Use of Minnesota's Renewable Water Resources: Moving Toward Sustainability

PRELIMINARY DRAFT

January 12, 2007

Executive Summary

Minnesota Statutes, section 103A.43, directs the Environmental Quality Board and Department of Natural Resources to coordinate a biennial state assessment of the availability of water to meet the state's long range needs. That is the focus of this report.

The purpose of this project is to better understand surface- and ground-water availability and the demands Minnesotans place on water. The goal is to help state and local officials manage water resources for the long term future and better plan for development. The project seeks to do this by:

- Bringing attention to what we know and don't know about renewable water resources
- Helping local and state governments make better-educated decisions about future development and water demand
- Helping decision makers develop and implement policy to manage water on a sustainable basis

The project evaluated current and future water demand, as well as the quantity of water that could be removed from the system on a renewable basis without drawing down the resource, all at the county scale. The project worked with published methods for generating sustainable supply values, developing five sets of renewable resource estimates. The analysis used the median amount of renewable water resources estimated for each county in making comparisons with demand for that county. The comparisons were made for reported and permitted use in 2005, and estimated use in 2030. In addition, the analysis adjusted appropriations from surface waters coming into a county, since resource estimates did not include such waters. It also removed non-consumptive water uses from the tally. The 2005 water use values were calculated by averaging each county's per capita demand for the years 1995 to 2005 in order to provide a baseline not artificially affected by a single year's climate. This same use rates were applied in estimating demand in 2030.

In 2005, only one county – Ramsey County– appeared to use more than 100 percent of its renewable water resource, reporting in at 135 percent. In the seven county metropolitan area, the percent of renewable resources ranged from 10 in Carver County to Ramsey County's 135. In Greater Minnesota, the range was from less than 1 percent in seven counties to 46 percent in Wright County. Three counties ranged between 50 and 75 percent and another three between 25 and 50 percent.

By 2030, the percent use of seven-county metropolitan area renewable resources ranged from 23 in Carver County to 177 in Ramsey County, while in Greater Minnesota the range was from less than 1 percent in six counties to 81 percent in Wright County. Four counties ranged between 75 and 100 percent, one county between 50 and 75 percent, and another four between 25 and 50 percent.

The project reached seven conclusions:

1. Minnesota might still be considered water rich, but the label may not fit as well as we once believed. Not surprisingly, the growth corridor makes the greatest demand on its renewable water resources, but care still must be taken with how local and state

officials plan for demand and allocate use throughout the state.

2. The degree to which a county uses its renewable resources, today and in the future, should help inform state monitoring and research priorities.
3. The project provides information useful in understanding the commitments of renewable water resources at the county level. However, it does not inform site-specific decision making.
4. The collection and management of data can be improved to streamline and aid future analyses.
5. The assessment should help water and land use planners identify where conjunctive use of surface and ground waters may need to be at the top of the list for consideration.
6. Research is needed to:
   - Define the location and vulnerability of ground water resources
   - Understand how much water is renewable; that is, how much can be taken for use on a long-term, sustainable basis without harming ecosystems
   - Investigate new means to quantify sustainable supply or ways to build upon existing supply methods
   - Understand the impacts of drainage or other land use practices on rates of recharge and means to quantify the impacts
   - Characterize the interactions of surface and ground waters, including the implications for water quality and quantity
   - Quantify the fluctuating amounts of water that ecosystems need to flourish

7. The next assessment of supply and demand should:
   - Fully integrate the assessment of imported waters
   - Evaluate the current effect and future risk of water quality degradation
   - Make assessments on a seasonal or monthly basis, as well as annually
   - Explicitly introduce ecosystem needs for water
   - Conduct analyses on the sub-county level where information about supply and demand is sufficient
   - Develop a sub-county level tool or model for state and local planners

Lastly, given the complexity of such analyses and the range of people likely to be interested in its outcomes, the next biennial edition should use both science- and citizens-based advisory committees to gain ideas and input.

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Introduction

"The effects of ground water development may require many years to become evident. Thus, there is an unfortunate tendency to forgo the data collection and analysis that is needed to support informed decision making until after problems materialize."[1]

As the quote suggests, the challenge of understanding water supplies, especially during an era of tight budgets, is daunting. Yet, adequate supplies of clean water provide the foundation for a healthy Minnesota economy, healthy ecosystems and a high quality of life. Water provides jobs, supports fish and wildlife, and is the cornerstone of a $10 billion a year tourism industry in Minnesota. However, with projected population and economic growth it is important to understand where water may be sufficient to meet future demands and where it may not. Otherwise, Minnesota's economy, environment and quality of life may be put at risk in the future.

In Minnesota the Legislature has established the legal and institutional framework to manage water supplies to meet today's needs while ensuring that future generations can meet theirs. The Department of Natural Resources regulates the appropriation of water and operates a number of supporting programs to ensure that water supplies meet a variety of economic and ecological purposes. *Minnesota Statutes*, section 103G.265 assigns DNR the task of managing water resources to "ensure an adequate supply to meet long-range seasonal requirements for domestic, agricultural, fish and wildlife, recreational, power, navigation, and quality control purposes."

Minnesota Statutes, section 103A.43, also directs the Environmental Quality Board and DNR to coordinate a biennial state assessment of the availability of water to meet the state's long range needs. That is the focus of this report.

The primary goals are to assess how water supply matches up with demand and to consider the implications for planning and policy. The analysis compares present levels of water use, as well as demand projected to the year 2030, with estimates of supply.

The report makes the comparison at the county level, a focus chosen for a number of reasons. Unlike statewide or regional analyses, the county level provides a greater likelihood of understanding where water may not be sufficient to meet the demands people and ecosystems place on it. The county also is a unit that citizens know and understand, making study findings potentially easier to communicate. In an ideal world, one might prefer to center the analysis on hydrologic units, despite the lack of visibility, since the resource in question is water. Unfortunately, our understanding of ground water – the supply source on which so many Minnesotans depend – is limited.

Aquifer boundaries and the volumes of water stored in them are largely unknown, except where county geologic atlases or other special studies have recently been completed. And in most cases throughout the state, the amount of water that can be withdrawn from these reserves on a long term, sustainable basis is unknown.

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[1] Alley, William M. *Tracking U.S. Groundwater: Reserves for the Future?* Environment, pp 10-25, April 2006

The concept of water sustainability is important to consider, as well, since it goes to the heart of Minnesota's goals for managing water, yet remains unclear to many. *Minnesota Statutes*, section 4A.07 defines *sustainable development* as "development that maintains or enhances economic opportunity and community well-being while protecting and restoring the natural environment upon which people and economies depend. Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs." In short, the concept suggests that people need the opportunity to live well while respecting the environment.

The DNR suggests a definition that adapts the concept to water use: "*Sustainable water use* is the use of water to provide for the needs of society, now and in the future, without unacceptable social, economic or environmental consequences."[2] Of course, the meaning of "without unacceptable environmental consequences" must be consistent with "protecting and restoring the natural environment upon which people and economies depend." As the department concludes, "working toward sustainability requires us to monitor and analyze more; to address demands collectively; to use water efficiently; and above all to recognize water's value to our neighborhoods, communities, economy, environment, and continued existence on this planet."[3]

The purpose of this project is to better understand surface- and ground-water availability and the demands we place on water. The goal is to help Minnesotans manage water supplies for the long term future and to better plan for development. The project seeks to do this by:

- Bringing attention to what we know and don't know about renewable water resources
- Helping local and state governments make better-educated decisions about future development and water demand
- Helping decision makers develop policy to manage water on a sustainable basis, and fund its implementation

Water Supply

Because it is difficult to estimate the amount of water available for use in any given area on a long term sustainable basis, the project applied five diverse means to generate estimates. Two of the methods, the high and low regional regression methods that the USGS uses to estimate annual recharge of surficial systems, are considered the high and low watermarks for the amounts that might be safely tapped. The remaining three methods produce results that generally fall within these boundaries, and are presumably closer to the amounts that might be sustainably tapped in a given area.

University watershed systems method. In this method, researchers at the University of Minnesota estimate the amount of water that might be tapped on a sustainable basis based on measurements of discharge from the system; for example, the ground water discharge that provides a stream's low flows. They relate supply characteristics to ecosystems, hydrology, soils and climate data, allowing the project to estimate water available for human needs throughout a region. The approach is based on the principal that water is a single resource, whether it shows up at any point in time as ground water or surface water. This method was used in 2001 to quantify water sustainability in the metropolitan region.[4]

The method examines the temporal and spatial variability of flow across Minnesota's ecoregions (Laurentian Mixed Forest, Eastern Broadleaf Forest and Prairie Parkland) and five hydrogeological subdivisions. It uses a factor analysis of annual rates of stream runoff and minimum monthly flows for each region based upon a lengthy period of record (from 1918 to 1967).

