TWIN CITIES METROPOLITAN AREA MASTER WATER SUPPLY PLAN

SEPTEMBER 2015

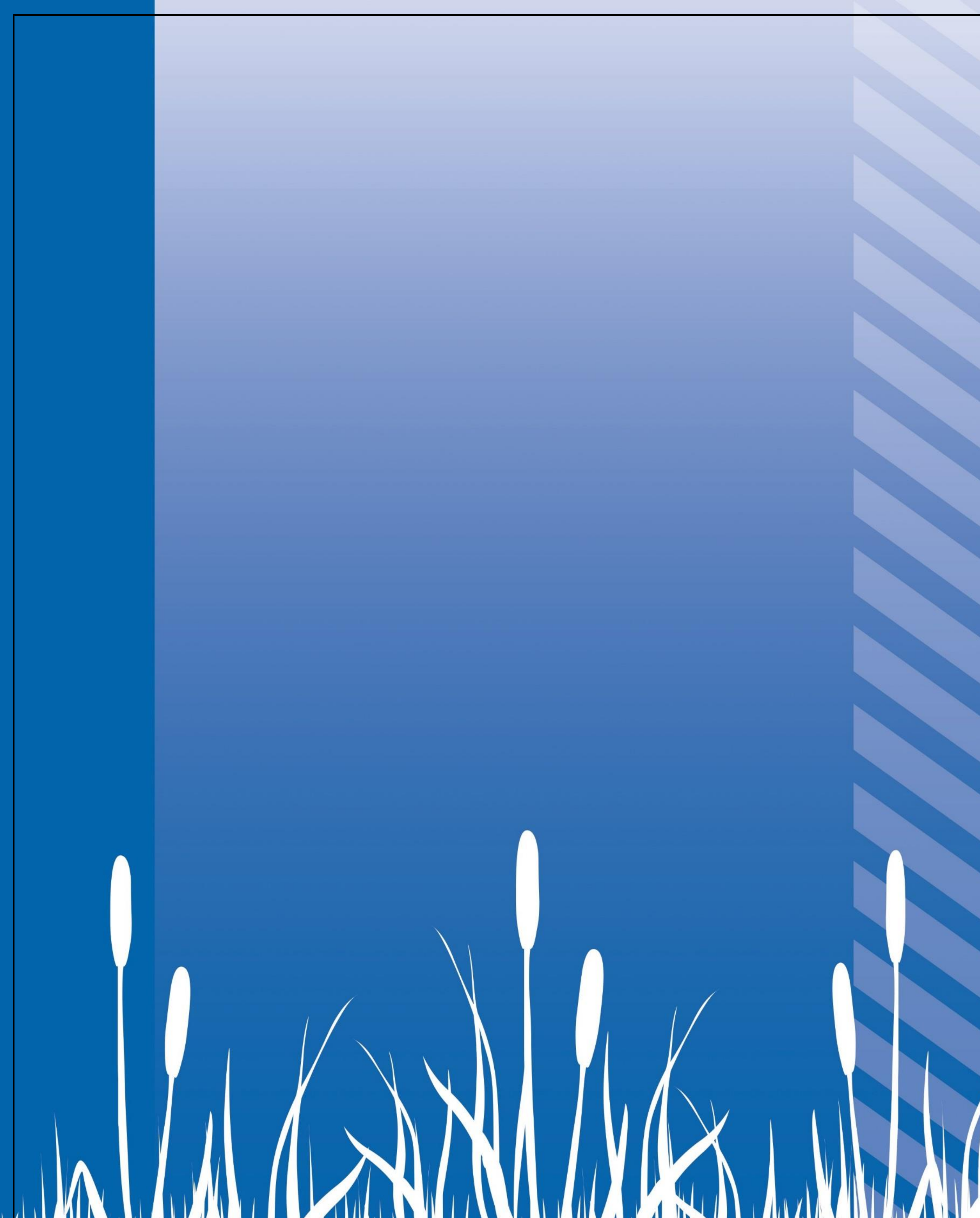


Table of Contents

This page intentionally left blank

1 Master Water Supply Plan Overview

The Twin Cities metropolitan area is endowed with a relative abundance of high-quality groundwater and surface water, which support over half of Minnesota's population and a thriving economy. Three major rivers, vast aquifers, and 950 lakes make us the envy of urban areas the world over.

But the region's water supplies are not limitless, and human activities can affect the quality and quantity of our water. Population growth and expanding development are increasing demands on our water supplies. In parts of the region, groundwater levels are declining, and in some cases, the effect has been to lower lake and wetland levels. Chapter 5 discusses these issues in more detail.

Balancing the many competing needs of the region's many water users, while protecting the region's diverse water resources, is a challenge and requires a coordinated, interdisciplinary and ongoing effort. Coordination among local communities, the Metropolitan Council, and state partners will help meet our future water supply needs.

The role of the Metropolitan Council in water supply planning, led by the Council's Environmental Services Division, is to help ensure a sustainable water supply and water quality by the following:

- Work with partner agencies and jurisdictions to develop this Master Water Supply Plan
- Maintain a database of technical information to be used for both local and regional planning
- Provide assistance to communities in developing their local water supply plans
- Identify approaches for dealing with emerging issues
- Review local water supply plans as part of the local comprehensive plan

This regional Master Water Supply Plan provides planning assistance to communities in the region – including guidance and tools - for water supply, so that they can take the most proactive, cost effective approach to long term planning and permitting to ensure plentiful, safe, and affordable water that supports the prosperity and livability of the region for future generations.

The Metropolitan Council is not a water supplier and has no intent or authority to take over local water supply systems. The regional planning process has been designed and applied to ensure local water suppliers have control of and responsibility for their water supply systems.

This chapter discusses the need for and benefits of regional water supply planning and provides a summary of the Master Water Supply Plan, including what it means for local plans to reflect this plan. Subsequent chapters provide details about the goal, water use, sources, issues, desired outcomes, implementation strategies, and roles and responsibilities.

Rationale for regional water supply planning

The Metropolitan Council recognizes the responsibility and authority of local water suppliers to provide water. A regional perspective is also important, because the effects of local water supply decisions do not stop at community boundaries. Communities often share the same or interconnected water supply sources, and the cumulative impact of decisions made by individual communities can be significant.

The Metropolitan Council forecasts that the region will add about 824,000 residents over the next 25 years. A pressing concern is the impact that future development might have on the reliability and availability of the region's water supplies.

The development of this plan is not motivated by widespread water shortages or crises. Rather, this plan is a response to the recognized benefits of developing and maintaining a plan that supports current and future populations without adverse impact to natural and economic resources.

Water is livability

Water is vital to the region's present and future quality of life. It is key to our identity as Minnesotans and what we want for our children.

Quality of life surveys repeatedly identify water-related features – parks, trails, beaches, etc. – as the region's most attractive features. Seventy-eight (78%) of the 2012 Residents Survey respondents considered water supply and water quality monitoring to be very important Council programs and responsibilities.

Water is prosperity

Water is vital to the region's present and future prosperity. Every sector of the region's economy is influenced by water – agriculture, manufacturing, mining, travel and lodging, and services. When critical water demands are met, health and economic impacts are avoided.

The Minnesota Department of Employment and Economic Development has reported that, in 2014, Minnesota has more Fortune 500 companies per capita than all but one state, with 18 Fortune 500 companies headquartered in the state. Among metropolitan areas, Minneapolis-St. Paul ranks first among the 30 largest metropolitan areas in the number of Fortune 500 companies per capita. Those companies rely on stable water supplies. Seven of the metro area's Fortune 500 companies each have water permits to use more than 1 billion gallons of water a year; others are large customers of public water supplies.

Benefits of the regional water supply planning process

With the Master Water Supply Plan, communities are better able to take the most proactive, cost effective approach to long term planning and water supply permitting to ensure plentiful, safe, and affordable water for future generations.

