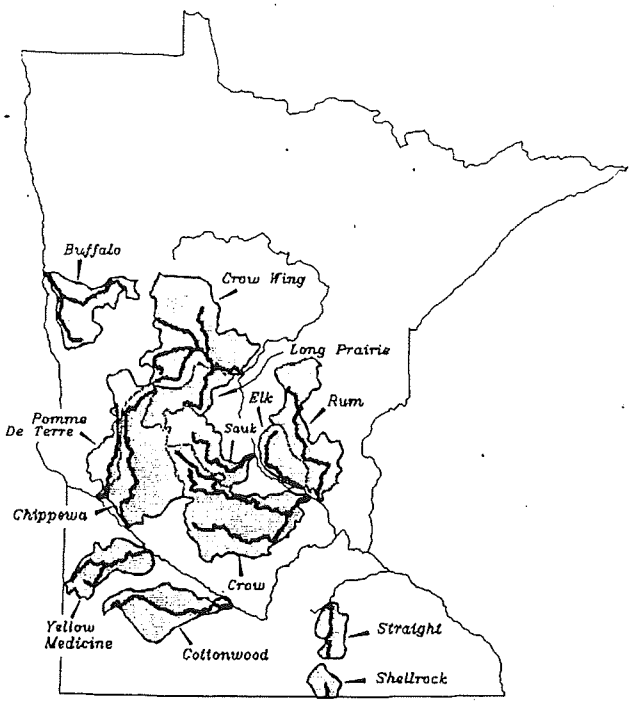

Figure 3. Watersheds with Suspended Appropriation Permits (Summer 1988)
Department of Natural Resources Map

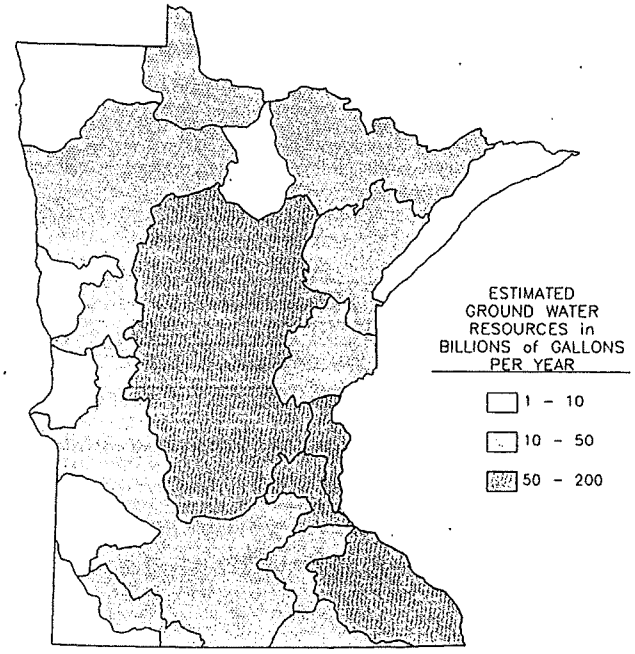

Figure 4. Estimated Ground-Water Resources
Minnesota Geological Survey Map

However, this study did not consider water quality in the analysis. Surface and ground water in this region are directly connected and susceptible to contamination. The Root River watershed has a potential for conflict because of its many trout streams. The state restricts water appropriations in trout streams. There are few lakes in the region, and the streams are important for such uses as hydropower and recreation. (See references 1, 15, 16, 18.)

GROUND-WATER SYSTEM

Ground water is available across Minnesota in 14 principal aquifers. Assessing the volume of ground water is very difficult due to the lack of information. Minnesota has a complex geologic system that compounds the difficulty. Geologic information is gathered from well data and special investigations. The use of this information does not lead readily to a determination of volume. The best statewide estimate of volume depicts the information by watershed (see Figure 4).

Ground-water sources are variable throughout the state. Ground water may occur in either bedrock or unconsolidated aquifers. Bedrock sources include granite, sandstone, and limestone. Unconsolidated deposits are loose materials, such as sand, gravel, and clay.

Basement rocks are the oldest and hardest layer of rocks. They usually underlie sedimentary bedrock formations that have higher yields because they are more porous. However, in northeast Minnesota, fractured basement rocks are the only aquifers available and are locally important. Fractures and cracks in these rocks may provide some storage space for ground water, but it is rare to have significant yields.

Highly productive sedimentary bedrock aquifers underlie the southern and eastern part of the state, which includes the Twin Cities. The Prairie du Chien-Jordan is the first high-yielding bedrock aquifer and supports the heaviest use. The deepest aquifer is the Mount Simon-Hinckley, which contains relatively pure, soft water. The Mount Simon-Hinckley is not hydraulically connected to the surface-water system. It recharges only very slowly through a confining layer above and at its limited surface exposure. Its hydraulic characteristics result in large declines in water levels due to pumping centers in Minneapolis and St. Paul.

Surficial sand and gravel aquifers are near the land surface in about one-third of the state. This makes them very vulnerable to contamination. The amount of water they contain varies considerably. The highest yields come from alluvial deposits along major river valleys and from glacial sand and gravel deposits. Many can meet the high rates of pumping needed for irrigation. However, in some areas, the outwash is too thin to maintain high water yields.

In southwest Minnesota, the basement rock is composed of hard, dense sandstone called quartzite. It is usually not considered a major water source. Since it may be the only source of water, it is locally important. The sedimentary bedrock in western and southwest Minnesota varies in thickness and yield.

Sand and gravel deposits, buried in the glacial drift, are valuable aquifers. They are especially important in western Minnesota, where the drift is thickest and where bedrock aquifers have poor water quality. However, the locations and dimensions of these are generally not known or understood. (See references 2, 26.)

GROUND- AND SURFACE-WATER LINKS

The relationship between streams and ground water is dynamic and may vary seasonally because of floods and increased summer pumping. Floods raise stream levels relative to ground-water levels in the banks surrounding a stream. This then slows or reverses the ground-water flow to the stream.

During summers, increased pumping for air conditioning, irrigation, and municipal supplies reduces ground-water levels and thus the rate of ground-water discharge to streams. Under certain conditions, pumping may reverse ground-water discharge to streams and instead draw water from streams into ground-water systems.

Surface-water bodies are an expression of the upper part of the ground-water system. Special studies in various locations confirm the interconnection between ground and surface water. They show that water discharge from aquifers to streams is a significant part of stream flow. For example, studies of the Mississippi River at Prescott, Wisconsin, indicated that during January 1977 (a dry year) and January 1982 (a wet year), ground-water discharge contributed about 25 percent and 15 percent, respectively, of the mean monthly flow of the Mississippi River.

Studies in the Rochester area indicate that the south fork of the Zumbro River loses water to the ground-water system. This recharge may result from the pumping of nearby high-capacity wells. (See references 5, 8, 9, 22.)

SHIFTS IN WATER SUPPLIES DUE TO CLIMATE

Variable weather conditions greatly affect water supplies. The past ten years show how quickly conditions can change from high to low water levels. From 1977 to 1986, Minnesota experienced some of the wettest conditions on record.

In 1985, water table levels were near or above their highest measured levels because of ten years of above normal-precipitation. Dozens of landlocked lakes rose to levels that flooded hundreds of lakeshore homes and cabins. Lake Pulaski in Wright County rose 5.9 feet from 1983 to 1986.

Then the drought hit. The precipitation shifted beginning in the fall of 1986. April through July precipitation in 1988 was 6.61 inches--the second driest in the last 100 years. The ground-water levels declined below previously recorded levels in most of the state. Levels were typically three to five feet below summer averages and about one foot below the recorded lows in 1976-77. These levels were typically eight feet below the recorded high levels in 1985.

In 1988, the Mississippi River at St. Paul reached low levels attained during the droughts of 1934 and 1976. Many lake levels dropped significantly. For example, Lake Minnetonka receded by 4.4 feet, while White Bear Lake dropped by 4.3 feet. Because of low water conditions, many local governments imposed conservation measures restricting water use for lawn sprinkling and car washing. (See reference 16.)