[2] Sustainability of Minnesota's Ground Waters, Department of Natural Resources, 2005
[3] Ibid.

[4] Minnesota Geological Survey 2001

The analysis produces an estimate of the amounts of water that might be safely pumped from ground water based upon the long term minimum monthly flows and the amounts that might be pumped from surface waters based upon long term average annual minus minimum monthly flows. The factor analysis makes it possible to assign sustainable use values to land parcels up-gradient from monitoring sites. The general concept is that a portion of the water that leaves the system is available to be tapped on a sustainable basis; that is, without harming the system or mining its reserves.

Net available precipitation method. This method recognizes that the amount of water ultimately available in a given location is determined by the amount of precipitation in the area minus losses to evapotranspiration, plus a portion of the water imported to the area. If one assumes that the combination of upstream or up-gradient water users and instream ecosystem users fully "appropriate" that imported water, then the sustainable level that users in a downstream area might appropriate is the net available precipitation.

Regional regression recharge methods. The USGS has estimated the average annual surficial recharge of water for all locations in Minnesota.[5] The regional regression recharge method is based on a regression analysis of recharge estimates with climate and soils data from regions within Minnesota. The analysis evaluated a variety of recharge methods, from local to regional scales over a series of temporal scales. The regional regression recharge method relies on a number of different soil and climatic variables, finding strong dependence on precipitation, potential evapotranspiration, and specific yield. It is accepted that recharge estimates can be quantified on local and basin scales. These findings were then scaled up to a regional scale in Minnesota. The result is a characterization of Minnesota's regional recharge values, providing a range of values for each county.

[5] Lorenz and Delin, United States Geological Survey, personal communication, June 2006

Recharge rates are mapped at the scale of soil associations, which can have considerably different recharge characteristics. The product is a high and low recharge value for each county. The high estimation method assumes that a county exhibits the high recharge value across the area, whereas the low estimation method assumes the county exhibits the lowest representative recharge value. Thus, the high and low estimates reflect these ranges.

Fractional precipitation method. Recharge to unconfined aquifers in Minnesota typically equals 20-25 percent of annual average precipitation. This project estimated county-level recharge using 20 percent of average annual precipitation as a simplified analysis to compliment the other more rigorous estimation methods. Precipitation data[6] was downloaded for each weather station in Minnesota, yielding average annual precipitation for the period 1971-2000. Each weather station within a county was averaged to generate a county-wide precipitation value. Twenty percent of this product is taken to be an estimation of recharge.

Recharge, discharge and sustainable yield. There are important distinctions to note in the concepts of natural and induced recharge, discharge and sustainable yield. They are worth mentioning here, since they describe significant limitations to supply estimation techniques. All but the University method for estimating sustainable supplies use recharge as a surrogate for sustainable supplies.

In a natural system over time, recharge equals discharge, where recharge is the water coming into the system and discharge is the water leaving it. This makes sense, since water would otherwise build up or drain out of the system.

However, if people were to remove the water coming into the system, they would risk depleting the discharge from the system. A system's discharge provides the flow in streams

[6] Midwest Regional Climate Center, http://mcc.sws.uiuc.edu/climate_midwest/maps/mn_mapselector.htm

when it has not rained in weeks. To eliminate such flows would damage the environment Minnesotans so value.

The concept of sustainable yield suggests that over time, the amount of water that can be safely pumped from an aquifer is equal to the amount of new recharge that is induced by the pumping. This preserves the system's discharge based upon the original recharge, which in turn protects surface water resources.

Since it is so difficult to distinguish between natural and induced recharge, these concepts remain largely theoretical. But, the lesson is to be wary of using recharge, alone, as a measure of the water that can be safely withdrawn from the system, unless other steps are built in to protect surface features and ecosystem functions. Consequently, all but the University method for estimating sustainable supplies should, in this way at least, be thought to overestimate the supply available.

Ground Water Resources Vary Across the State of Minnesota

Ground water is everywhere beneath Minnesota's land surface, but it is not necessarily *available for use* everywhere. The distribution of aquifers in the state is uneven. The varying types and layers of sediment and rock under the land surface in an area determine whether any aquifers are present from which to pump ground water. The types of sediment and rock also determine whether an aquifer is capable of supporting large withdrawals or only able to support limited use.

Ground water recharge

Ground water recharge is defined by the USGS as "the process by which water crosses the water table and enters surficial, unconfined aquifers." Recharge to confined aquifers occurs by leakage through the overlying confining layers, though at much smaller rates than recharge to surficial aquifers. Recharge occurs across the entire landscape, but at varying rates depending on soils, precipitation, and other factors. In Minnesota, much of the ground water recharged to aquifers flows through and ends up in streams, lakes, and wetlands.

Minnesota Rules 6115.0630 subpart 12

"Protected flow" is defined as the amount of water required in the watercourse to accommodate instream needs such as water-based recreation, navigation, aesthetics, fish and wildlife habitat, water quality, and needs by downstream higher priority users located in reasonable proximity to the site of appropriation.

Source: Department of Natural Resources

Water Demand

The project evaluated a number of approaches to estimating future demand for water. The "gold standard," a proprietary software program, was considered but rejected on the advice of the Metropolitan Council, which has used the program and concluded its data intensity did not justify the results for the analysis at hand. In fact, analysts agreed that the key factors of water demand might be effectively represented by separate algorithms. This was attempted early on, but found to be unworkable owing to data compatibility issues.[7] After much analysis, the project chose to base estimations of future water demand on the per capita water use experience of Minnesotans by county and population extrapolations made by the State Demographer.

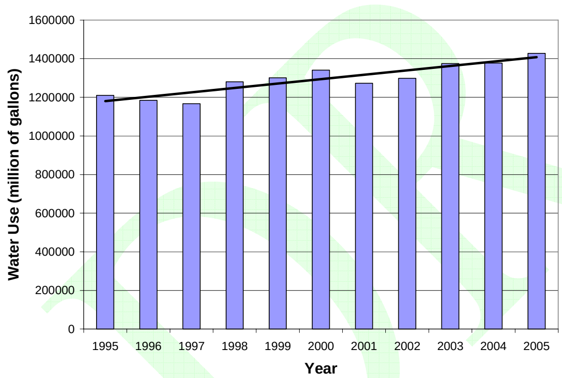
Estimates of future water demand were developed based upon average reported county

[7] DNR organizes its business water use data by different categories than those used by the U.S. Department of Commerce, so that state and federal labor projections, considered the best predictor of future business water demand, could not be used.

per capita water use for the period of 1995 – 2005, added to estimates of unpermitted use drawn from DNR and MDH databases. While per capita use increases during this 11 year period, the project assumes that such increases in the future will be negated by expected efficiencies and that per capita use will remain constant to the year 2030. Figure 1 shows the statewide water use experience for 1995 – 2005, during which total statewide use increased 18 percent, while per capita use increased by 6 percent. (A full page map of Figure 1 is located in Appendix E as Figure 6.)

Because the average per capita use over the decade integrates behaviors over a range of climatic conditions, the project used that statistic to calculate a climate-normalized use estimate for each county in 2005. These estimates then provided the base for demand projections to 2030. This approach avoids the influence of specific weather conditions in 2005 on water use in that year.

Figure 1. Minnesota Annual Water Use Trends (1995-2005)



Another set of demand adjustments was made to set up an "apples to apples" comparison with supply estimates. One adjustment was to identify and remove appropriations from water imported into a county. Since the project's estimates of sustainable supplies are based on the water generated by rainfall within each county, appropriations made from waters imported into a county were not judged appropriate to include in the analysis. For example, appropriations by Minneapolis from the Mississippi River would not be counted in the Hennepin County assessment, since Mississippi River waters are not included in estimates of the county's sustainable supplies.[8]

The project defines surface waters that originate outside a county as *imported* waters. The extent to which a source of water might be imported was evaluated when the affected uses exceed 50 million gallons per year. In such cases, use totals were reduced to the extent that their water source originated outside a county.