The plan supports this work by providing planning assistance to connect growth planning coordinated by the Metropolitan Council with water supply permitting conducted by the Minnesota DNR.

Benefits of the Master Water Supply Plan include:

Regional perspective informs local planning. Water does not follow political boundaries, and water use decisions can have impacts that extend across multiple jurisdictions. The Master

Water Supply Plan provides a perspective and tools to help develop and implement local plans that support sustainable water supplies across the region.

Better data, better analyses. The specific water supply sources and associated regional and local issues identified in this plan are supported by analyses based on the best available regionally consistent data and tools, such as the Minnesota DNR water use database and regional groundwater flow model (Metro Model 3). This regional approach to water supply assessment objectively highlights potential problem areas and thus reduces the likelihood that water supply problems will develop “under the radar”.

Clearer and more consistent guidance for the plan and permit development and review process. The regional and local issues identified in this plan were assessed in close cooperation with the DNR and other agencies, and issues relevant to each community are outlined in the community’s water supply profile in Appendix 1.

Economies of scale. This plan helps communities realize economies of scale in multiple ways. With a focus on working with partners to develop tools and other resources, communities may be able to reduce or eliminate costs associated with assessing their water resources. In addition, this plan compiles publicly available and regionally consistent data for communities. Additional resources, including Metro Model 3 and the Conservation Toolbox, are also provided. As development expands and demand increases, opportunities for interjurisdictional partnerships will, too. Continuous updating of technical analyses will identify such opportunities for cooperation to supply water in both the short and long term.

Water supply planning required under state law

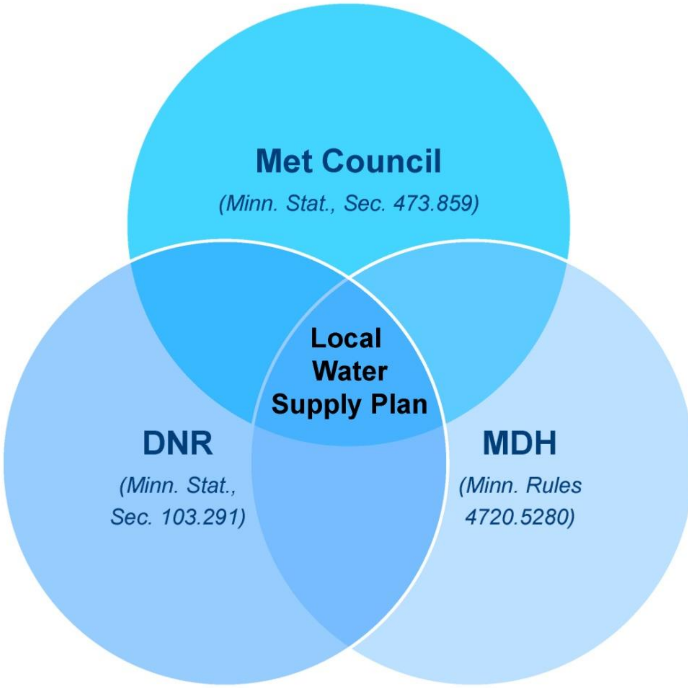
Public water supply plans

A water supply plan is required for all communities within the metropolitan area with a municipal water supply system, as a required element of the local comprehensive plan (Minn. Stat., Sec. 103G.291).

The Minnesota DNR and the Metropolitan Council have jointly developed a local water supply plan template. Using the template supports communities in fulfilling important statutory obligations including:

- Minn. Stat., Sec. 103G.291 to complete a water supply plan, including demand reduction
- Minn. Stat., Sec. 473.859 to address water supply in local comprehensive plans
- Minn. Administrative Rules 4720.5280 to address contingency planning for water supply interruption

Figure 1. In the metro area, completing the local water supply plan template fulfills three agency requirements



Communities without public water supplies do not need to prepare a water supply plan, but they should include information about plans to protect private water supplies in appropriate sections of the local comprehensive plan.

Communities and utility boards adopt the water supply plan, if one is required, along with the local comprehensive plan.

Comprehensive plan content

Under the Metropolitan Land Planning Act (Minn. Stat., Sec. 473.859), local governments must review and update their local comprehensive plans every 10 years, including an implementation program that describes public programs, fiscal devices, and other specific actions to be taken to implement the comprehensive plans. The implementation plan shall contain:

- A description of official controls, addressing **water supply** and a schedule for the preparation, adoption, and administration of such controls;
- A capital improvement program for **water supply**

Water supply planning activities and advisory committee

The Metropolitan Council has provided technical assistance and planning studies to support community water supply planning for several decades, but it wasn't until 2005 that the Minnesota Legislature specifically directed the Metropolitan Council, under Minn. Stat., Sec. 473.1565, to:

> "carry out planning activities addressing the water supply needs of the metropolitan area,…[including] development and maintenance of technical information;

recommendations for clarifying roles, streamlining decision-making and approval processes, and funding; and the development of a twin cities metropolitan area master water supply plan... that:

- Provides guidance for local water supply systems and future regional investments.
- Emphasizes conservation, interjurisdictional cooperation, and long-term sustainability; and
- Addresses the reliability, security, and cost-effectiveness of the metropolitan area water supply system and its local and sub-regional components."

The same legislation also created a Metropolitan Area Water Supply Advisory Committee (MAWSAC), which is a policy advisory committee consisting of representatives from state agencies, counties, municipalities, and utilities. Members are appointed by the Governor, and the membership is defined in statute. MAWSAC members provide guidance to local water supply planning efforts in accordance with the Master Water Supply Plan.

In 2015, the Legislature amended Minn. Stat., Sec. 473.156 to include a technical advisory committee to provide input on regional water supply planning activities.

The Metropolitan Council is also guided by a variety of local stakeholders through several sub-regional water supply work groups established to provide input on the scope and results of sub-regional water supply studies.

Developing and updating the Master Water Supply Plan

The Metropolitan Council strives for collaboration, integration, and accountability in all its work. These guiding principles have shaped how the Master Water Supply Plan was developed and updated.

The process for developing the 2010 Master Water Supply Plan began in 2006 with a series of public meetings and workshops, guided by the Metropolitan Area Water Supply Advisory Committee. Public meetings were held regularly throughout the process to get input from city planning and utility staff, elected officials, and other interested people. Progress reports were provided to the Minnesota Legislature in 2007, and a formal public review period occurred in 2009. The Master Water Supply Plan was approved by the Metropolitan Council in March 2010, and the DNR Commissioner approved the plan in July 2010.

After completing the Master Water Supply Plan in 2010, the Council partnered with state agencies, private consultants and communities to complete several technical and outreach projects that strengthen regional and local water supply planning efforts, including better integration of water supply planning and local comprehensive planning.