WATER QUALITY AFFECTS AVAILABILITY

Water quality directly affects water availability. Pollution prevents certain uses. The historic answer to polluted water is to dig deeper wells or look for other sources, but this is not always possible. There are no easily accessible sources of clean water for some of the contaminated municipal and private water supplies.

St. Paul and Minneapolis rely on the Mississippi River for their water supplies. A major petroleum spill occurred in 1991 near the headwaters but fortunately did not contaminate the river. Next time, however, this may not be the case. This near miss illustrates the problems inherent in protecting the Mississippi from contamination. It also points out the need for water users to have contingency plans in case spills occur. Since Minneapolis only has a 24-hour water reserve, this incident put pressure on the city to have a workable back-up strategy.

A recent study shows how one water use can influence other water uses. Water infiltrating through the surficial sand aquifer is usually clean water with low total dissolved solids. Where it has passed through heavily fertilized fields, it leaches out nitrogen. Normally, this water would stay near the top of the water table and discharge to surface water.

However, in a study at Lakewood Shores in Benton County, water pumped from high-capacity wells artificially transported water deep into the aquifer to the point where domestic well users were drawing high-nitrate water. Shallow monitoring wells still showed low nitrate-nitrogen levels, while domestic wells at 60 and 70 feet had at least 20 parts per million nitrate-nitrogen. This is double the standard for drinking water, making the water unavailable for drinking unless treated. (See reference 14.)

SURFACE- AND GROUND-WATER USE

AN IMPORTANT part of life in Minnesota has always been the use of its many water resources. Settlements developed along the rivers, which were used for transportation and water supplies. Ground water gradually became a vital source in the early 1900s. Uses were for self-supplied industrial purposes, municipal supplies, water-driven sawmills and flour mills, and hydroelectric plants.

Water use varies across the state. Per capita water use doubled from the 1940s to the late 1970s due to home and garden life-style changes, and it continues to increase. Since the late 1960s, the preferred source for public supplies and irrigation has changed from surface to ground water. Irrigation has dramatically increased with the use of ground water. The increase in use of this source is a cause for concern, since the least is known about this resource.

Power generation is the biggest water use. However, much of this water is not consumed, meaning it is available for other uses. Mining and paper production use large amounts of water in northeastern Minnesota. Water for industrial use is declining. Irrigation is important in much of the state. In many areas, an industrial or other specific local use may significantly affect water availability.

In the Twin Cities, much of the suburban growth relies extensively on ground water for its supply. There are now 490 municipal wells in the region with 25 percent drilled in the 1980s. The Prairie du Chien-Jordan is the most heavily used aquifer. Multiaquifer wells that pass through several units are the second largest source. Most of these wells pass through to the Mount Simon-Hinckley, providing a conduit for pollution to this important aquifer. The well code prohibits multiaquifer wells, but many wells were constructed before this prohibition.

Many important water uses are not quantified here but should be considered when evaluating water needs. They include water needed to sustain plants and animals, for recreational uses, such as swimming and boating, and for navigation. (See references 3, 8, 9, 21.)

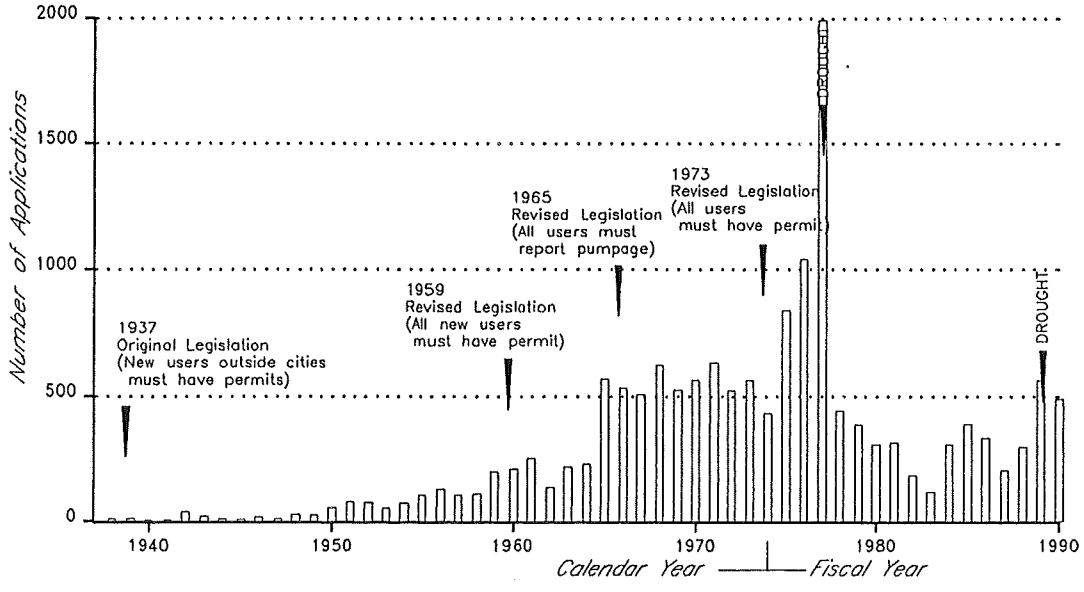

Figure 5. Appropriation Permit Applications 1938-1990 (Department of Natural Resources Graphic)

ASSESSING WATER USE

Water use information is incomplete. Relying only on information from state permits poses problems for estimating total water use. Minnesota does not require a permit of domestic users serving less than 25 persons or those using less than a minimum amount (10,000 gal/day or 1 million gal/year.) Thus, these uses can only be estimated.

State permit and pumping requirements expanded significantly throughout the years. Long-term data about water use has varied, reflecting these changes (see Figure 5). There are estimates that 10 to 15 percent of the irrigators do not report their use. An unknown number of users required to have permits do not have them. Despite broad reporting requirements, ambiguity still exists about some major water uses. For example, "public supply" reported use may include industrial and commercial as well as domestic uses; these uses are not broken out when reported.

The state does not routinely verify or analyze data for any insight into the effect of water use on availability. Overall trends in water use are instructive. However, it is more important to understand where water demand is occurring or is projected to occur in relationship to relevant water supplies. This requires state and local governments to project future water use--something not now being done.

The state does not estimate consumptive use. Yet it is important to know how much water is consumed to understand the amount available for other uses. For example, 60 percent of reported water withdrawals are for power production, most of which is not consumed. In contrast, 9 percent of reported water withdrawals are for irrigation. Most of this is consumed and not available for other uses.

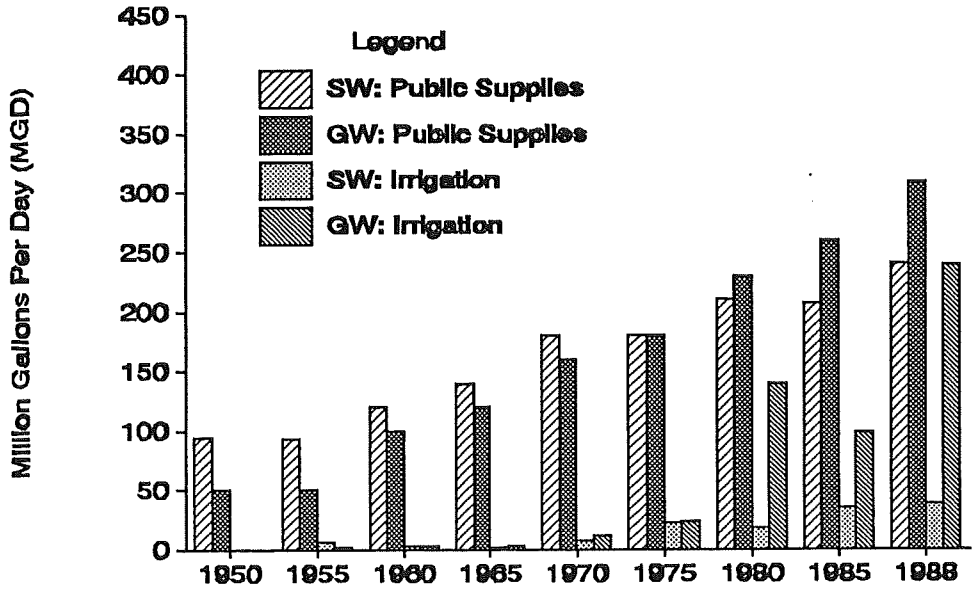

Figure 6. Trends in Surface- and Ground-Water Use Department of Natural Resources Graphic

SPECIFIC SURFACE- AND GROUND-WATER USES

Public Supply

Reported public supply water use increased 228 percent between 1950 and 1989, from an estimated 53 billion gal/year to 174 billion gal/year. This is eight times greater than the population increase during the same period. Reported use during the drought of 1988 was at a record high.