When assessing how a county's water use compares to its sustainable supply of water, it also is important to take into account whether the water is consumed. If an appropriation is returned to a surface water source in close proximity to its intake and is available for reuse, the use is non-consumptive. The appropriation of ground water is generally consumptive regardless of how it is used, because ground water is generally not discharged back to its source aquifer.

Steam-power cooling is an example of a largely non-consumptive water use. The project assumed that such cooling consumes 2 percent of an appropriation[9], with 98 percent returned for use by other activities.

Other assumptions and sources of error in this exercise should be noted: a) water use information is often approximated where reported values are lacking; b) unpermitted use in Minnesota is not precisely known, but is instead estimated; c) future water use was estimated based on experiences of the years 1995-2005, and may not reflect use under extreme conditions; and d) the location, extent and renewability of ground water resources is largely unknown.

An additional assessment was done that compared the total permitted water volume to

[8] In future years, the authors would like to include such uses, but this edition of the project was unable to develop sustainability estimates and an accounting method for such imported waters.

[9] "Measuring and Estimating Consumptive Use of the Great Lakes Water", Great Lakes Commission, 2003.

supply. Permitted values are generally greater than reported use values because they represent the maximum quantity permittees may use. Thus, permitted volumes were totaled for each county and compared to supplies to provide another perspective in the supply – demand assessment. These estimates were not projected to 2030, however, since permitted amounts generally include a future component.

Comparison of Supply and Demand

Comparisons of the water Minnesotans used in the year 2005, adjusted as described above, the water permitted for use in 2005, and the water we expect Minnesotans will use in 2030 were made to the supplies estimated to be sustainably available.

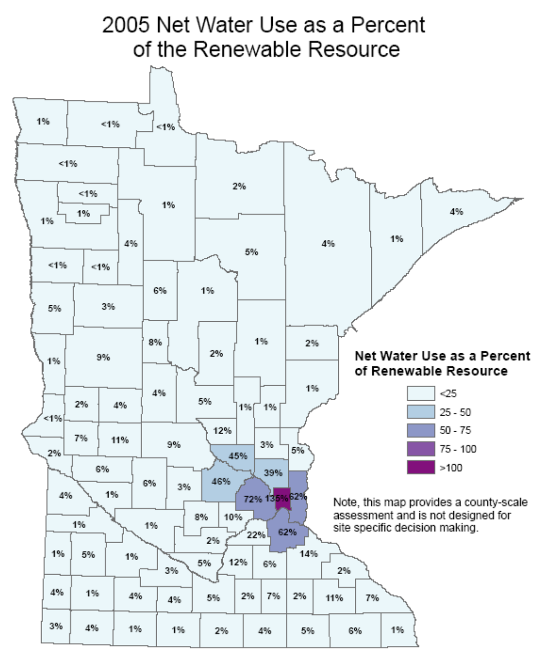
A note on nomenclature is appropriate here. If upon comparison, the water use in a given county is greater than the amount of water estimated to be sustainably available, then that county is labeled “over appropriated.” This means only that more water is demanded from a county’s “home grown” supply than may be available over the long term. This may mean that water users are mining a county’s waters – i.e. pumping reserves faster than they can be replaced – or drawing upon reserves that one way or another are imported from another county. It might also mean that mined ground waters are, or will be, drawing on surface waters at a greater pace than usual, potentially drawing down low flows, lake levels or wetlands. The uncertainties and assumptions of the assessment notwithstanding, a county in this position might be well advised to manage its water carefully.

Results

In evaluating the status of water consumption in Minnesota, the project compared the amount of water used in 2005 and the projected water use in 2030 to the amount of water that could be withdrawn on a long term, sustainable basis. The results were reported as the percentage of renewable resource being used.

If the water use documented in 2005 or projected in 2030 were greater than the amount of water estimated to be sustainably available, that county would be considered “over appropriated.” This would mean that more water was demanded than could be made safely available over the long term. Another way of saying this is if the rate of water use were to be greater than the renewable resource, the county would be considered over appropriated.
The year 2005 was used as the baseline of the assessment since it is the most recent year with a complete data set. The findings of this comparison are listed as a percentage of the renewable resource that is currently being used. Figure 2 reports the 2005 results and is entitled “net” because it reports the results after accounting for imported water and non-consumptive use.

Figure 2

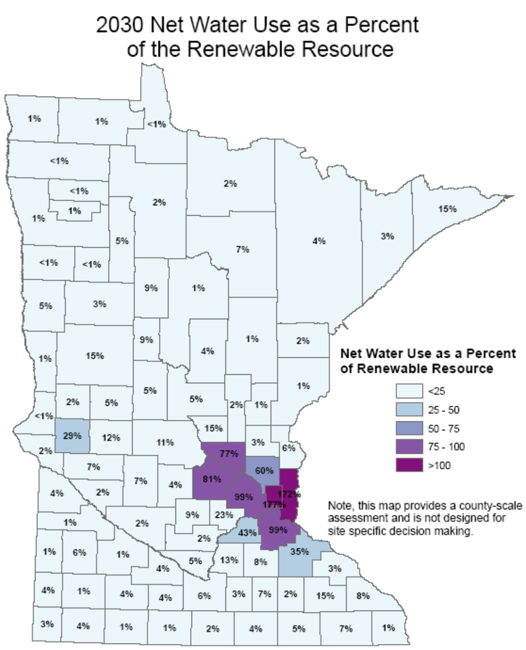


In 2005, only one county appeared to use more than 100 percent of its homegrown renewable water resource – Ramsey County reporting 135 percent. This may suggest that Ramsey, a small county with a large population base, draws on the water resources of adjoining counties.

In the seven county metropolitan area, the percent of renewable resources ranged from 10 percent in Carver County to 135 percent in Ramsey County. In Greater Minnesota, the range was from less than 1 percent in seven counties to 46 percent in Wright County. There were three counties between 50 and 75 percent and another three between 25 and 50 percent. The same counties showing higher percents of use in 2005 also showed higher percents in 2030.

A full page map of Figure 2 is located in Appendix E as Figure 7. Figure 8 in Appendix E, 2005 Gross Water Use as a Percent of the Renewable Resource, shows this comparison before imported waters and non-consumptive use have been removed.

Figure 3



Future water use was estimated for 2030 based on population extrapolations made by the State Demographer and the Metropolitan Council. The findings, shown in Figure 3, were listed as a percent of the renewable resource expected to be allocated.

In 2030, Ramsey County continued to be above 100 percent, with Washington County's growth also pushing its estimated use above renewable resource levels (177 and 172 percent, respectively). Dakota and Hennepin counties each reported in at 99 percent.

In the seven county metropolitan area, the 2030 percent of renewable resources ranged from 23 percent in Carver County to 177 percent in Ramsey County, while in Greater Minnesota the range was from less than 1 percent in six counties to 81 percent in Wright County. Four counties ranged between 75 and 100 percent, one county between 50 and 75 percent, and another four between 25 and 50 percent.

A full page map of Figure 3 is located in Appendix E as Figure 9. Figure 10 in Appendix E, 2030 Gross Water Use as a Percent of the Renewable Resource, shows this comparison before imported waters and non-consumptive use have been removed.

Conclusions and Recommendations

To many, the results of this project, although preliminary in nature, are surprising. How could a county possibly be pumping more water today than the system might tolerate long term? How could several others already be using a high percentage of their renewable supplies? And, on the other hand, how could so many counties where water seems in short supply, show up as comfortably within their capacity?

While the assessment and conclusions do not account for surface water coming into a county or even for ground water that may, in effect, be drawn from a neighboring county, they signal an early caution to those concerned about the ability of water resources to sustain development.

Some ground water experts are not surprised by the findings. They note that the vast reserves of ground water underneath the Twin Cities metropolitan area were deposited thousands of years ago, subsequently covered and largely blocked from direct access to recharge waters. To what extent is water in these systems largely a one-time opportunity? The answer is unclear.

This uncertainty makes the call for careful and cautious allocation of water from buried aquifers anywhere in the state prudent. It makes better understanding of where ground water can be found, how much fills each aquifer, how vulnerable it is to contamination, and how much can be sustainably and safely tapped an obvious state priority. It also makes better knowledge of the connection to surface waters important for a number of reasons, including the contribution ground water makes to surface flows – low flows are, in fact, ground water discharges – and how these contributions may be put at risk by ground water use; the need to consider conjunctive use of surface and ground waters; and the influence ground water may have on the quality of surface waters, and vice versa.