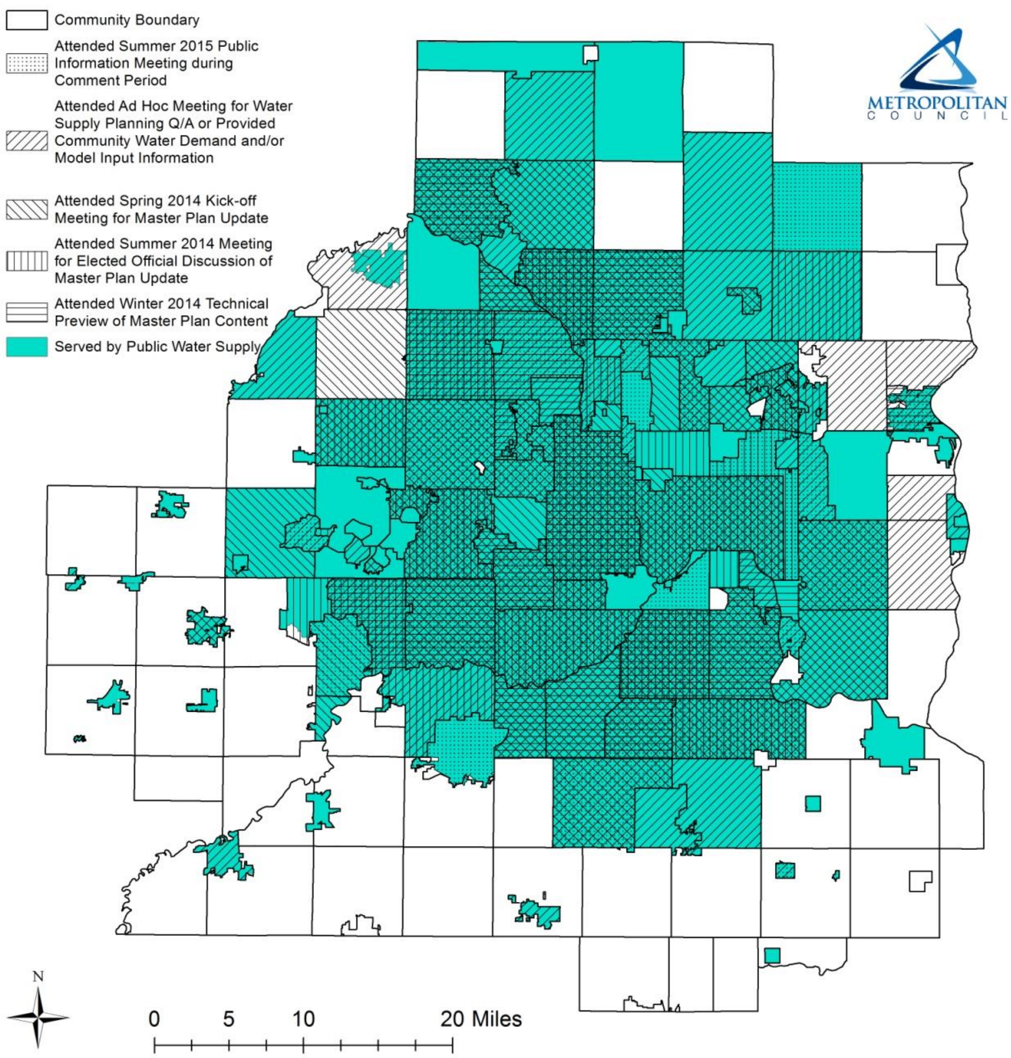
The 2015 update of the Master Water Supply Plan incorporates new technical information and feedback from many stakeholders, and it reflects changes to the regional development framework, *Thrive MSP 2040*, and the *Water Resources Policy Plan*. Stakeholders were engaged through:

- Metropolitan Area Water Supply Advisory Committee presentations and discussion
- Community Technical Work Group presentations and discussion
- Public meetings during plan development (over 260 attendees representing more than 75 communities)

- Ad hoc community meetings during plan development (45 attendees representing over 32 communities)
- One-on-one discussions, including data sharing, between Council staff and community planning and utility staff during plan development (over 90 public water suppliers)
- Information shared on the Council's website
- Formal public review period and process

Overall, the communities participating in Master Water Supply Plan outreach serve over 85% of the metropolitan area's population.

Figure 2. Communities engaged in Master Water Supply Plan outreach events and one-on-one discussions. Blue communities are partially or wholly served by a public water supply system.



Updating the Master Water Supply Plan

The Master Water Supply Plan is updated regularly to reflect the best available information. Updates of the Master Water Supply Plan will incorporate new technical analyses to provide the most up-to- date information about the region's water supplies, emerging issues, and water supply alternatives; and they will reflect new regional policies and system growth projections.

The Master Water Supply Plan may be updated if and when the following triggers occur:

Triggers

- 10-year updates of the Metropolitan Council's *Thrive MSP 2040*
- Legislative actions mandate significant changes in Metropolitan Council's or partners' roles or responsibilities
- New technical analyses significantly change our current understanding of the water supply issues or approaches identified in this Master Water Supply Plan and/or in the water supply profiles in Appendix 1

Scope and Process

Following 10-year updates of the *Thrive MSP 2040* and concurrent with the update of the *Water Resources Policy Plan*, the Master Water Supply Plan will be updated as follows:

- The policy advisory committee (MAWSAC) and a technical advisory committee will be consulted for guidance about the scope and schedule for the plan update
- Local stakeholders will be asked to provide input about the format, content, regional water supply issues and challenges, and technical analyses
- Draft plan will be reviewed the policy advisory committee (MAWSAC), a technical advisory committee, and others and approved by Met Council for a formal public review, including a public notice and hearing
- Public feedback will be incorporated and the final plan will be approved by the policy advisory committee (MAWSAC) and adopted by Met Council

Other triggers may lead to ad hoc updates to the technical information and guidance in the Master Water Supply Plan appendices, such as the community water supply profiles. The update process for appendices is:

- Review by a technical advisory committee and communities impacted by the change
- Updated community water supply profiles will be posted on the website, along with technical reports describing the technical project in question
- Paper profiles will be mailed to impacted communities

Changes to the Master Water Supply Plan in 2015

The 2010 Master Water Supply Plan was updated in 2015 to integrate with *Thrive MSP 2040*, the region's 30-year comprehensive plan. The update also incorporates new technical information.

What is new

Most notably, the update incorporates new data and information that has been collected since 2010 and is available on the Council website:

- New Metropolitan Council population forecasts
- Metropolitan Council analysis of groundwater and surface water relationships
- Minnesota Geological Survey mapping of the vulnerability of bedrock aquifers to flow through glacial sediments
- Aquifer tests by the Minnesota Department of Health based on data collected through community source water protection programs since 2009
- New surface water and groundwater level monitoring data from the Minnesota DNR

- Water supply alternative feasibility assessments conducted by Metropolitan Council in partnership with communities
- Updated regional groundwater flow model (Metro Model 3)

The update also includes revision to satisfy Governor Dayton's 2014 Executive Order to implement plain language and compliance with the Americans with Disabilities Act.

What stays the same

The core of the 2010 Master Water Supply Plan remains the same, including:

- The rationale for regional water supply planning
- Goal
- Guiding principles
- Key water supply sources and challenges
- Statutory roles and responsibilities of the Metropolitan Council and partners

Changes between the 2010 and 2015 versions of the Master Water Supply Plan

Chapter 1 of the updated plan contains the information provided in Chapter 1 of the original plan, including the rationale and history of regional water supply planning, the legislative mandate, and a summary of benefits of metropolitan area water supply planning process to partners and stakeholders.

Chapter 2 of the updated plan contains the information provided in Chapter 2 of the original plan, including the goal and guiding principles. The updated chapter also provides an overview of water supply policies in the updated *Water Resources Policy Plan*.

Chapter 3 of the updated plan contains the water use information provided in Chapter 3 of the original plan (which both discussed use and sources), but updated to reflect more recent information and more detail about water conservation.

Chapter 4 of the updated plan contains the water source information provided in Chapter 3 of the original plan (which discussed both use and sources), updated to include more information about wastewater and stormwater reuse.

Chapter 5 of the updated plan contains the water supply issue information provided in Chapter 5 of the original plan, updated to include the results of new groundwater flow model scenarios.

Chapter 6 of the updated plan contains information about the outcomes to be achieved through implementation of the Master Water Supply Plan. This is new content.

Chapter 7 of the updated plan contains information about specific implementation strategies that the Metropolitan Council will implement. This corresponds to Chapter 6 of the original plan, although more detail is provided and strategies are more closely aligned with the Metropolitan Council's updated Water Resource Policy Plan policies.