This increase may reflect several factors: expanded domestic use, increased population, improvements in water use estimates, and the switching of industrial, commercial, and domestic users from self-supplied sources to public supplies.

Most public systems in the state rely on ground water. Of 708 municipal appropriation permits in 1990, 675 were for ground-water sources, compared with 33 permits for surface water. Ground water provided 34 percent of public water supplies in 1950 and was 63 percent in 1989 (see Figure 6.)

Relatively few public supply systems use surface water. Minneapolis relies completely and St. Paul, predominantly on the Mississippi River for supplying seventeen communities with water. These two utilities account for two-thirds of the surface-water used for public supplies in Minnesota.

St. Paul and Minneapolis water utilities locate their water intakes in Anoka County. Surface-water use for these two public supplies show a leveling off. The use of most other public supplies, such as those in Moorhead and St. Cloud, is increasing (see Figure 7).

In 1980, 16 counties had public supply use totals over 500 million gal/year of ground water. Eight of these recorded use of over 1,000 million gal/year (see Figure 8).

By 1989, 43 counties recorded the use of over 500 million gal/year of ground water. Use in 21 counties exceeded 1,000 gal/year. Figure 9 shows where this growth has occurred. Note that the high range has significantly increased.

The metropolitan area accounts for 56 percent of the total public supply ground-water use. Their use increased 411 percent during this period. The volumes used in other areas are not as large as in the Twin Cities. However, many public suppliers around the state show significant increases in use. Some of these increases may have a significant local effect on water availability.

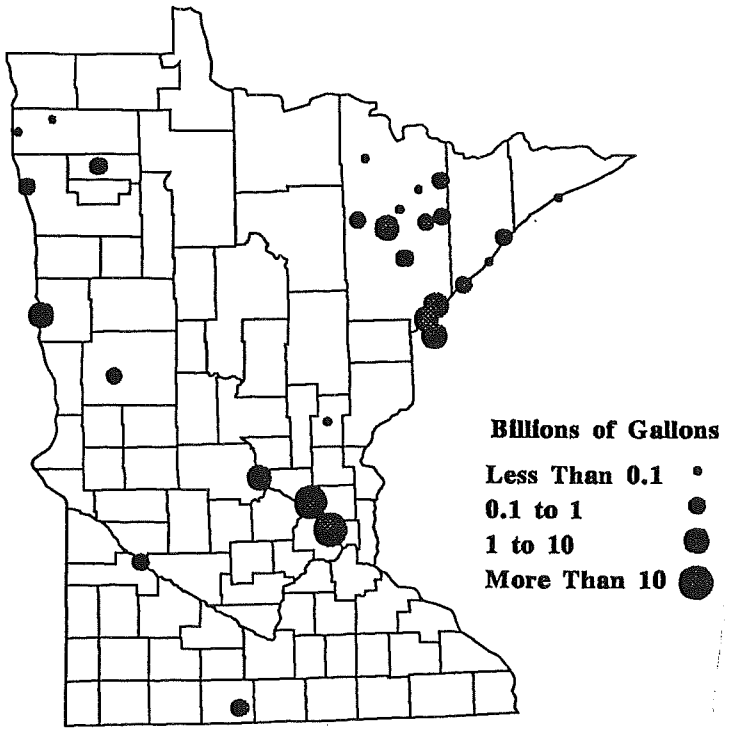

Figure 7. Surface Water: 1989 Public Supply Use
Minnesota Planning Map

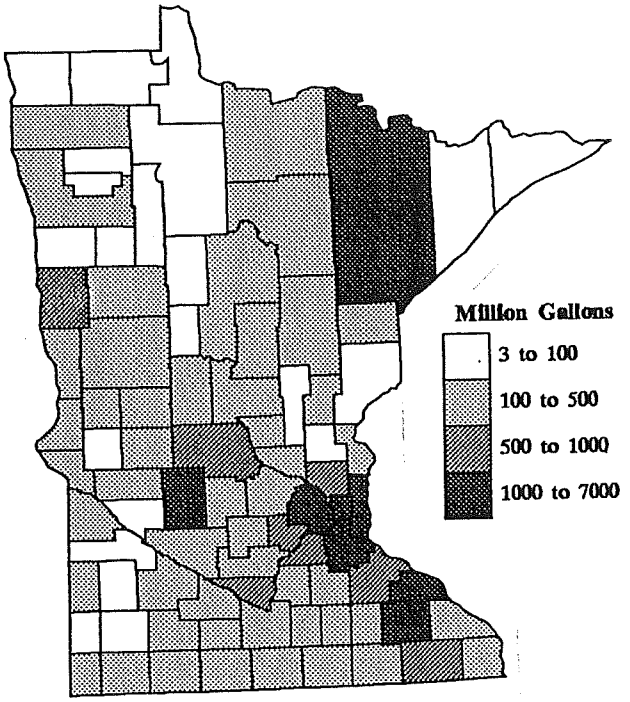

Figure 8. Ground Water: 1980 Public Supply Use

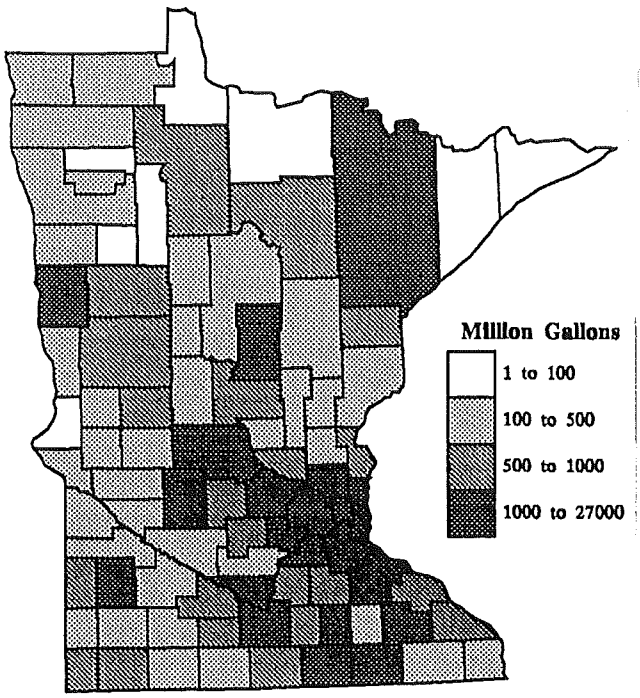

Figure 9. Ground Water: 1989 Public Supply Use

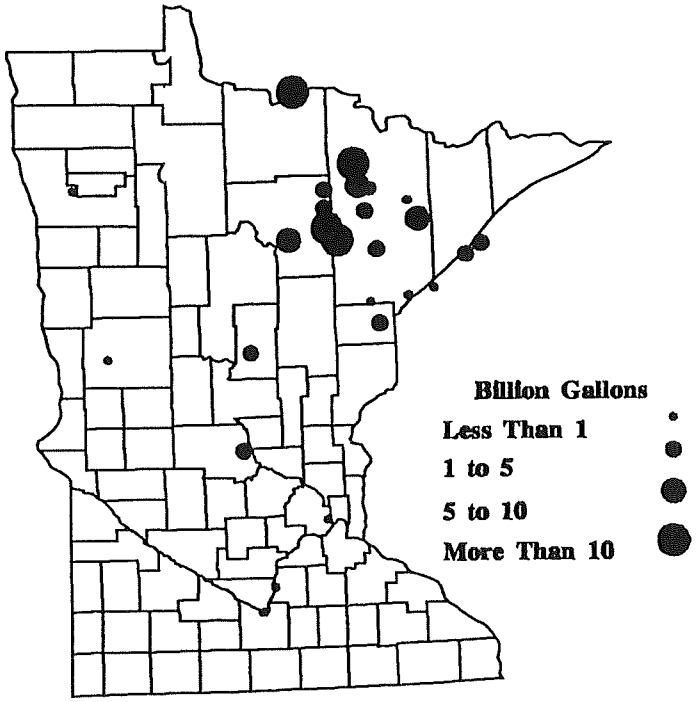

Figure 10. Surface Water: 1989 Industrial Use
Minnesota Planning Maps

Industrial Use

A few industries strongly influence the total industrial water use. Thus, any changes in the biggest water users greatly affect the total amount of water used. Reported industrial water use increased until the late 1960s, when it began falling off. Reported use in 1989 was 120 billion gal/year, down from a high of 511 billion gal/year in 1965 and 216 billion gal/year in 1980.