1. A water-rich state for now. The analysis documents that although Minnesota might still be considered water rich, the label may not fit as well as we once believed. Not surprisingly, the greater metropolitan area makes the greatest demand on its renewable water resources, but care still must be taken with how local and state officials plan for demand and allocate use throughout the state.

Table 1. Priority-setting factors

1. Current percent of renewable resource in use
2. Projected percent of renewable resource use
3. Likelihood of large water user coming in
4. Direction and rate of community growth
5. Availability of known, alternative sources
6. Seasonality of demand
7. Seasonality of supplies
8. History of water well level changes
9. History of drought permit suspensions
10. Ecosystem needs

2. An element of priority setting. The degree to which a county uses its renewable resources, today and in the future, should help inform state monitoring and research priorities, whether they involve the addition of monitoring wells or the commitment to a ground water investigation. Table 1 suggests 10 factors that the state might employ in setting priorities.

3. A screening tool for local planning. The project provides information about renewable water supplies at the county level. While the numbers represent county-wide totals, they can be converted into smaller units to illustrate the potential effect of a development on a county's supplies. Table 2 shows the renewable waters estimated to exist in the hypothetical median Minnesota county.

Table 2. Water use in a typical county

So, what does an average Minnesota county look like? Using median values, we find the middle-of-the-road county to be characterized by:

- An area of 716 square miles
- Renewable water resource of 54,722 million gallons a year
- Gross water use of 2,111 MGY
- Net water use (after removing imported waters and non-consumptive water use) of 1,823 MGY
- 2005 use at 3.3% of the county's renewable water resource

What happens if we add a high water-using industry to the county? Adding an industry that uses 750 million gallons of water per year would be equivalent to:

- 1.4% of the county's supply
- 36% of the county's current gross water use (41% of the net use)
- 10 square miles of renewable water

This summary assumes that the water supply is evenly distributed over the county, which is not realistic. However, it does provide a basic tool for putting a proposed new water use in perspective.

The table illustrates how the renewable water resource estimate can be converted into a land-based rate and used to describe the relative commitment a community would make in granting a particular new use or accommodating projected population growth. For example, location of a facility using 750 million gallons in the median county would take 1.4 percent of the county's renewable water resource and the hypothetical equivalent of 10 square miles of the renewable resource.

4. Improved data collection and management. While a technical and thus perhaps less attractive subject, the collection and management of data within the water appropriation permit program is critical to the assessment of water demand in Minnesota. The rigor of this and future biennial assessments hinges partially on permit reporting and enforcement. Despite staff cutbacks required by budget shortfalls – which have not helped the program – and despite a major drought, staff made significant and time-consuming contributions to the project.

One issue that remains (while nothing unique to this particular program) is that databases tend to be designed and managed to inform the originating program and not to enable easy use in a broader policy or management context. In this case, for example, the particular source of the supply was not always identified, the status of permits (active or inactive) was not always clear, and some permits did not have a continuous history of reporting. In addition, the categories employed to characterize various uses did not correspond with those used by the federal government. This prevented the project from using employment projections to estimate future water demand in the business sector.

Finally, the program may be able to streamline data entry and free up staff for database assessment by employing software that enables water users to enter their reports directly online.

5. Planning for use of surface and ground water. As demand for limited supplies grows, the conjunctive use of surface and ground waters will become more common place. The 2030 assessment should help water and land use planners identify where conjunctive use may need to be at the top of the list for consideration.

In addition, state law, notwithstanding, federal case law requires that a state demonstrate it will need a particular supply of water within 50 years before it can deny a party in another state the right to appropriate it. Is Minnesota in a good position to meet that test? This project is a step toward that end.

6. Research needed to move forward. Research needs to improve the state's understanding of Minnesota's renewable water resources including:

- Defining the location and vulnerability of ground water resources
- Understanding how much water is renewable; that is, how much can be taken for use on a long-term, sustainable basis without harming ecosystems
- Investigating new means to quantify sustainable supply or ways to build upon existing supply methods
- Understanding the impacts of drainage or other land use practices on rates of recharge and means to quantify the impacts
- Characterizing the interactions of surface and ground waters, including the implications for water quality and quantity
- Quantifying the fluctuating amounts of water that ecosystems need to flourish

7. Lessons for the second edition. The next assessment of supply and demand should:

- Fully integrate the assessment of imported waters
- Evaluate the current effect and future risk of water quality degradation
- Make assessments on a seasonal or monthly basis, as well as annually
- Explicitly introduce ecosystem needs for water
- Conduct analyses on the sub-county level where information about supply and demand is sufficient
- Develop a sub-county level tool or model for state and local planners

Lastly, given the complexity of such analyses and the range of people likely to be interested in their outcomes, the next edition should use both science- and citizens-based advisory committees to gain ideas and input.

Appendix A

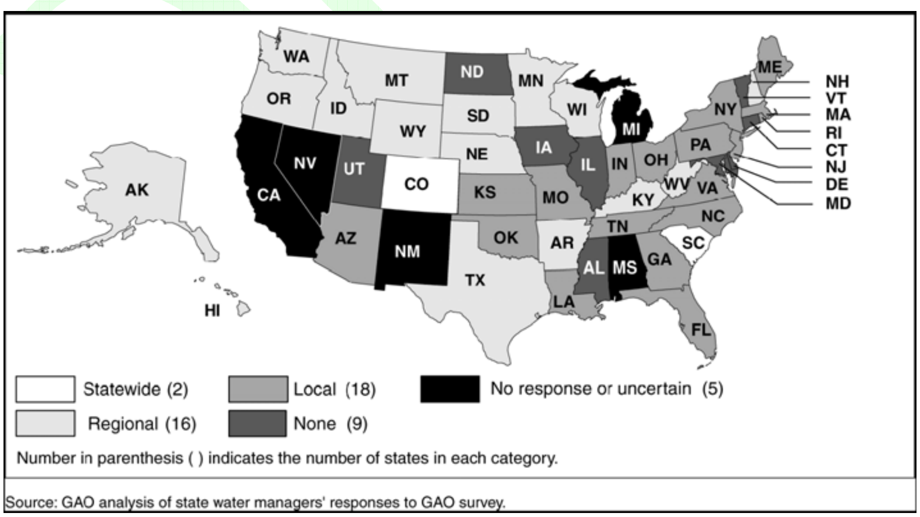
A National Issue

National water availability and use has not been comprehensively assessed in 25 years, but current trends indicate that demands on the nation's supplies are growing. In particular, the nation's capacity for storing surface water is limited and ground water is being depleted. At the same time, growing population and pressures to keep water instream for fisheries and the environment place new demands on the freshwater supply. The potential effects of climate change also create uncertainty about future water availability and use.

State water managers expect freshwater shortages in the near future, and the consequences may be severe. Even under normal conditions, water managers in 36 states anticipate shortages in localities, regions, or statewide in the next 10 years. Drought conditions will exacerbate shortage impacts. When water shortages occur, economic impacts to sectors such as agriculture can be in the billions of dollars. Water shortages also harm the environment.

Source: *Freshwater Supply: States' View of How Federal Agencies Could Help Them Meet the Challenges of Expected Shortages* GAO-03-514 July 9, 2003

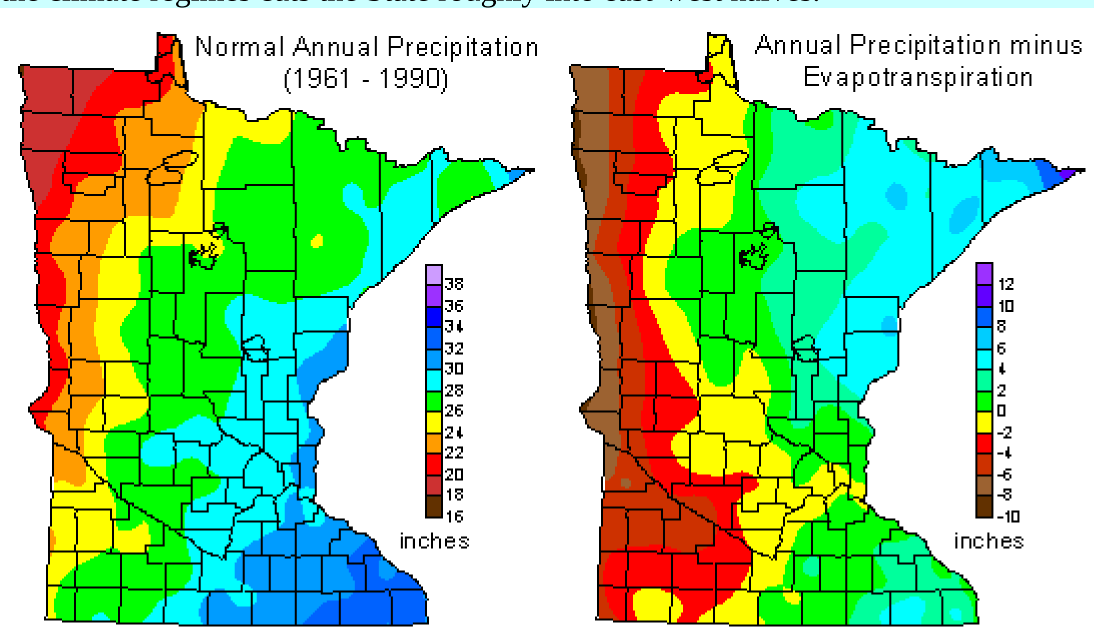
Figure 4. Extent of State Shortages Likely over the Next Decade under Average Water Conditions