Chapter 8 of the updated plan contains information about the roles and responsibilities for water supply planning in the region. This chapter expands on the information provided in Chapter 4 of the original plan.

How the Master Water Supply Plan guides local planning

The Master Water Supply Plan provides communities in the region with planning assistance for water supply in a way that:

- Recognizes local control and responsibility for owning, maintaining and operating water systems
- Is developed in cooperation and consultation with municipal water suppliers, regional stakeholders and state agencies
- Is approved by the Metropolitan Area Water Supply Advisory Committee, a policy advisory committee
- Protects critical habitat and water resources over the long term
- Meets regional needs for a reliable, secure water supply
- Highlights the benefits of integrated planning for stormwater, wastewater and water supply
- Emphasizes and supports conservation and interjurisdictional cooperation
- Provides clear guidance by identifying key challenges/issues/considerations in the region and available approaches without dictating solutions

Local water supply plan considerations

The Master Water Supply Plan is updated regularly to reflect the best available information. Updates of the Master Plan will incorporate new technical analyses to provide the most up-to-date information about the region's water supplies, emerging issues, and water supply alternatives; and they will reflect new regional policies and system growth projections.

A local water supply plan template has been jointly developed by the Minnesota DNR and the Metropolitan Council (Council) to meet the water supply requirements of both agencies. Completing the template fulfills the requirements by the Minnesota Department of Health (MDH) to address contingency planning for water supply interruption in source water protection plans.

Information in Appendix 1 may be helpful to metropolitan area public water suppliers as they complete the local water supply plan template. Appendix 1 provides a general overview of local and sub-regional water supply conditions for communities, counties, watersheds and subregions in the seven-county Twin Cities metropolitan area: water use, source, and potential issues. This information should be considered in addition to more locally specific characteristics, as they are available, to verify and/or evaluate potential issues and develop local plans.

Completing Parts 1-4 of the local water supply plan template and submitting it as part of the local comprehensive plan is the way community plans can reflect the Council's water supply-related policies and the Master Water Supply Plan. Figure 3 illustrates the process for the Council and DNR review of the local water supply plan.

The Council's review of the local water supply plan will focus on the following content that addresses key elements of this Master Water Supply Plan.

Extended water demand projections

Extended water demand projections (through 2040 and estimated for full build-out) should be included in Part 4 of the local water supply plan template. These projections should be consistent with the population forecasts in the community's systems statement. Assumptions of water conservation impacts on demand projections may be supported by information provided in Part 3 (Conservation Plan) of the local water supply plan template.

Potential water supply issues

The discussion of resource sustainability in Part 1-E of the local water supply plan template should acknowledge the potential water supply issues identified on the community water supply profile in Appendix 1 of the Master Water Supply Plan. While the information in each water supply profile is generally based on regional analyses, it can be used in local planning and can be verified and/or refined with more local analyses. This information should be considered in addition to more locally specific characteristics, as they are available, to verify and/or evaluate potential issues and develop local plans.

Monitoring and ongoing evaluation

Part 1-E of the local water supply plan should include information about existing and planned resource monitoring and analysis needed to evaluate the local effects of community water use and to provide early warning of unidentified or developing water supply issues. Metropolitan Council recognizes the value of monitoring and ongoing evaluation to reduce uncertainty about regional water supply sustainability; the Council will provide technical guidance upon request for this part of the local water supply plan. However, the DNR and the community are the primary partners responsible for developing the details of the monitoring and evaluation plan.

Water conservation

Water conservation practices can effectively reduce the demand placed upon groundwater and surface water sources as well as municipal water supply systems. Part 3 of the local water supply plan should provide a detailed water conservation plan, which may also inform extended water demand projections in Part 4. Metropolitan Council will provide technical guidance and tools such as the Conservation Toolbox to assist in the development of this portion of the local water supply plan. However, the DNR and the community are the primary partners responsible for developing the details of the conservation plan.

Proposed approaches to meet extended water demand projections

Building on the information provided in Part 2 of the local water supply plan template, Part 4 of the local water supply plan template should describe:

- The adequacy of the existing water supply system to meet demand through 2040. Proposed approaches to meet water demand through 2040, if the current system is inadequate to do so, that consider the potential issues identified for the community within Appendix 1 of the Master Water Supply Plan and by local monitoring and evaluation. Proposed approaches may include:
    - Continuing to use existing groundwater or surface water sources, supported by monitoring and evaluation to provide warning of developing problems and a plan for back-up should limitations occur.
    - Using new (currently not in use) approaches with a lower likelihood of causing well interference, aquifer or surface water impacts, or added treatment costs due to contamination. Potential approaches include expanded conservation, interconnections with neighbors, groundwater, surface water, reclaimed stormwater, and reclaimed wastewater.

In some cases, a multi-community approach may be warranted. The DNR and Metropolitan Council will provide planning assistance and technical information to support development of multi- community water supply management plans, where appropriate.

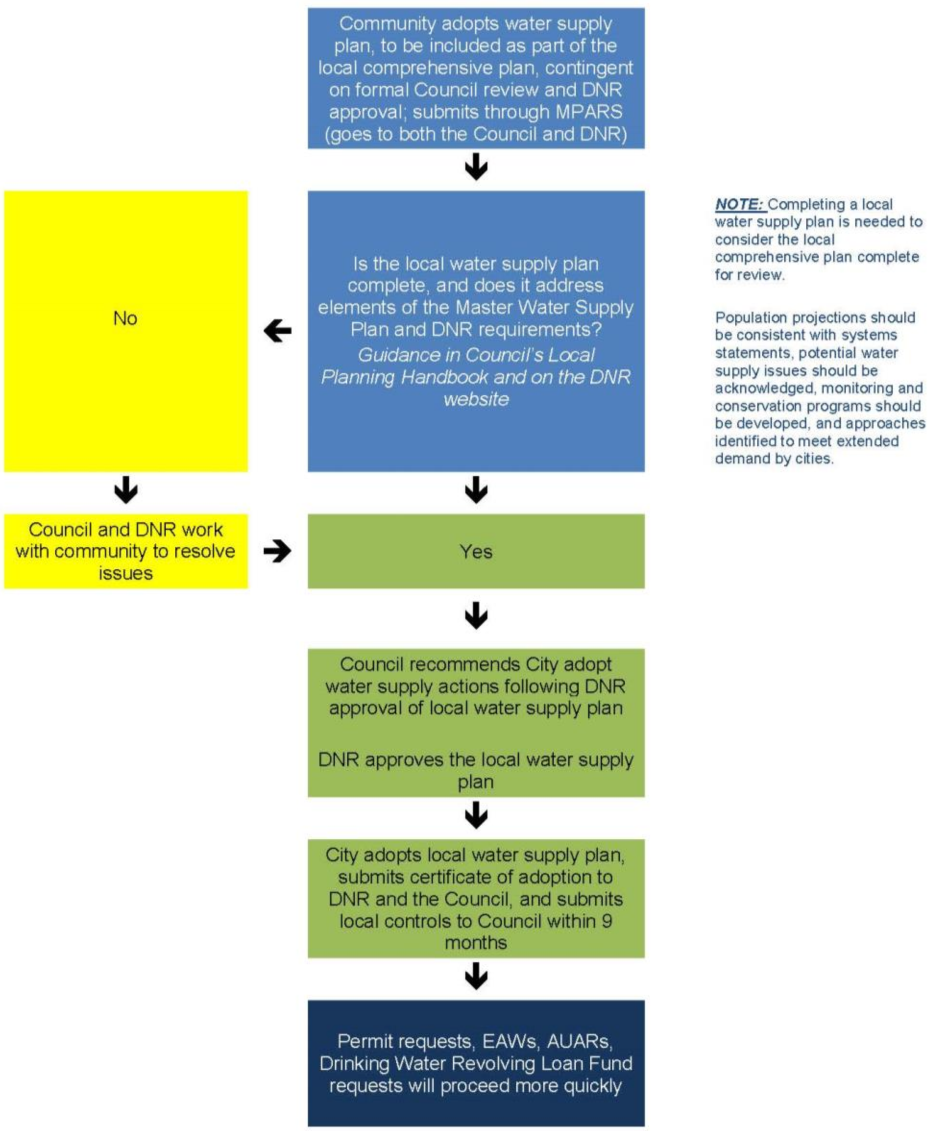
Metropolitan Council will also help support the work outlined in the local water supply plan template through public outreach to increase knowledge by the general public about water supply issues, partnering on technical studies, promoting and supporting water conservation, investigating reuse of treated wastewater, and supporting investments in water supply. Results from these efforts will be incorporated into regional analyses and in future updates to the Master Water Supply Plan.