The decline may reflect several factors: an economic downturn in industries that use large amounts of water; improvements in water use estimates; the switching of industrial and commercial users from self-supplied sources to public supplies; and more recycling of water.

Water used for sugar beet processing illustrates a recent industrial change in water use. Due to environmental protection measures, five major

Minnesota processing plants dropped their water use from 3,094 acre feet in 1973 to 806 acre feet in 1985. These plants converted to a closed-loop system, recycling water through the plant many times before it is finally treated and discharged. While this decreases the amount withdrawn, it increases the percentage consumed. (See references 9, 26.)

Surface-water accounts for approximately 75 percent of all self-supplied industrial use. Most of this use is in northeast Minnesota. Of the total surface-water used by industry, about ten mining permits account for 58 percent and five paper or pulp permits account for 29 percent of the surface-water used. Shifts in the mining industry greatly affect total industrial water use. Overall, industrial surface-water use has leveled off. Specific increases or decreases may be locally significant (see Figure 10).

Ground-water use comprises about 25 percent of total industrial water use. The largest category is agricultural processing, which uses 46 percent of the total. Permits for this use number about 120. Other uses include metal processing, manufacturing, and petroleum and paper processing (see Figure 11).

Between 1980 and 1989, reported industrial ground-water use showed a 47 percent decline. Some of this decline could be due to changes in the accuracy of the data. Some may also reflect some users switching to public supplies. Specific increases or decreases may be locally significant.

Power Generation

Thermoelectric power is and historically has been a major water user. It is the largest volume use. Less than 1 percent of all permits are for power generation, but it accounted for 60 percent of water withdrawals in 1988. Surface water is the primary source. Most of the water used for power is returned to its source and available for other uses. (See reference 7.)

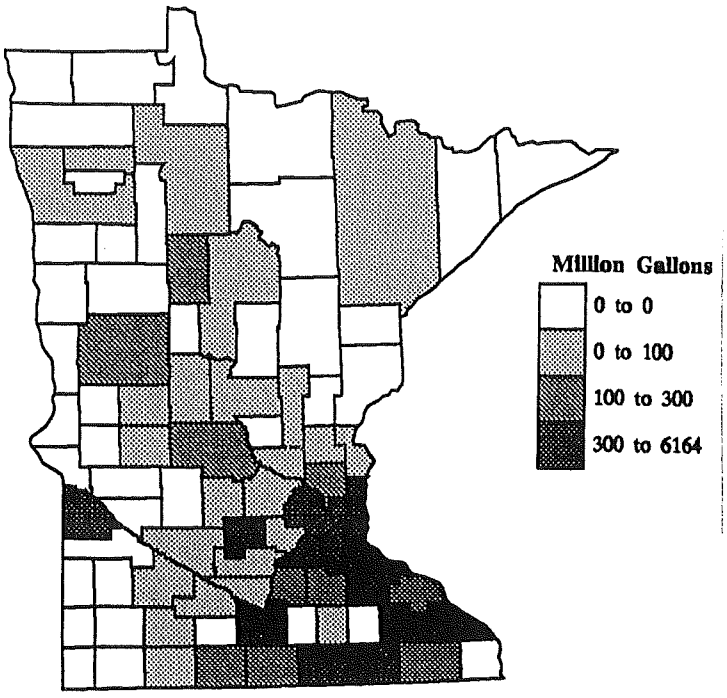

Figure 11. Ground Water: 1989 Industrial Use

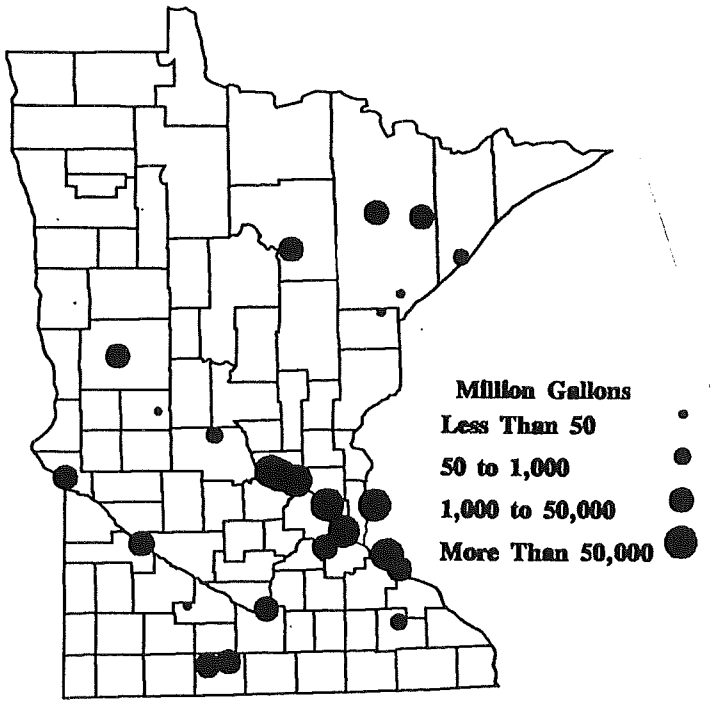

Figure 12. Surface and Ground Water: 1989 Power Use
Minnesota Planning Maps

Irrigation

Irrigation began in the early 1920s. By 1961, reported permitted use was about 5,902 million gallons (mostly surface water) for use on an estimated 20,000 acres. By 1989, reported permitted use was about 86 billion gallons for use on an estimated 540,450 acres. Ground water accounts for 86 percent of withdrawals for irrigation, consuming most of the water used.

Irrigation occurs on only 2.3 percent of all cultivated land in the state, although the percentage is much higher for some crops than others. Half of all irrigated acreage is for corn, followed by soybeans, alfalfa, and potatoes. Many fruits and vegetables grown for local markets are irrigated. Counties with the greatest number of irrigated acres are Dakota, Otter Tail, Pope and Stearns. Golf course irrigation more than tripled since 1985. It now totals about 4 percent of irrigation use. (See references 7, 26.)

Surface water was initially the primary source of irrigation water. It now accounts for only 14 percent of the total water used for irrigation. Of this amount, 50 percent is in wild rice production. The largest concentration of surface-water permits is in Wadena, Todd, and Sherburne counties. Clearwater, Aikin, and Polk counties report the highest surface-water use, primarily for wild rice flooding. Surface-water use for irrigation increased 18 percent from 1980 to 1989.

Ground-water use for irrigation significantly increased in the late 1970s. Much of the irrigation occurs from surficial sand and gravel aquifers. Between 1980 and 1989, ground-water irrigation use grew 74 percent, and the number of active wells increased 28 percent. Currently, 95 percent of all major crop irrigation, such as for corn and soybeans, is from ground-water sources. Irrigation is intensifying in central and west-central Minnesota. Thirty-seven counties experienced a 50 to 1,000 percent increase in irrigation use (see Figures 13 and 14).