Appendix B

Figure 5. Precipitation and Evapotranspiration in Minnesota

Due to its position in the continent, Minnesota is located on the boundary between the semi-humid climate regime of the eastern U.S., and the semi-arid regime to the west. Semi-humid climates are areas where average annual precipitation exceeds average annual evapotranspiration, leading to a net surplus of water. In semi-arid areas, evapotranspiration exceeds precipitation on average, creating a water deficit. In Minnesota, the boundary between the climate regimes cuts the State roughly into east-west halves.



Source: http://www.dnr.state.mn.us/climate/water_availability.html

Appendix C

Challenges in Assessing Water Demand

Assessing water demand on a county basis is a challenging proposition, but through the DNR permit process, as well as the MDH municipal supply records, a log of historic use is available that documents the volume of consumption and water use trends. These numbers form the base of current demand totals, with the challenge being to extrapolate these values to future consumption. Some specific questions to be addressed by a water sustainability analysis include:

- How will fluctuations in weather patterns impact water use?
- How will per capita water use change in the future?
- In which counties will high water-using industries expand?
- What will be the impact of improved water technologies and the EPA's water efficiency initiative?
- What impact might ethanol plants have on the water landscape?
- Do the current DNR and MDH reporting requirements provide the level of detail necessary for adequately quantifying water use?
- Can improvements be made to state information systems, such as reconciling use categories with those used by the federal government and adding source detail to databases?
- How can we accurately document unpermitted use in Minnesota, and is it a significant contribution not only to water use but to consumption?
- What is the long-term impact of expanded water treatment facilities discharging to surface waters versus private systems recharging onsite?
- How can we better quantify the fluctuating amounts of water that ecosystems need to flourish?

Limitations in Quantifying Supply

Water is taken from both ground- and surface-water sources in Minnesota. However, aquifers have not been well defined, and the available supplies held within them are not well understood. More research is needed in this area and in evaluating how aquifers respond to withdrawal stress on the system (e.g. possibly through increased rates of recharge).

Additionally, ground water that is consumed is discharged to surface water features. Anything that can be done to maximize use of surface waters and minimize ground water use will help preserve ground water reserves. Questions that need to be addressed include:

- How do we accurately determine sustainable recharge?
- How might we better define the extent of ground water aquifers in Minnesota?
- How can we best preserve surface water features that are sustained by ground water sources?
- What impact does ground water quality have on quantity?
- What effect does ground water have on surface water quality?
- Neither ground- nor surface-water sources follow county boundaries; thus, how can we best assess these features on a county basis?
- How does recharge in a dynamic aquifer system respond to water withdrawals?
- What is the impact of drawdown in one county on the neighboring areas?
- How might consumption better be quantified in assessing permit approvals?

Appendix D

Understanding Key Terms

Common terms used to describe water quantity and use need definition so that we all understand statements that are made and the relationships between the several concepts.

Starting with "renewable water supply," a term frequently used to describe our water supply without consideration of what it implies, the Earth has only so much water of which most is saline. The "renewable" concept can apply to the cycling of water that happens with rain and snow falling on the land, running into lakes and rivers, soaking into the ground to become ground water, and then being restored to the atmosphere through evaporation to start the cycle all over again. So for a given locality, the "renewable water supply" depends on the precipitation that falls on it; the amount that collects to be considered "water supply" is what's left over after the direct evaporation from the land and after the plants intercept, take up and release the amount they need. So the "renewable water supply" can be roughly defined as precipitation minus evapotranspiration.

Obviously that amount is a maximum of water in circulation; only a portion of that amount can be used without extreme consequences to the natural water resources that we value highly in Minnesota. "Water availability" is another term that is often used interchangeably with "renewable water supply." I believe most of us mean that the water has accumulated in a quantity that we deem sufficient for some of it to be used without accounting for the consequences. In other words, the presence of water in a stream or an aquifer is a measure of "water availability." The supply "available for use" is usually determined through a regulatory evaluation of the consequences of its use after accounting for the needs of the environment for instream flows, recreation, navigation, hydropower, and a host of other uses including other withdrawal uses already permitted.

Finally there is the "sustainable water supply" which is based on an assessment of those consequences of withdrawals or diversions and the desires of the populace. The question is truly "what do you want to sustain?" If the answer is to maintain the wetlands, lakes, and streams at a relatively high level, less ground water can be used. If society is willing to compromise and allow some lowering of these levels, more water can be withdrawn. And, should climate change result in a change in the precipitation, the whole cycle will need to be reevaluated.

Ground Water Information Needs

Technical

- Complete geologic mapping of aquifers or potential aquifers at county scale using modern tools
- Compile up-to-date regional and statewide aquifer maps
- Accelerate aquifer testing to determine aquifer characteristics
- Further analyze connections between aquifers and lakes, wetlands, streams or springs
- Expand the use of estimation techniques such as modeling to evaluate options for proposed ground water development

Planning

- Emphasize that water has high value and is a scarce resource
- Broaden conservation practices beyond major cities to statewide and to all regulated uses
- Work with state agencies, utilities, communities, and industry to encourage use of water-efficient appliances
- Continue subregional and regional water supply planning and expand participation to more stakeholders
- Develop and implement a process for designating and managing areas where ground water supplies are limited and water levels are declining

Monitoring

- Restore measurement frequency and expand the observation well network to develop water-level data for aquifers in areas of increasing ground water demand
- Capture and analyze ground water level data and pumpage from permittees
- Construct new ground water level monitoring wells in selected locations to enhance the capability to anticipate needed information and monitoring
- Expand and coordinate precipitation, stream flow, and lake level monitoring to fully examine the impacts of actual or potential ground water withdrawals
- Analyze and report information by aquifer including an evaluation of the impacts of withdrawals

Regulation

- Examine ground and surface water levels and flows for trends in conjunction with water use statistics
- Determine whether adequate authority exists for the DNR Commissioner to establish water resources management areas within which withdrawals may be limited and allocated according to a plan to be developed through a participatory process involving stakeholders
- Adjust permitted pumping rates or withdrawal amounts within water resource management areas when needed to meet the goals determined by stakeholders in their planning effort
- Work with the regulated community to gain these mutual understandings:

1. There is no absolute volume of water that they can be guaranteed
2. Conditions will vary and water use adjustments may be required
3. Flexibility in sources, design and operation must be built into any water use installation to reduce risk

Source: *Sustainability of Minnesota's Ground Water: A Statement of Issues and Needs*, Division of Waters, Department of Natural Resources, St. Paul, Minnesota 2005.

Using Thresholds to Limit Decline of Artesian Aquifer Water Levels

In some Minnesota locations, high volume pumping has resulted in long term declines in water levels. In the past several years, the DNR has attempted to prevent excessive pumping and water level drawdowns in confined aquifers by developing *threshold elevations* for new appropriators in aquifers that have the potential for long-term declines in water levels. The establishment of threshold elevations is meant to limit or prevent the mining of water from a confined aquifer.

The threshold elevation approach is intended to allow appropriation from an aquifer, but also provide a buffer to protect its structural integrity. As currently developed, an aquifer will have two threshold elevations: the first, set at 50 percent of the pre-pumping available head, is meant to act as a warning or trigger level to appropriators. In general, this 50 percent level should not be reached until the well has been pumped for some time. If drawdowns reach the 50 percent level, appropriators should be increasing the frequency of water level monitoring, actively investigating alternate water supplies, implementing more aggressive water conservation measures and possibly cutting back their appropriation rates.