More detailed guidance on how local plans can incorporate water supply considerations is provided in the Metropolitan Council's *Local Planning Handbook*.

Review process

Metropolitan Council and DNR cooperate in the process to review local water supply plans. Figure 3 shows the decision process review of water supply plans, including the benefits of completing and approving a local water supply plan.

Figure 3. Metropolitan Council's local water supply plan review process, including coordination with DNR and plan submittal through the MNDNR Permitting and Reporting System (MPARS).



2 Water Supply Goal for the Region

This chapter discusses the goal, guiding principles and vision of the Master Water Supply Plan. These elements are expressed through Metropolitan Council's water supply policies and implementation strategies in the *Water Resources Policy Plan*, with this Master Water Supply Plan providing more detail.

This information shapes the approaches recommended for meeting the water demand outlined in Chapter 3. Implementation of these policies will help the region achieve the outcomes discussed in Chapter 6. Chapter 7, Implementation Strategies, provides more detail about roles and responsibilities, milestones, and possible funding sources.

Goal: A sustainable water supply now and in the future

The Master Water Supply Plan's single overarching goal is that the region's water supply is sustainable now and in the future.

The premise of sustainability as the foundation of water supply planning is recognized in Minnesota statute and the Twin Cities metropolitan area's long-range plan, *Thrive MSP 2040*.

Minnesota statutes, section 4A.07 define sustainable development for local government 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."

Minnesota statutes, section 103G.287 provides the following definition of sustainable water use:

> "…water use is sustainable when the use does not harm ecosystems, degrade water quality, or compromise the ability of future generations to meet their own needs."

Thrive MSP 2040, states that planning for water supply sustainability means:

> "...promoting the wise use of water through expanding water conservation and reuse, increasing groundwater recharge, and optimizing surface water and groundwater use."

Evaluation of sustainability considers a wide variety of information, and Chapter 5 provides more detail. While this Master Water Supply Plan incorporates the best regional information available in 2015, insights may change over time as new technical information becomes available and policies change.

Vision for a sustainable balance of sources

Considering the statutory definitions and regional long-range plan above, the region's water supply may be considered sustainable when water users maximize their use of existing water supply infrastructure investments within the sustainable limits of available sources, and use water in a way that:

- Is efficient and conserves water

- Maintains aquifer levels consistent with safe yield conditions defined in Minnesota statutes
- Maintains surface water by managing withdrawals, including diversions of groundwater that support them, to maintain projected flows and elevations
- Minimizes impacts to groundwater flow directions in areas where groundwater contamination has, or may, result in risks to the public health
- Recognizes uncertainty and seeks to minimize risk

Multiple approaches

This plan recognizes that, across most of the metropolitan area, groundwater is the principal water supply source. Public and private water providers and users have invested many millions of dollars in water supply infrastructure. The Metropolitan Council recognizes the value of these investments and supports plans and water supply management that leverage this infrastructure to meet needs within the sustainable limits of water sources. Where demand exceeds the sustainable limits of existing sources, water conservation and other sources are available to support demand.

With access to multiple water sources, the Twin Cities metropolitan area is relatively water rich. As a region, a strategic and coordinated use of all available water supply sources simultaneously supports the region's economy and the quality of life that is so highly valued. And a diverse set of water sources provides better flexibility – to better manage rapid growth, extreme weather conditions, and other risks.

Like an investment portfolio, the region needs a combination of water sources that:

- Supports our growth objectives
- Considers cost and time
- Distributes risk by diversifying

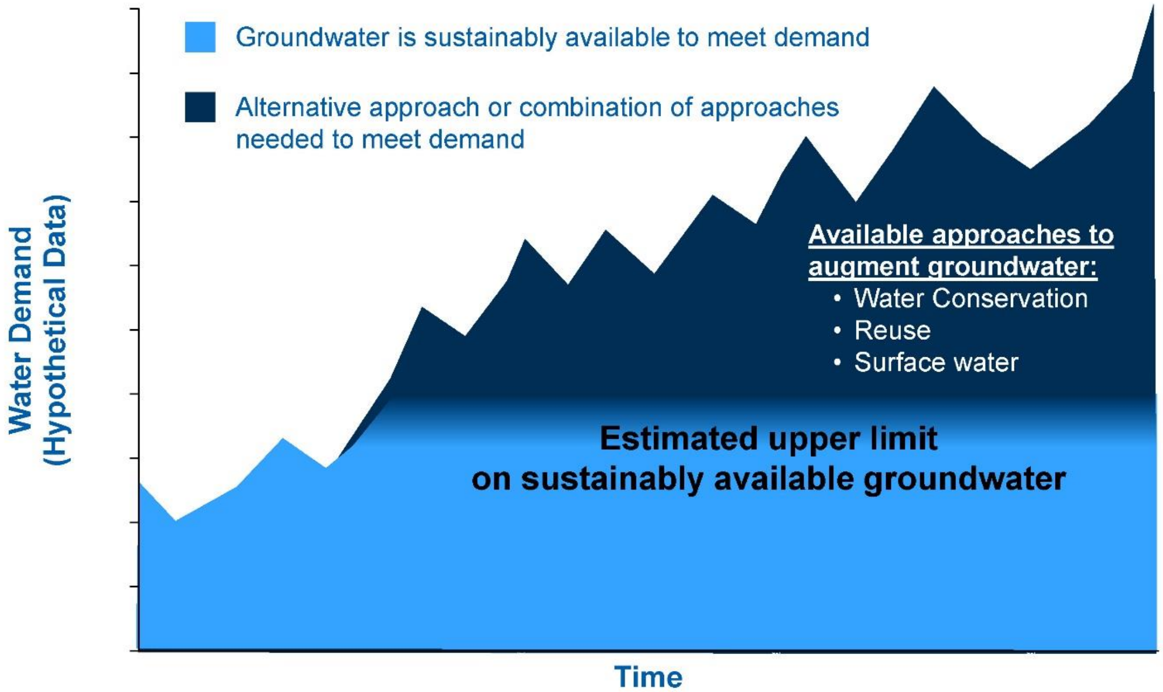
There is no single solution for ensuring a long term sustainable water supply across the metro area. There are generally six water supply approaches available across the region, and communities can consider which combination works best for them:

- Water conservation
- Groundwater
- Stormwater reuse
- Surface water
- Enhanced recharge
- Reclaimed wastewater

Together, this combination of sources can provide more than enough water for our region's needs. In parts of the region, however, some sources may not be enough to meet planned demand. Strategies like water conservation can expand immediately and may eliminate the need for additional options or buy time to consider other steps. Other strategies, like expanding surface water infrastructure, take longer to implement but can alleviate pressure on groundwater systems in areas where it is not possible to reduce demand for potable water. Like financial investments, a deliberate collection of water supply sources, programs, and infrastructure can provide the best short and long-term water supply options. Figure 4 illustrates the vision for regional water supply sustainability.