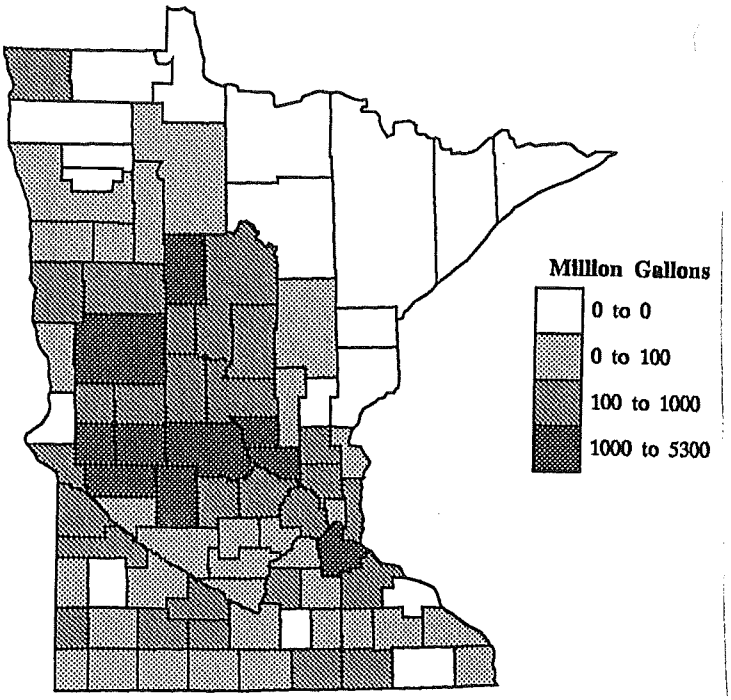

Figure 13. Ground Water: 1980 Irrigation Use

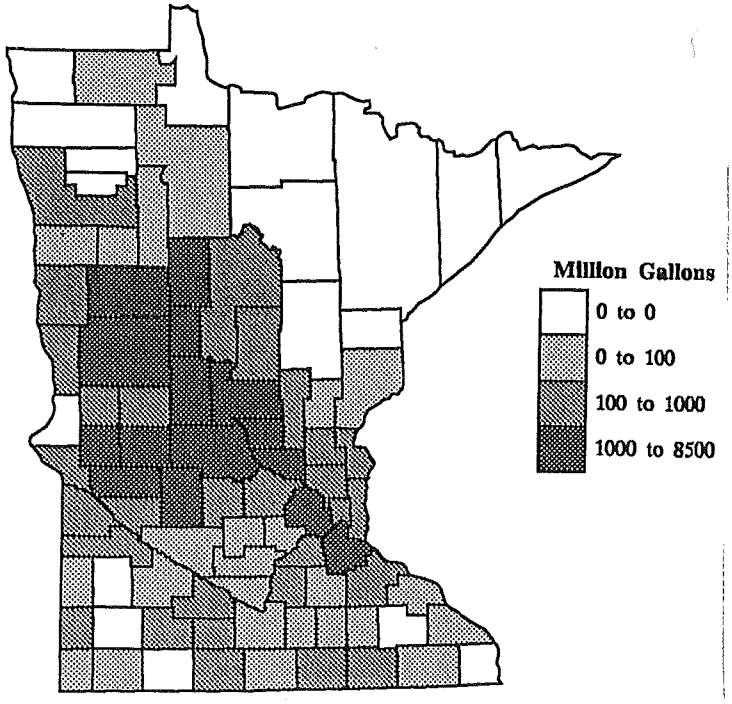

Figure 14. Ground Water: 1989 Irrigation Use
Minnesota Planning Maps

Livestock

Much livestock production occurs in a band running from Winona County to Otter Tail County. Most beef cattle and hogs are raised in counties along the Iowa border. Stearns County is the largest livestock water user. It is a leading dairy producer and also a major source of turkeys and chickens. The U.S. Geological Survey estimates a 37 percent decline in total water use between 1950 and 1985. This probably reflects the decrease in cattle population. While production of other animals, such as turkeys, increased during this time, the volume water consumed is small compared to that of cattle on a per-animal basis. (See reference 26.)

OVERALL WATER USE

Surface-water users usually locate near major rivers. The largest volume of surface-water use is for thermoelectric power production. Public water supplies for the Twin Cities are also a vital use. Surface-water use is very important in northeastern Minnesota for mining and paper production. Wild rice production also relies on surface water (see Figure 15).

Surface-water use has increased, although not as substantially as ground-water use. Forty-six counties show no use or a decrease in surface-water use, while 22 show an increase.

Ground-water use has increased rapidly since the late 1960s, especially for public supplies and irrigation. By 1980, the amount used in 45 counties totaled 500 million gal/year or more (see Figure 16).

Ground-water use continues to increase, especially for public supplies and irrigation. By 1989, the amount used in 61 counties totaled 500 million gal/year or more (see Figure 17).

Fifth-six counties had a 50 percent to 500 percent reported increase in use between 1980 and 1989. As expected, counties with population growth show ground-water use increase. In addition, ground-water use is increasing in areas with population decreases, such as in Pope and Becker counties, usually as the result of agricultural use (see Figure 18).