The second threshold elevation is set at an elevation equivalent to 25 percent of the pre-pumping available head. When the 25 percent threshold is reached, appropriations from the aquifer should cease altogether or pumping minimized to such a degree that water levels stop declining. Any or all of these recommended actions should be included in a permit as additional conditions.

The threshold elevation approach has been applied successfully at several sites in Minnesota in managing confined aquifer water levels.

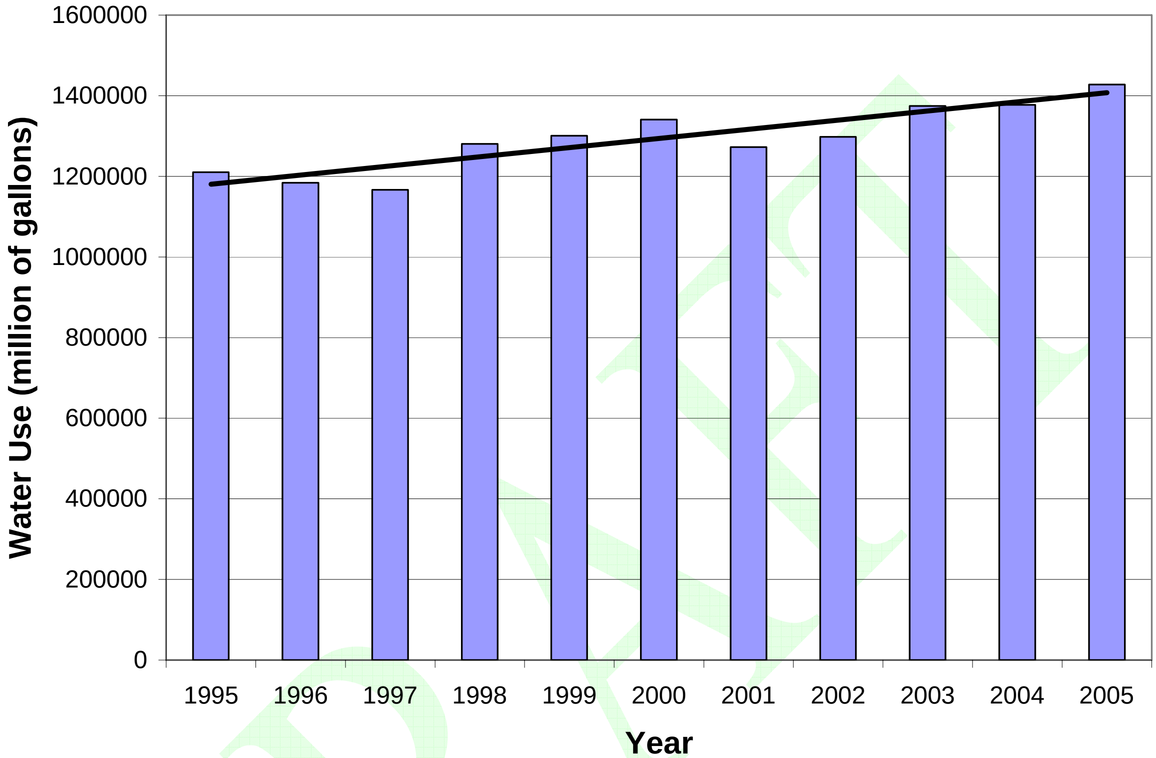
Source: Department of Natural Resources

Appendix E

Water Use as a Percent of Minnesota's Renewable Water Resource

Figure 6	Annual Water Use Trends (1995 – 2005)
Figure 7	2005 Net Water Use
Figure 8	2005 Gross Water Use
Figure 9	2030 Net Water Use
Figure 10	2030 Gross Water Use
Figure 11	2005 Net Permitted Water Use
Figure 12	2005 Gross Permitted Water Use

Figure 6. Minnesota Annual Water Use Trends (1995-2005)



During the period examined, 1995-2005, per capita water use in Minnesota showed an increase of 6%. This increased rate of consumption, coupled with a population increase of 26% by 2030 demonstrates the need for planning and assessments, such as this.