Figure 4. Vision for regional water supply sustainability.

Sustainable water supply management will maximize the region's use of existing water supply infrastructure investments – usually groundwater - within sustainable limits. Water conservation and other approaches can be used so that water is available to meet current and future demand. Alternative approaches to groundwater use can be combined to avoid exceeding the sustainable limits of groundwater and other sources.



A combination of water supply approaches can maximize the use of existing water supplies and system investments within the sustainable limits of the resource and use other approaches to meet demand above those limits. Where infrastructure changes are needed – such as to address needs for increased treatment, reducing impact on natural and recreational resources – all available options should be considered, with input from neighbors and other partners who may know of opportunities for added value and cost-sharing.

Appendix 4 provides some case studies of local examples of alternative approaches to water supply, which move the region toward achieving our goal of sustainability.

While there are important benefits to long term planning, there is uncertainty about the future. Tools like regional groundwater flow modeling, discussed in Chapter 5, can be used to explore a range of possible future conditions. Regional modeling is a planning tool, not a regulatory tool, and it provides useful information to support regional planning and cooperation that ensures sustainability. Working collaboratively with the local providers to develop and share sound technical information and implementation tools will be the pathway to success in the area of sustainability.

Guiding principles

Sustainable water supply planning needs to consider the interrelationships among surface water and groundwater, water quality and quantity, and water and land use. As these links are evaluated, both objective technical information and subjective human values (such as those addressed in *Thrive MSP 2040*) come into play. Water supply planning must be based on principles that strike a balance between technical information and human values. The following principles inform water-related decisions in the region:

- Water supply planning is an integral component of long-term regional and local comprehensive planning.
- An understanding of the region's long-term water supply availability and demand is necessary to identify a specific community's or sub-region's water sources.
- All hydrologic system components, naturally occurring and man-made, must be carefully evaluated when making water infrastructure plans.
- The quality of the region's water is a critical component of water supply planning.
- Inter-jurisdictional cooperation is a viable option for managing short-term water supply disruptions and sustainably meeting long-term water supply needs.
- Regional and local cost-effectiveness and fair cost-sharing are considered when identifying water supply options.
- Wise use of water supplies is critical to ensuring adequate supplies for future generations.

Policies

The Master Water Supply Plan provides information and guidance to support the implementation of the Council's water supply-related policies, found in the *Water Resources Policy Plan*, guided by the principles above:

Policy on Sustainable Water Supplies*.* The Council recognizes the crucial role of local control and responsibility for owning, operating, and maintaining water supply systems. The Council will work with our local partners and others to develop plans that meet regional needs for a reliable water supply that protects public health, critical habitat, and water resources over the long-term.

Policy on Assessing and Protecting Regional Water Resources. The Council will continue to assess the condition of the region's lakes, rivers, streams, and aquifers to evaluate impacts on regional water resources and measure success in achieving regional water goals.

Policy on Water Conservation and Reuse. The Council will work together with partners to identify emerging issues and challenges for the region and solutions that include the use of water conservation, wastewater and stormwater reuse, and low impact development practices in order to promote a more sustainable region.

Investment Policy. The Council will strive to maximize regional benefits from regional investments.

3 Water Use Now and In the Future

The region's water supplies have supported public health, economic development, parks and recreation in our region for generations. In short, our quality of life. Going forward, our region is expected to grow and change, with increasing demand for water.

This chapter discusses the region's current water use and how it is expected to change in the future. By 2040, it is estimated that the region will need about 100 million gallons of water per day more than in 2010, if current water use practices continue. Consequently, it will become increasingly important to ensure that the water use is sustainable and sufficient for future generations, while protecting the environment and natural habitat.

Comparing trends in water use with Chapter 4's information about available sources suggests that future water use should be matched to the best combination of sources available to sustainably meet demand.

Water use priorities defined by Minnesota statutes

Water is withdrawn for a wide range of purposes by multiple users in the region. Should multiple users request water above the sustainable limits of the same source, state law establishes the priority for allocating water by who is using it and for what purpose, according to the six categories listed below, in order of priority (2013 Minnesota Laws Chapter 103G.216):

- Domestic water supply, excluding industrial and commercial uses of municipal water supply, and use for power production that meets the contingency planning provisions
- Use of water that involves consumption of less than 10,000 gallons of water per day
- Agricultural irrigation and processing of agricultural products involving consumption in excess of 10,000 gallons per day
- Power production in excess of the use provided for in the user's contingency plan
- Uses, other than agricultural irrigation, processing of agricultural products, and power production involving consumption in excess of 10,000 gallons per day
- Nonessential uses

Meeting all of the region's current and future water needs – as demand grows and competition for limited resources increases – means that our use of water will need to be more efficient and matched to the most appropriate sources. For example, nonessential non-potable uses such as car washes or boulevard irrigation may be better supplied by treated stormwater than by groundwater treated to drinking water standards.

Users of water sources in the region

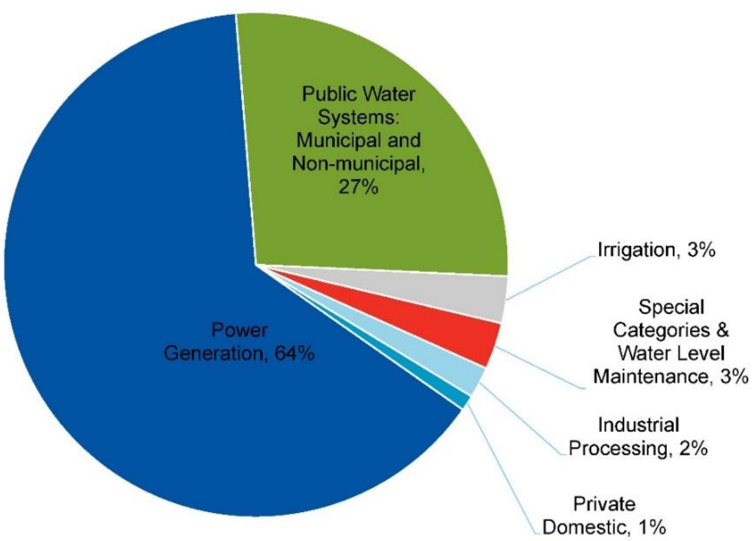
The best source of water use information is data submitted by water appropriation permittees to the Minnesota Department of Natural Resources (DNR). Between 1988 and 2012, these data were stored in the State Water Use Data System (SWUDS). In 2013, the DNR developed a new database to house and manage these data, the Minnesota DNR Permitting and Reporting System (MPARS). In this report, SWUDS data is used to represent recent patterns and trends in water use; MPARS 2014 data represent a snapshot of current water use.

In recent years (2003-2012), the metro area used an average of 1,300 million gallons per day of both surface water and groundwater. Power generation used the most water (Figure 5). However, the metropolitan area power plants mostly use open-loop cooling systems where relatively little water is consumed; the rest is returned directly back to the surface water from which it came. That leaves public water systems (predominantly municipal), irrigation, special categories and water level maintenance, and industrial processing as the four largest consumptive water uses. Most of this water does not return to its original source (Table 1).

Table 1. Recent and expected future water use by major category in the Twin Cities metropolitan area. This information is discussed in more detail later in this chapter.

Category	2003-2012 Yearly Average (millions of gallons per day)	Future Demand Expectations
Power generation	866	Non-consumptive use to increase and consumptive use to remain constant
Public water systems: Municipal and non-municipal	364	Increase significantly
Irrigation: Major crop & non crop	36	Relatively constant or increase slightly
Special categories & water level maintenance	36	Remain relatively constant
Industrial processing	26	Remain relatively constant
Private water supply (domestic)	16	Decrease

Figure 5. Water consumed in the Twin Cities metropolitan area, 2003-2012 average.