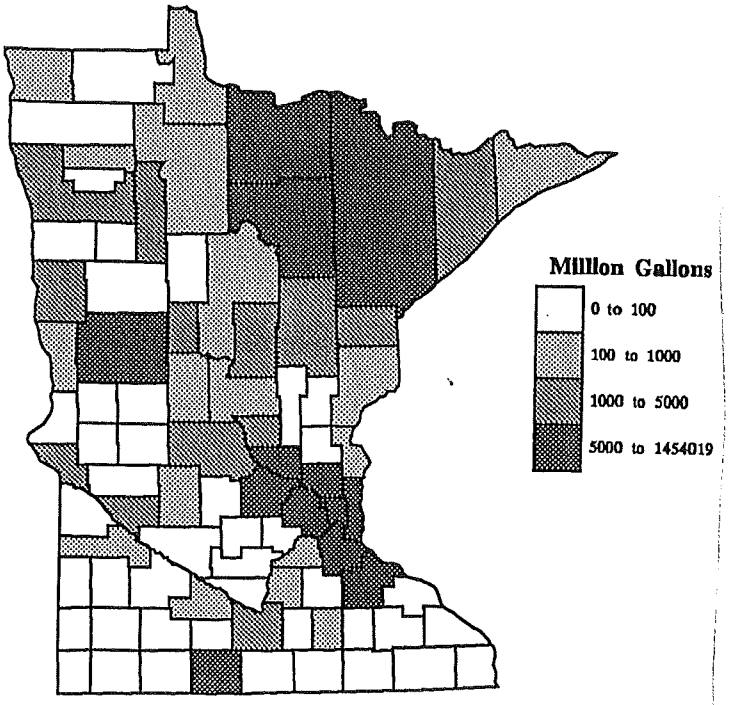

Figure 15. Total Surface-Water Use: 1989
Minnesota Planning Map

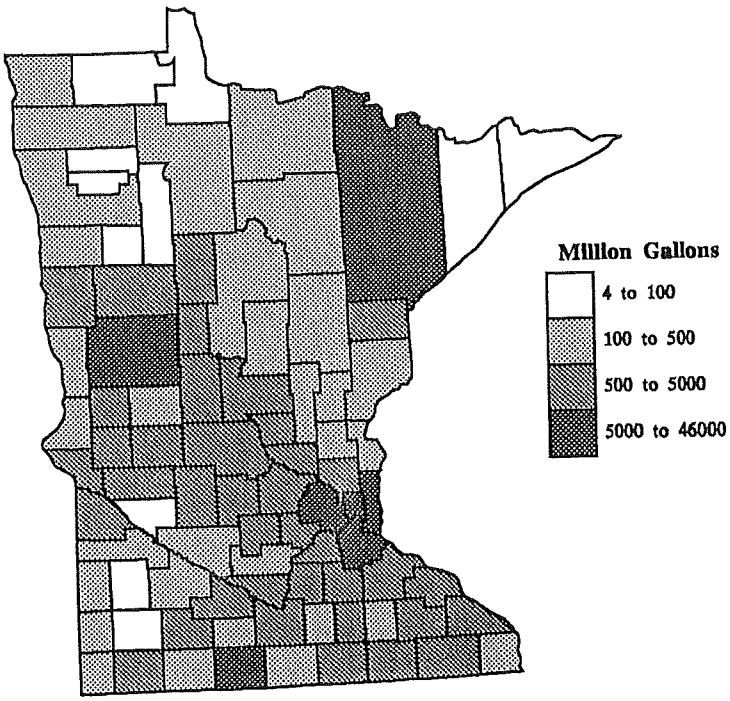

Figure 16. 1980 Total Ground-Water Use: 1980

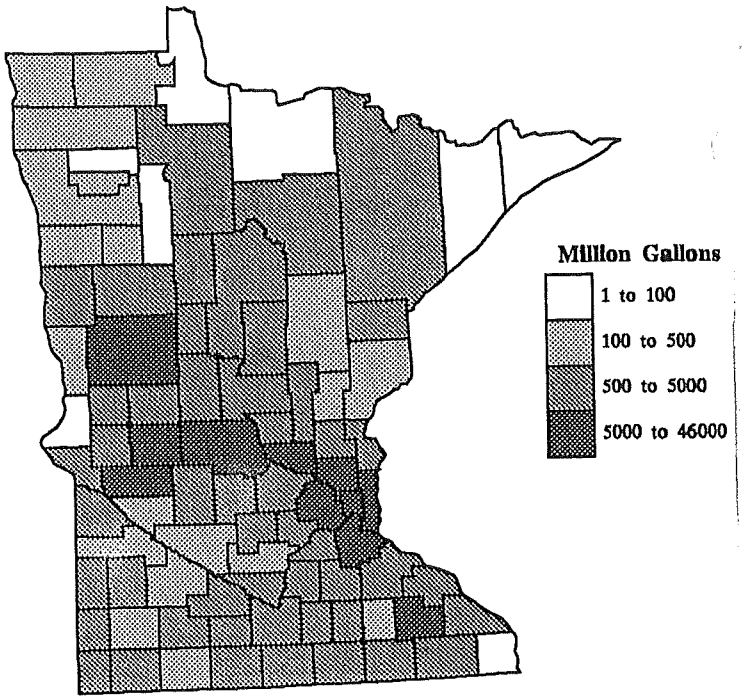

Figure 17. Total Ground-Water Use: 1989

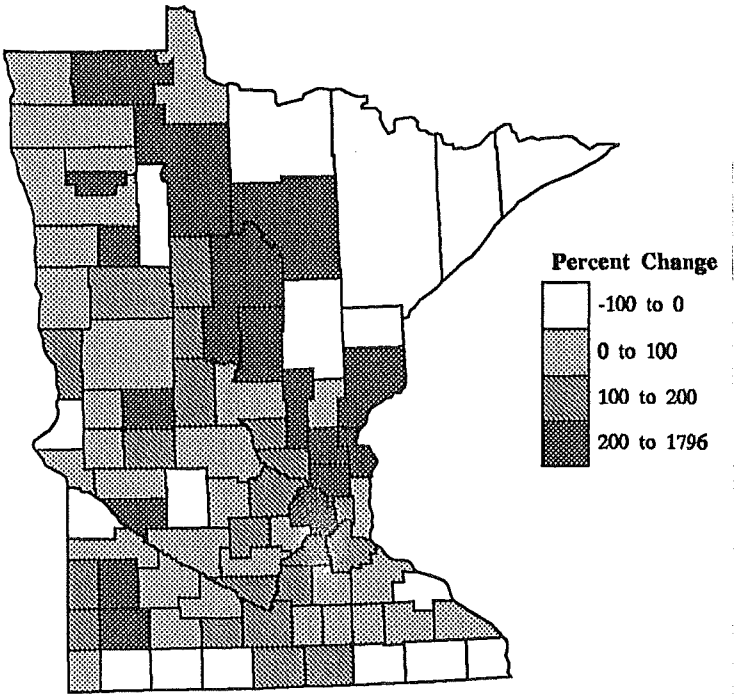

Figure 18. Total Ground-Water Use: 1980-1989 Percent Change
Minnesota Planning Maps

POPULATION CHANGE AND WATER USE PROJECTIONS

POPULATION GROWTH directly affects the amount of water used. Twin Cities population growth is highest in newer suburbs and fringe areas. Outward expansion of the densely settled urban areas slowed during the early 1980s but resumed in the last half of the decade (See figure 19).

Population and economic growth outside the Twin Cities is increasingly concentrated in a series of regional trade and service centers. The suburban and fringe areas of these centers are growing more rapidly than the city proper. Populations of small towns near the regional centers are also increasing rapidly.

Increases in water use accompany this growth. For example, the St. Cloud area shows this type of growth pattern. From 1980 to 1990, St. Cloud's population grew from about 42,000 to 49,000. St. Cloud's water utility is doubling its water supply capacity and plans to triple the capacity by 2010. Surrounding cities and townships grew by even higher rates with each local unit independently developing its own water supply. (See reference 17.)

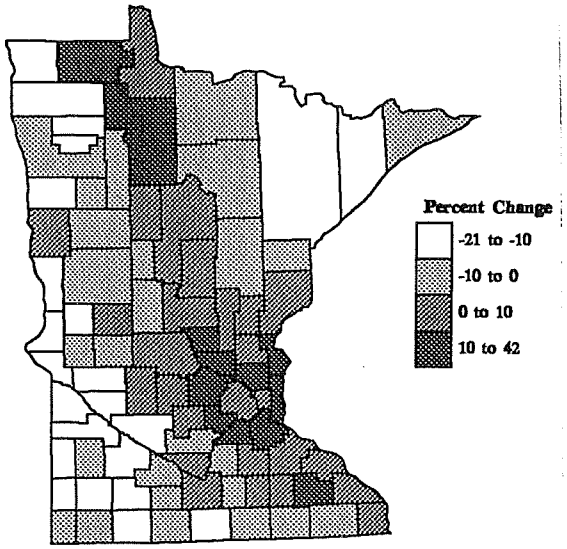

Figure 19. Percent Change Population: 1980 to 1990, Based on the 1980 and the 1990 Census
Minnesota Planning Map

PROJECTIONS FOR WATER USE

Metropolitan Area

A recent Metropolitan Council study of water availability for the Twin Cities found that overall, there is enough water, but drought, contamination, or growth pressures could cause supply problems.

Growth is not uniform throughout the area. Three areas expected to have significant growth rely solely on ground water as their source of supply. Thus, the demand on ground water will increase. The Prairie du Chien-Jordan aquifer, which is the most productive aquifer, is available in most of the region. However, this aquifer does not extend to the northern and southern portions growth.

While overall demand for water in the Twin Cities is increasing, it is not increasing in all use categories. Some uses are being phased out, while others are leveling off. Projections indicate that by the year 2010, overall residential demand will increase by 17 percent from 1988 levels. Commercial use is projected to rise 9 percent (see Figure 20).

The U.S. Geological Survey developed a model of present and projected ground-water withdrawals in the Twin Cities that suggests that even a small increase in ground-water withdrawals focused in existing pumping centers could significantly reduce water levels in the major aquifers. Pumping increases are expected to result in large cones of depression. This translates into possible reduction in stream flow and higher pumping costs in the Twin Cities.

One way to reduce the likelihood of these kinds of problems is to spread out the spacing of high-capacity wells within an aquifer. Another way is for large water users, such as public suppliers, to share supplies across political boundaries, rather than each drilling wells.

The Metropolitan Council study concludes that the regional surface-water system capacity, during times of normal climatic conditions, far exceeds the capacity of the ground-water system. However, severe drought can stress the surface-water system beyond its capacity. The Council recommends relying more on surface-water sources during times of surplus, along with conservation. (See references 4, 15, 23.)

Greater Minnesota

To develop water use projections for this study, the U.S. Army Corps of Engineers used the IWR-MAIN Water Use Forecasting System, a computer model. Estimates were developed for water demand in the year 2000 for the 80 Minnesota counties outside the metropolitan area. The model provides only very rough projections of water use due to difficulties calibrating this national model for Minnesota water use and getting the detailed data necessary to run it. The projections for overall state use are more reliable than those for specific county use.

The model forecasts increases of 23 percent in residential, 6 percent in commercial/industrial, 18 percent in institutional, and 15 percent in miscellaneous uses (see Figure 21).

The model suggests continued increases in water use in most of the state, with some areas having significant growth in use. If the trend continues, new supplies will come from ground water. This could lead to problems in maintaining ground-water yields and stream flows in some parts of the state.