Figure 7

2005 Net Water Use as a Percent of the Renewable Resource

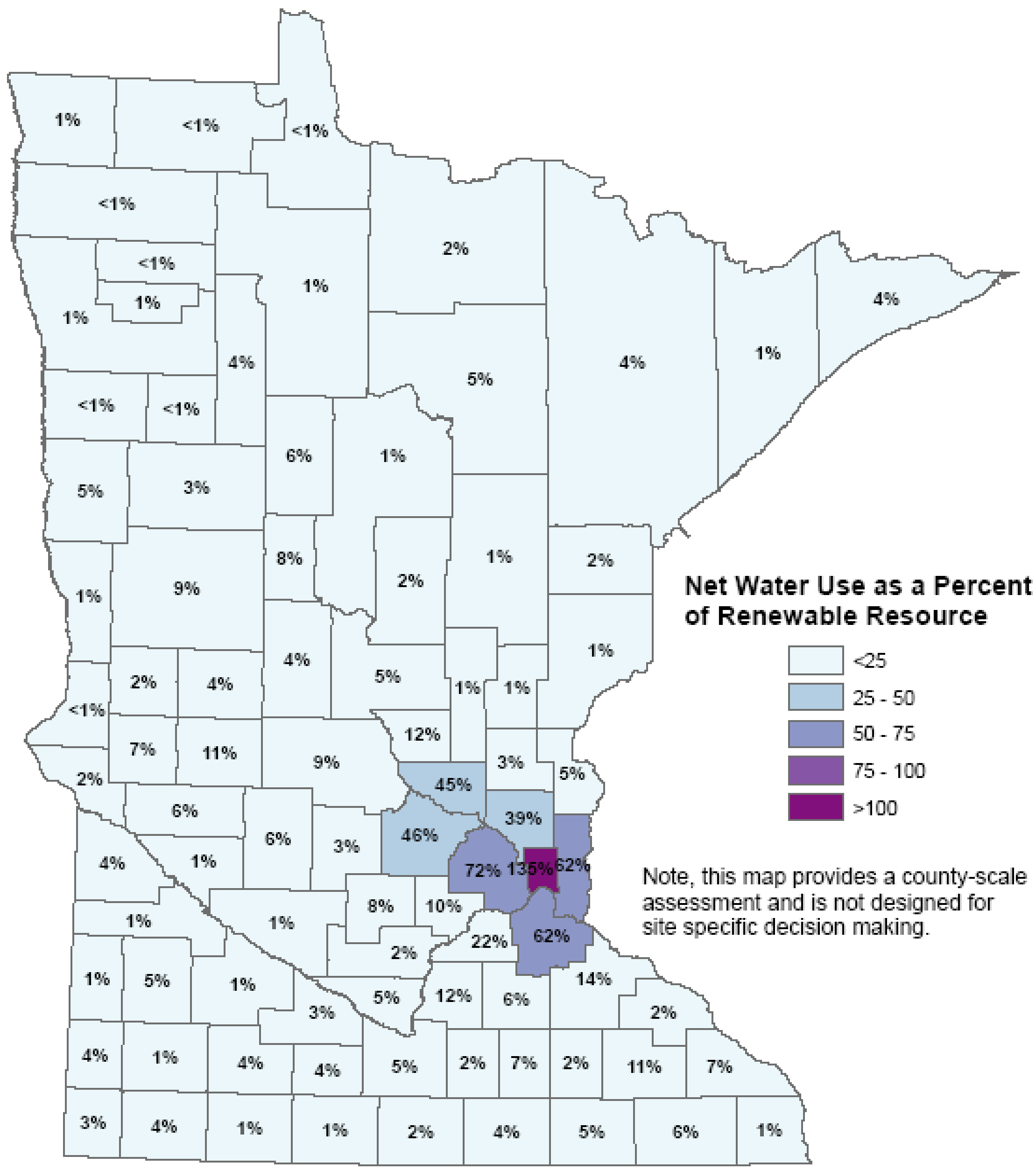


Figure 8

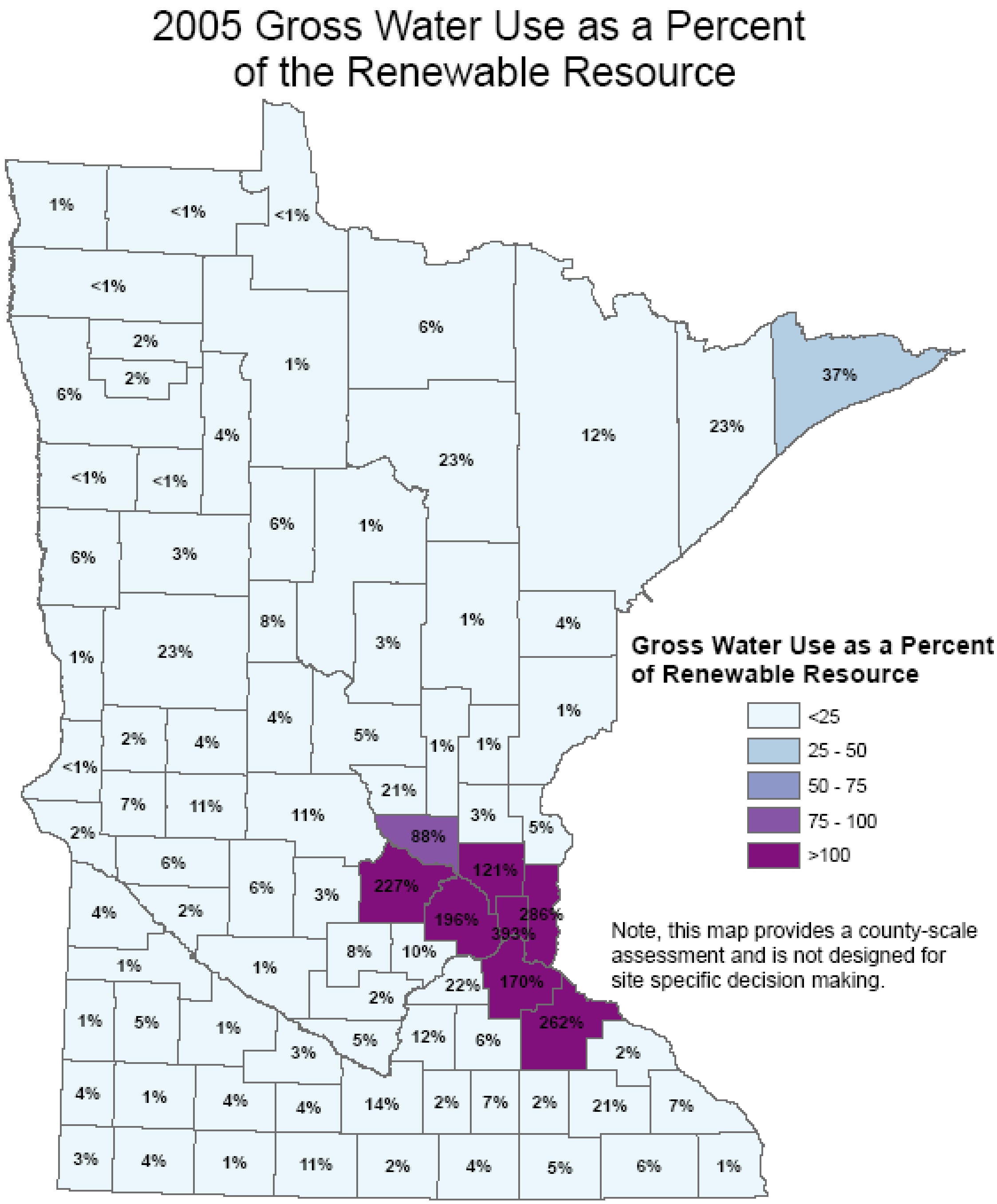

2005 Gross Water Use as a Percent
of the Renewable Resource
1%
<1%
<1%
<1%
6%
2%
2%
1%
6%
37%
4%
12%
23%
23%
<1%
<1%
6%
1%
6%
3%
8%
1%
4%
3%
1%
23%
4%
1%
2%
4%
5%
1%
1%
<1%
21%
7%
11%
11%
3%
5%
2%
88%
6%
6%
3%
227%
121%
4%
2%
196%
286%
393%
8%
10%
1%
1%
22%
170%
2%
1%
5%
1%
262%
3%
5%
12%
6%
2%
4%
1%
4%
4%
14%
2%
7%
2%
21%
7%
3%
4%
1%
11%
2%
4%
5%
6%
1%
Gross Water Use as a Percent
of Renewable Resource
<25
25 - 50
50 - 75
75 - 100
>100
Note, this map provides a county-scale
assessment and is not designed for
site specific decision making.

Figure 9

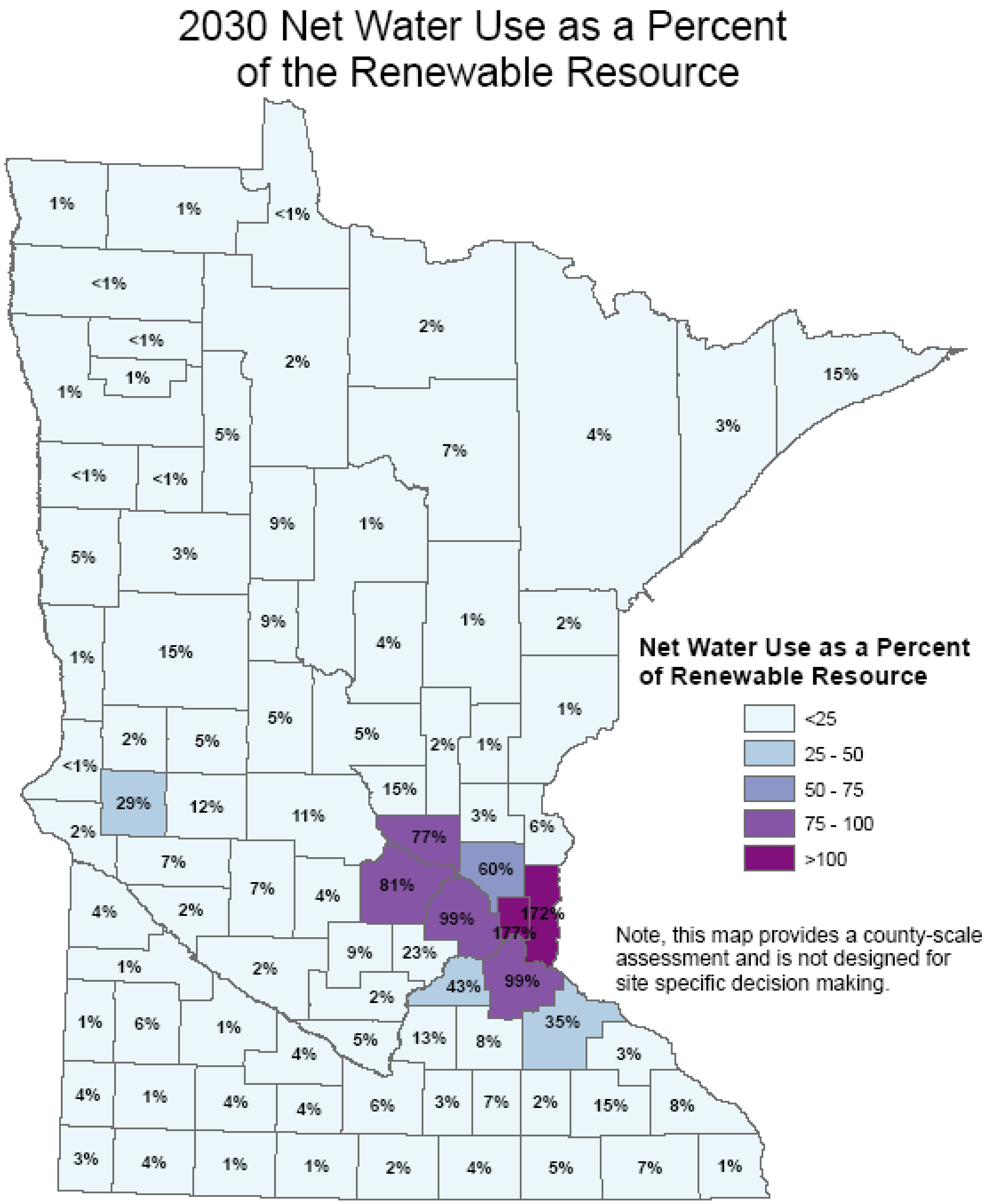

2030 Net Water Use as a Percent of the Renewable Resource
Net Water Use as a Percent of Renewable Resource
<25
25 - 50
50 - 75
75 - 100
>100
Note, this map provides a county-scale assessment and is not designed for site specific decision making.