Power generation – self supplied

Power generation is the single largest water use in the metropolitan area, and water used for energy production above what is identified in contingency plans is the fourth water use priority in the state.

From 2003 to 2012, an average of about 866 million gallons of water per day was used by power plants in the metropolitan area. Most of the water used for power generation comes from surface water sources, but a small percentage comes from groundwater.

Because power generation is so dependent on surface water supply, drought response is a critical component of contingency planning. For example, the *System-wide Low-flow Management Plan for the Mississippi River above Saint Paul, Minnesota* helps ensure that "run-of-river" operations are maintained by hydropower operators during low flow to minimize artificial flow fluctuations resulting from power generations and to protect aquatic resources.

Although power generation is a large water demand, almost all of this water is used and then returned back to its original source. Consequently, power generation, although a large use, is not a primary focus of the Master Water Supply Plan.

Public water systems

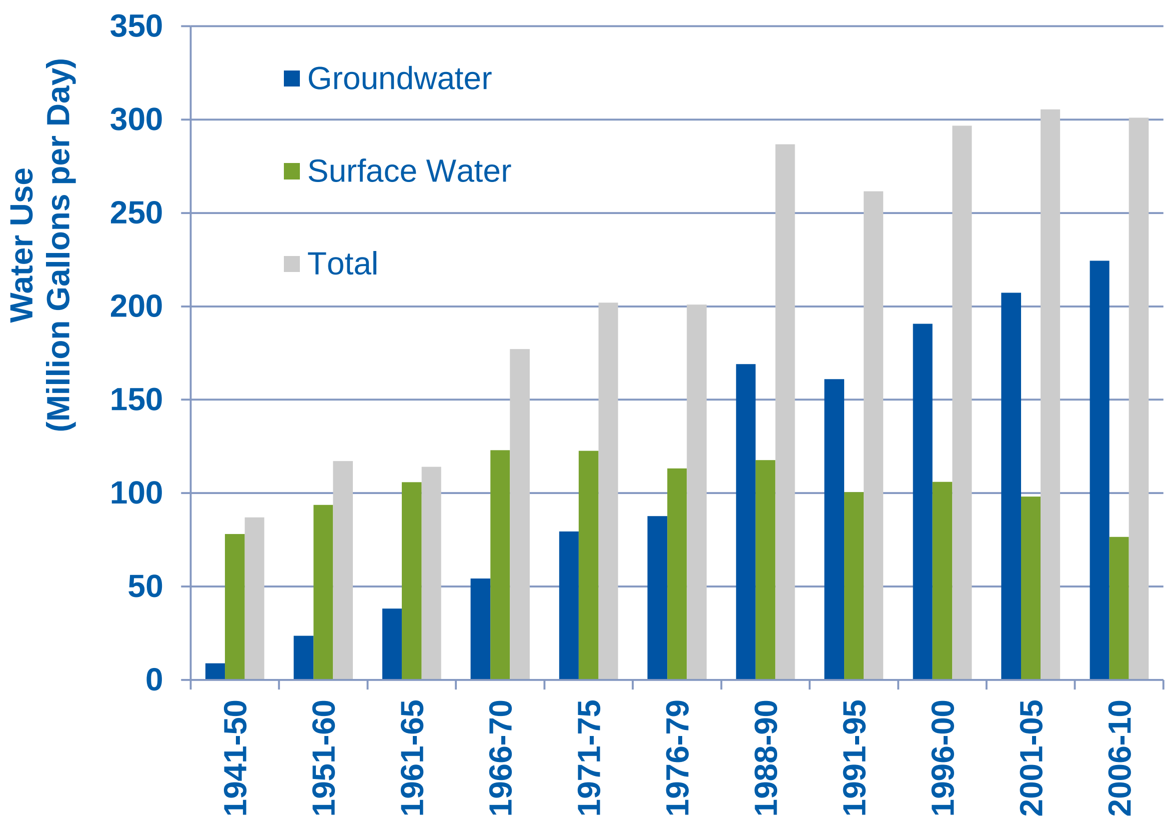
Public water supply by community municipal and nonmunicipal systems is the second largest, and fastest growing, water demand in the metropolitan area, due primarily to population growth. Over 120 separate public water suppliers provide the bulk of the region's drinking water and supports commerce and industry. A relatively small amount of public water supply is provided by commercial and institutional water works and private waterworks.

Municipal systems provide water for a variety of purposes. Water use for domestic purposes is first priority, but other municipal use for commercial, industrial, irrigation or other purposes is usually fifth or sixth priority. Local water supply plans should identify and prioritize these uses as part of emergency preparedness planning.

From 2003 to 2012, public water supply systems used an average of about 364 million gallons per day for residential, industrial and commercial uses.

Today, most of the water used by public water suppliers comes from groundwater, although this has not always been the case (see Figure 6).

Figure 6. Shift in use of groundwater (blue bar), surface water (green bar), and total combined water (gray bar) as development has grown out from the urban core, by decade in the, Twin Cities metropolitan area, 1941-2010. A gap in data exists between 1979 and 1988 due to a change in water use tracking.



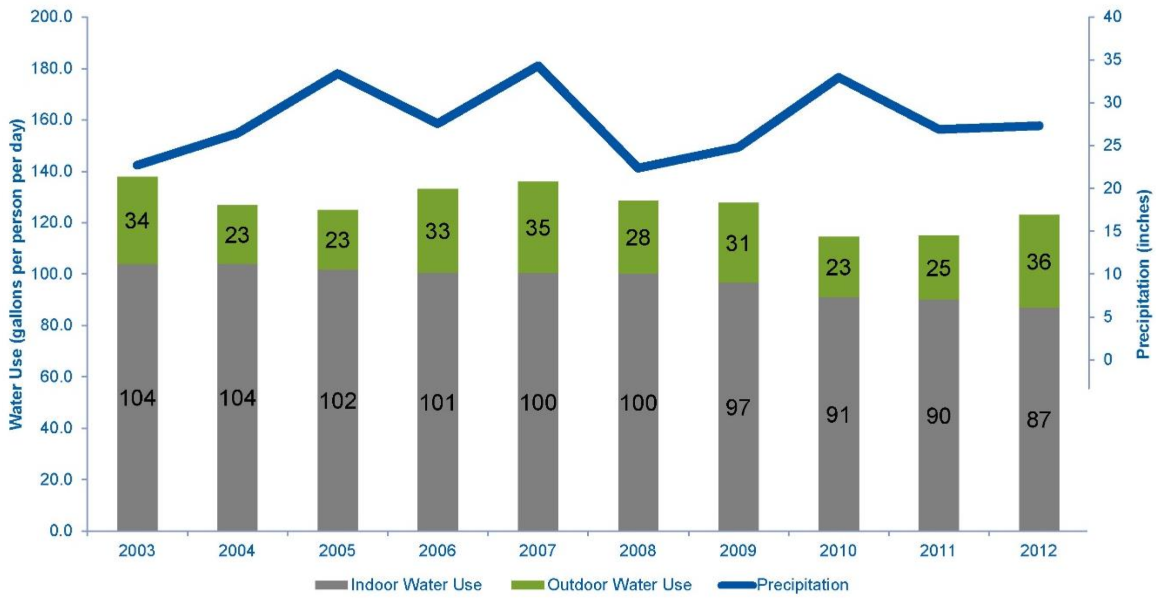
As for private domestic wells, groundwater is a primary source for public supply across most of the region, because of its widespread availability, relatively good water quality and low treatment costs. However, in some locations, increasing groundwater withdrawals raise the risk of impacting neighboring wells and groundwater-supported surface water features.

Over the course of a year, most water is used indoors for household purposes and commerce and industry (Figure 7). During summer months, however, a significant amount of water is used outdoors, mostly for seasonal businesses and lawn watering.