In evaluating future water use, the Metropolitan Council's study points out issues that also apply to Greater Minnesota. Future water availability depends on development patterns and the capacity of the water supplies. (See reference 6.)

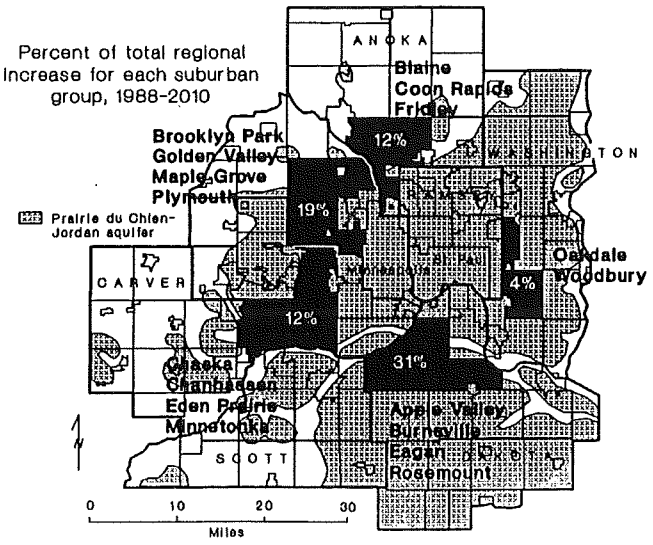

Figure 20. Metropolitan Area Predicted Municipal Water Demand
Metropolitan Council Map

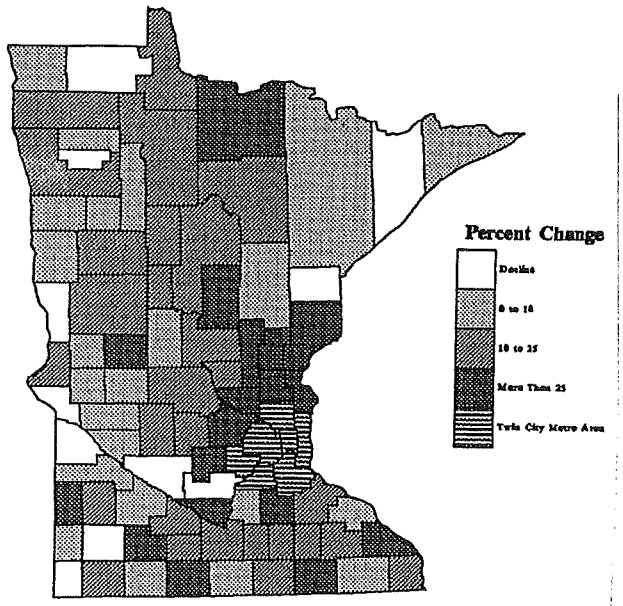

Figure 21. Projected Percent Change in Water Use, 1990-2000
Minnesota Planning Map

LOCAL, REGIONAL AND STATE MANAGEMENT

MINNESOTA STATE and local governments are in a good position to manage water supplies and demand. But the capability and cooperation necessary to do this must be strengthened. Too often, government reacts to specific demand requests with insufficient information or consideration of an overall supply-and-demand strategy.

LOCAL AND REGIONAL ROLES

Local governments have land use and growth management authority. All Greater Minnesota counties are developing or have comprehensive water plans. These plans contain information on water supplies and use and any expected changes. In addition, counties must examine the implications for present and future water and land uses.

However, due to lack of data and priority, the state has not pushed for a serious examination of water availability. Thus, most counties did not seriously consider water supply, use, and demand management, nor did they develop water use projections. There is little regional cooperation in managing water demand.

In the Twin Cities region, there are 46 water management organizations developing surface-water plans. Six of the seven counties are devising ground-water plans. Neither of these efforts requires managing water supplies and use.

Counties, cities and towns in the Metropolitan area must have comprehensive plans and manage their growth according to a framework developed by the Metropolitan Council. The Metropolitan Council is proposing to develop another framework for managing water supplies for the over 2.2 million people, 130 municipalities, and 1,300 water appropriators in the region.

STATE ROLE

Minnesota has a good legal framework to manage water use. However, it has some gaps, and staff resources are limited. The state water appropriation permit system illustrates some of the problems. The Minnesota Department of Health regulates well construction. It either requires a permit or notification of planned well construction.

The Department of Natural Resources regulates water appropriations and requires a permit for larger-volume users. However, construction of a well usually takes place before an appropriation permit is sought. This makes the appropriation process reactive. An applicant may have a large investment in a well and may expect to receive an appropriation permit.

Restricting ground-water use in times of drought is difficult. The DNR must verify that the use will draw down surface-water supplies, but the lack of ground-water data impedes this determination. However, the law does restrict surface-water appropriators during times of drought. Thus, where ground and surface water are directly connected, surface-water users face water restrictions while ground-water users do not.

Surface-water users must prepare contingency plans, but ground-water users need not. Conjunctive use of surface and ground water is not promoted. Thus, once a ground-water permit is given, the user often ceases to use surface water, even if it is more abundant. The permit process would also benefit from reviews by other agencies, such as the Pollution Control Agency and the Department of Agriculture, to recommend the best management practices as permit conditions.

Most water utilities profit from increased water use. Thus, there is little incentive to promote conservation or share supplies. Conservation plans are now required only for new or amended permits. There are no state standards or teeth in conservation planning and little planning to manage demand.

WORK UNDERWAY AND FUTURE NEEDS

While this assessment identified much that is needed to strengthen the water management system, many important activities are in progress or recently accomplished. These include:

- Seven county geologic atlases are completed and three are in progress.
- One regional sensitivity assessment is completed and two are underway.
- A regional aquifer study is proceeding in the Red River basin.
- Research on the interaction between surface and ground water is progressing in the Straight, Minnesota, and Mississippi rivers.
- More gaging stations and observation well stations have been established and more will be established in the future.

The following are some initiatives to improve data management:

- The Environmental Quality Board has adopted a water resources monitoring plan to improve state water-related information management.
- The Land Management Information Center is establishing a Ground-Water Clearinghouse to tie together aquifer and water use information.
- In cooperation with the Minnesota Geological Survey, the DNR is improving the system that ties water use to the appropriate aquifer.
- Flow meters are now required for those with state appropriation permits. This will aid permit enforcement and provide more reliable data.
- The DNR has new data quality procedures for auditing annual water use data and has improved access for the public through the Ground-Water Clearinghouse.

Other initiatives are:

- The Metropolitan Council has conducted an extensive study of water availability for the Twin Cities area. Its analysis is a model for the type of work needed in other places, especially those areas experiencing growth pressures.

- For this report, the U.S. Army Corps of Engineers developed water use projections for the 80 counties outside the Twin Cities.

- Through Environmental Quality Board efforts, the Department of Health agreed to change its municipal water supply survey form to request more information from municipal water suppliers about the types of water uses in each system.

- The MDH is spearheading efforts to protect public wellhead areas from contaminants that may have an adverse affect on human health.

- The Environmental Quality Board, the Metropolitan Council, Minneapolis, the Pollution Control Agency, and the Corps of Engineers have initiated a joint effort to address potential contaminant sources on the Mississippi River. A model was developed to estimate the travel time for spills. A river defense network will be designed to aid in spill response.

Minnesota needs to continue to strengthen its water management system. To improve state and local governments' ability to manage water, the Environmental Quality Board has made recommendations that center on developing a complete information base and an effective management framework. These are detailed in the Issues and Recommendations section of this report.

APPENDIX

Selected Minnesota Authorities Related to Water Availability

Minnesota has various laws and rules that allow the state to ensure that water is available for human and environmental needs. In addition, local governments have authority to control growth and land use, which may directly affect water supplies. Still, many omissions and uncertainties hinder comprehensive water supply management.

The following is a list of selected authorities:

Under M.S. 103A.43, the Environmental Quality Board is charged with assessing the quantity of surface and ground water and the availability of water to meet Minnesota's needs. This assessment is part of a report on water related-issues due every odd-numbered year.