Figure 10

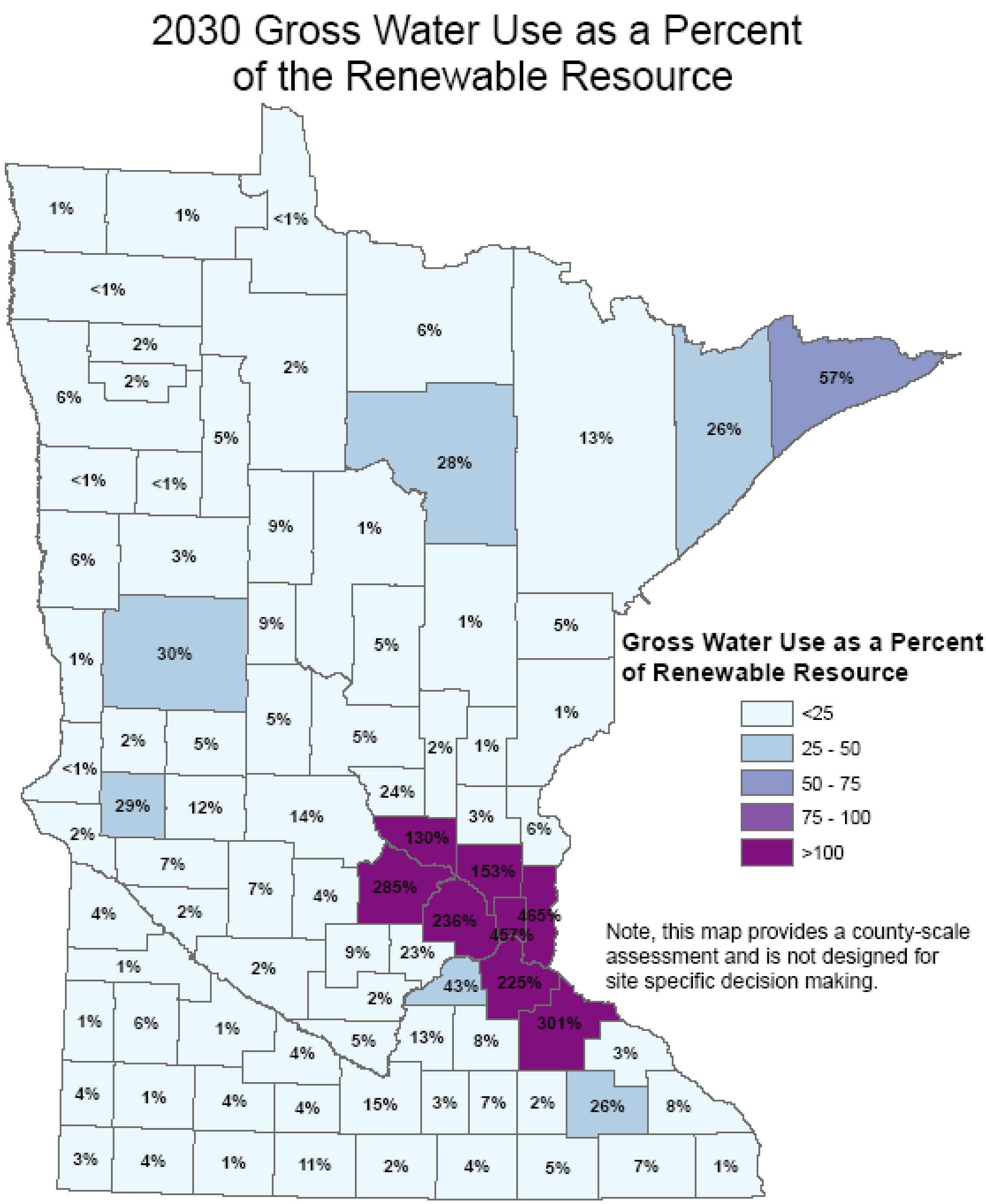

2030 Gross Water Use as a Percent
of the Renewable Resource
Gross Water Use as a Percent
of Renewable Resource
<25
25 - 50
50 - 75
75 - 100
>100
Note, this map provides a county-scale assessment and is not designed for site specific decision making.

Figure 11

Net Permitted Water Volume as a Percent of the Renewable Resource

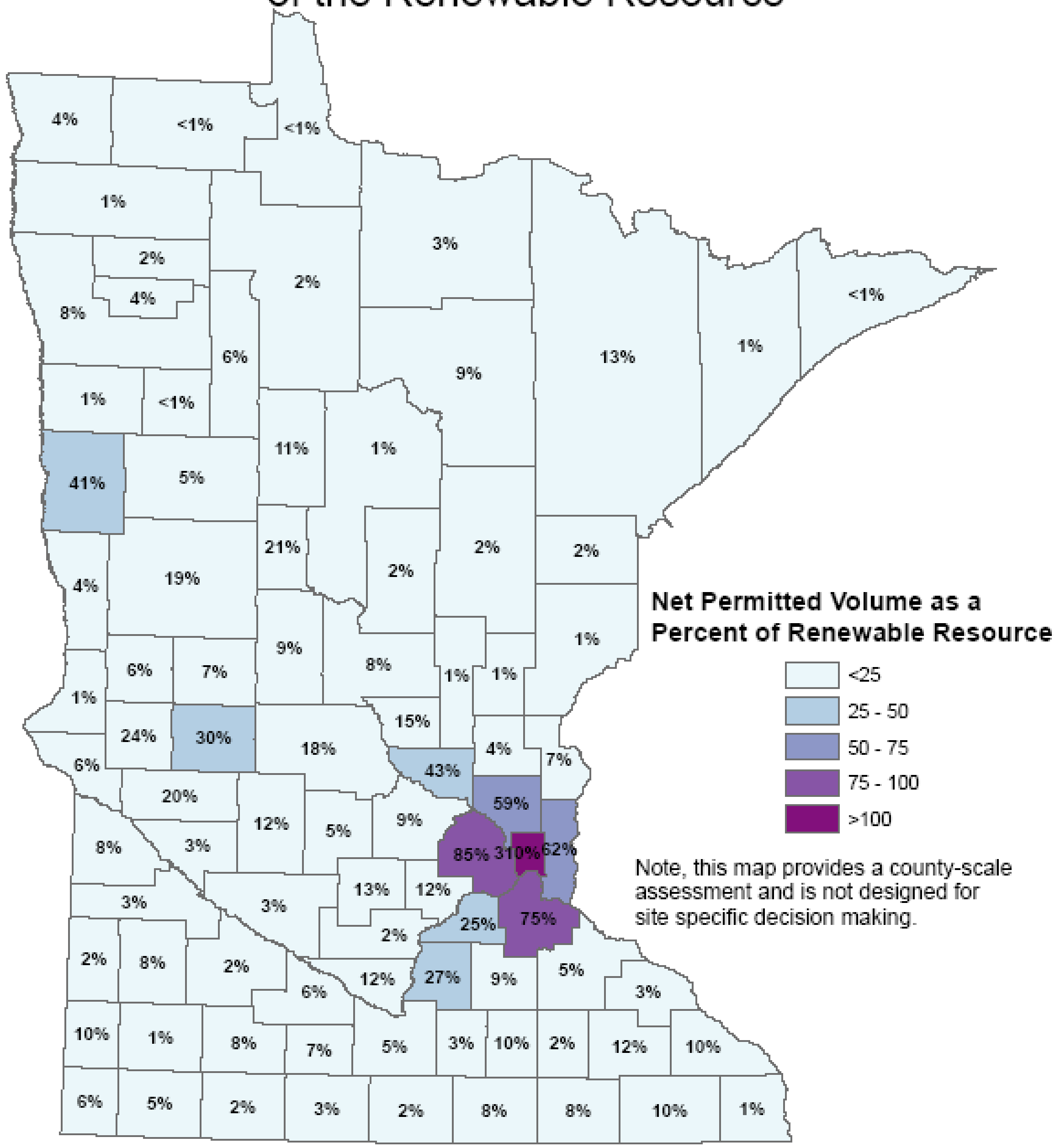


Figure 12

Gross Permitted Water Volume as a Percent of the Renewable Water Resource