Priorities for water allocation are established under M.S. 103G.261. The first priority is use for domestic supply and use for power production meeting certain conditions. Industrial and commercial water users on municipal supplies need to be readily identified for the DNR to restrict their use.

The DNR can limit appropriation permits in watercourses under M.S. 103G.285 subd. 2 to protect instream flows. During the recent drought, 195 permits were suspended. However, to most effectively regulate stream flows, adequate stream gaging is necessary. Under M.R. 6115.063 subd. 12, the state can establish protected flows to protect the ecology of a stream. However, few protected flows are established and those that are, are not sufficiently supported by research.

Applicants for surface-water appropriations under M.S. 103G.285 subd. 6 are required to have a contingency plan in case their appropriation is restricted. The contingency plan must define alternatives to protect surface water if the appropriation is restricted. The plan must be feasible, or the permittee must agree to withstand the results of not being able to appropriate water. Ground-water appropriators are not required to prepare contingency plans.

M.R. 6115.0670, subd. 3, C(2) provides for the restriction of ground-water appropriation to protect instream flows. In order to limit ground-water withdrawals, there must be "substantial evidence, that a direct relationship of ground and surface waters exists . . . ." This means that site-specific evaluations are necessary to restrict ground-water appropriations. Consequently, even though ground-water appropriations can affect stream flows, they are not restricted.

The DNR can limit the amount and timing of ground-water appropriated to a safe yield under M.R. 6115.0670 C(1). Due to the lack of information about ground-water systems and safe yield, it is difficult to enforce this rule. Thus only a few permits have been restricted or denied.

To conserve the Mount Simon-Hinckley aquifer, M.S. 103G.271 Subd. 4a prohibits the DNR from issuing new water use permits from this aquifer in most circumstances except for potable water use. A conservation plan is also required. The law also terminates all appropriations from the aquifer for once-through systems in the Twin Cities by December 31, 1992, and from other once-through systems by 2010.

Under M.S. 103G.101 subd. 1, the DNR is responsible for developing a water conservation program that must include the allocation and development of waters of the state. This program must be used to guide issuing water appropriation permits. In addition, under M.R. 6115.0770, the DNR may analyze water use practices of permittee holders or applicants and require efficient water use. However, under M.R. 6115.0750, long-term permits remain in effect as long as the conditions of the permits are followed. Without routine updating, long-term appropriators may escape conservation requirements.

The DNR can work cooperatively with others to develop water appropriation and use management plans under authority in M.R. 6115.0810. This type of plan could aid areas where there is local interest and water use is likely to increase or severe water availability problems already exist.

The Department of Health must be notified before a well is constructed, according to M.S. 1031.205. Permits are required for monitoring wells and dewatering wells. An appropriation permit is not required before a well is constructed. Thus, a well is usually constructed before an appropriation permit is sought.

The MDH is authorized to approve the site, design, and construction and alteration of public water supplies under M.S. 144.383. It also reviews public water supply plans under authority in M.R. 4720.0010. However, even for public water supplies, wells are usually constructed before appropriation permits are secured. MDH administers the well code, M.R. 4725, that specifies well construction, sealing, and standards.

MDH exercises authority for the federal Safe Drinking Water Act in Minnesota. Under this act, Minnesota is required to develop a program to protect public wells from contamination. In addition, it must require public water systems to have contingency plans in case of well or wellfield contamination. Contamination poses a serious threat to both ground- and surface-water supplies. However, most public water suppliers do not have adequate contingency plans in the event of contamination.

Local governments have various authorities to control land use and growth. County authority is found in M.S. 394.21-394.37, and city authority is found in M.S. 462.351-462.361. Comprehensive water management authority for counties in greater Minnesota is found in M.S. 103B.301-103B.355. Most greater Minnesota counties have comprehensive water plans or are developing them. However, many plans did not evaluate water supply and demand issues thoroughly.

The Metropolitan Council is required to prepare and implement a regional water supply plan under M.S. 473.156. Twin Cities local governments are required to prepare watershed management plans under M.S. 103B.231. Forty-six watershed management organizations in the Twin Cities are developing these plans. Metropolitan counties can voluntarily prepare ground-water plans. Six of the seven counties have plans underway. M.S. 473, the Metropolitan Land Use Planning Act, details the Metropolitan Council and local government responsibilities for land use planning and growth management in the region.

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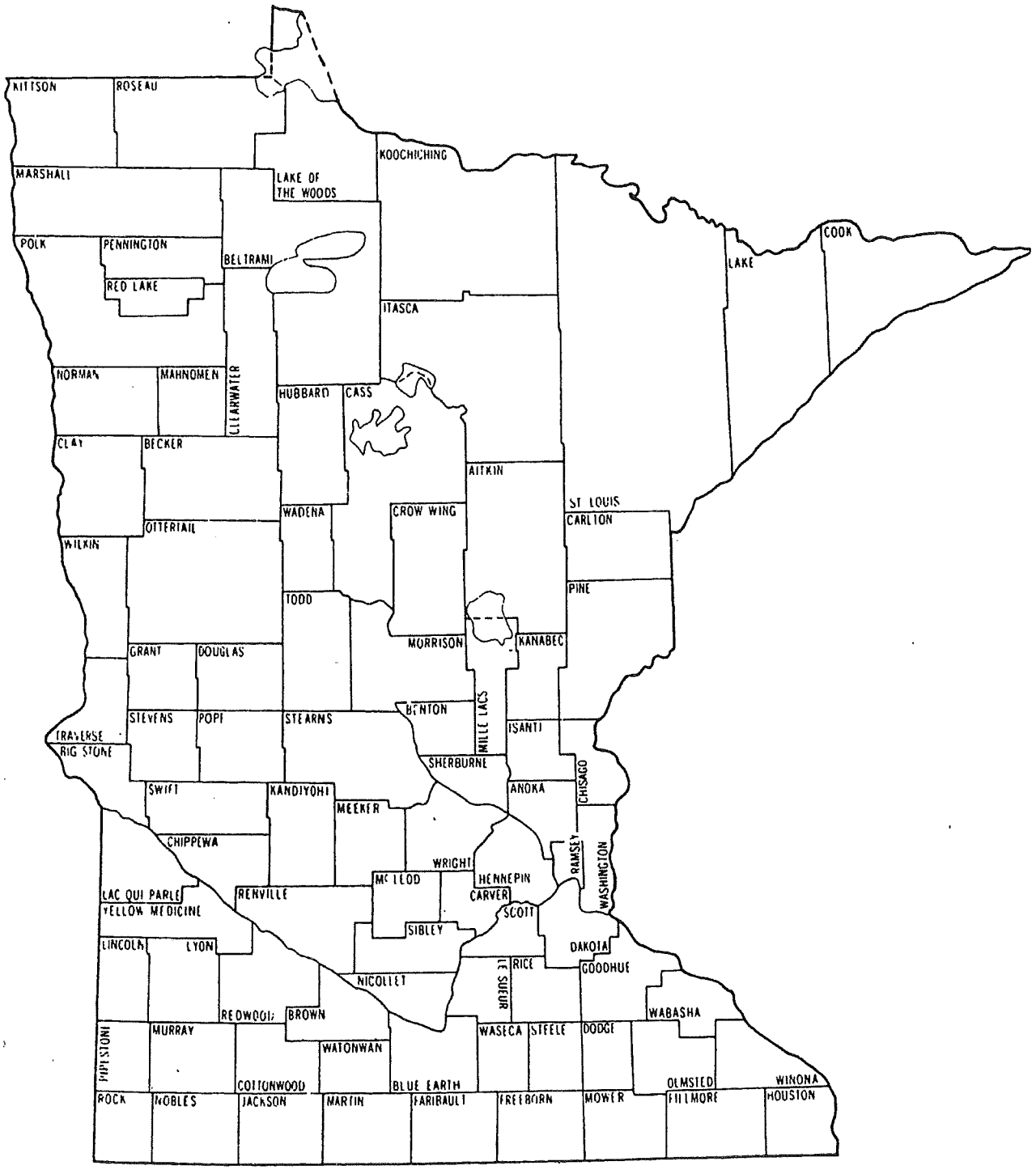
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