Minneapolis Water Works and Saint Paul Regional Water Services are the region’s largest public water suppliers; the Minneapolis system uses more water in the summer, while the Saint Paul system uses more in the winter months.

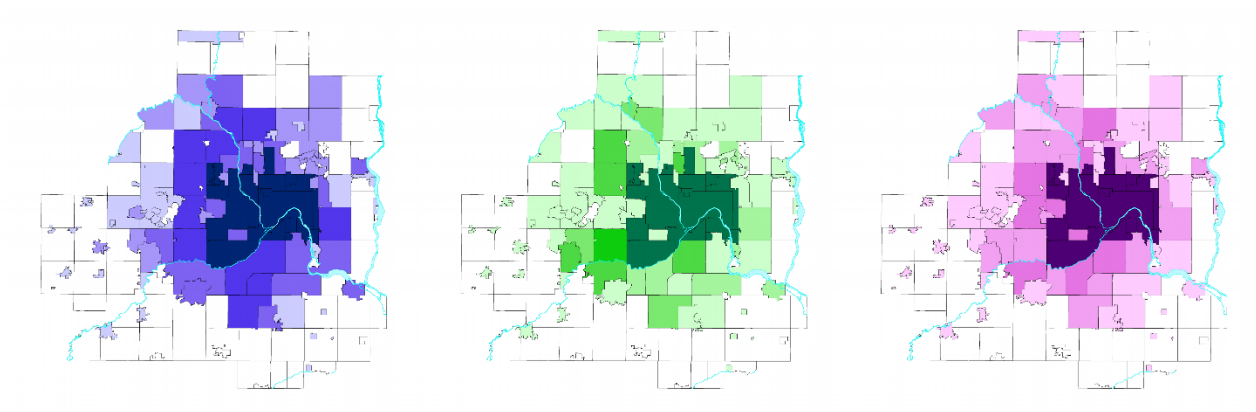
Between 2003 and 2012, the average resident used about 125 gallons of water per day for residential and other uses. Figure 7 illustrates average yearly indoor (gray) and outdoor (green) water use per person in the metro area. Over time, the amount of water used per person for indoor purposes has gone down. More efficient indoor appliances as well as economic conditions may be contributing to this trend. Outdoor water use, however, does not seem to show the same trend. Growth patterns, weather, economic conditions, and technological changes are factors that can affect outdoor water use but in ways that are difficult to predict.

Figure 7. Indoor and outdoor per capita water use, Twin Cities metropolitan area, 2003-2012.



Water demand varies among communities based on community size, land use and other factors. A 2014 survey of public water suppliers identified only two – Minneapolis Water Works and Saint Paul Regional Water Services – that averaged more than 60 million gallons per day from 1988 to 2012. About half of the region's public water suppliers (52%) averaged less than one million gallons per day (Metropolitan Council, 2015d). The three maps in Figure 8 illustrate the relative volumes of water provided by public water suppliers for residential (blue), industrial (green) and commercial (purple) uses in metro area communities. Over the period 1993-2012, the average residential water use was about 63% of total water sales, commercial was about 25%, and industrial was about 2%. Municipal water use in all three categories is highest in the urban core and generally diminishes outward from Minneapolis and Saint Paul. High water use, particularly residential, can be seen along major transportation corridors like Interstate Highways 94 and 35 which are associated with higher populations and commercial and industrial development.

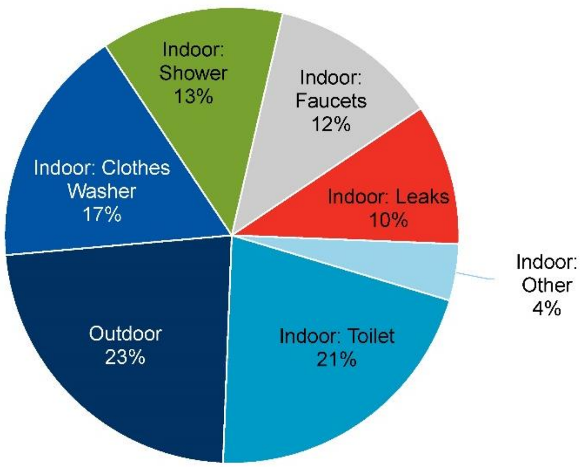
Figure 8. Relative volumes of water used by metro area communities for the period 2003-2012 for residential (blue), industrial **(green) and commercial (purple) uses. Darker colors indicate higher use; white indicates communities without public water supplies.**



Residential

Residential water use is the largest category of municipal water use in the metropolitan area, and has the highest priority. Between 2003 and 2012, approximately 63% of municipal water was used by residents for drinking and cooking, bathrooms and laundry, and for outdoor uses like lawn watering. Between 2003 and 2012, metropolitan area residents each used an average of about 94 gallons per day for residential purposes. However, this amount varied from community to community and from summer to winter. In some communities, summer water use is more than three times that of winter water use, while water use in other communities is more even during the year. As a region, approximately 23% of residential water is used outdoors, mostly for irrigation.

Figure 9. Estimated percent of residential water consumption by type of use, Twin Cities metropolitan area, 2003-2012.



While domestic water use is the State's first priority, this is generally assumed to mean indoor use. Outdoor water use is considered nonessential and the first to be curtailed during an emergency. Enforcement, however, is challenging because this use is distributed among so many people and locations.

Commercial

Commercial water use is the second largest category of municipal water use in the region, but is the state's fifth-priority water use if emergencies arise. This means that, during an emergency, these uses may be curtailed per local emergency response plans.

Between 2003 and 2012, businesses in the metro area used about 25% of municipal water supplies. The amount of water used varied from community to community. In some cities, such as New Brighton and Shakopee, almost half of the municipal water supply supports commercial, industrial, and institutional customers. Others, such as Birchwood Village and Centerville, reported very little commercial or other nonresidential water use.

Industrial

Industry is the third largest category of public water supplies. Like commercial use, this is a fifth- priority use and subject to restriction in an emergency.

Between 2003 and 2012, approximately 2% of municipal water use supported industry. However, industrial water demand varies greatly from community to community. In some communities such as South St. Paul, almost a third of the municipal water supply is used by industrial customers. In others, none.

Some industries, however, have their own water appropriations and wells and do not rely on municipal systems. That use is discussed later in this chapter.

Irrigation – self supplied

Water is used for irrigation on major crops, golf courses, nurseries, and landscape/athletic fields; the amount varies from year to year depending on weather, and approximately 36 MGD were used for irrigation between 2003 and 2012. About two-thirds of irrigation is for major crops (22 MGD). Nine MGD were used between 2003 and 2012 for golf course irrigation, and approximately 4 MGD each for landscape/athletic fields and for nurseries. Agricultural demand for major crop irrigation is the third- priority water use in the state.

Currently, there are approximately 57,500 irrigated acres in the region (U.S. Department of Agriculture, 2014). Agricultural water use is seasonal, so although annual totals are not as high as municipal water use, summer seasonal use is very high, particularly in rural areas with sandy soils such as Dakota County.

DNR reports that water is used for major crop irrigation by over 400 permittees in the Twin Cities metropolitan area.

Special categories & water level maintenance – self supplied

Water supplies are used for many other purposes, as well. Between 2003 and 2012, for example, approximately 17 MGD was used for water level maintenance – some long term at quarry dewatering sites and some short-term at temporary construction projects. An additional 14 MGD was used for special categories – the largest including pollution containment (11 MGD), sewage treatment (2 MGD), and snow and ice making (0.5 MGD).

The largest quarry dewatering project is at the Kraemer Quarry in Dakota County. Recently, a partnership between Kraemer Quarry, Burnsville and Savage has been established to treat the water for municipal supply and offset groundwater pumping. Groundwater pumping for pollution containment can also be an important factor in local water supply planning. While it is a small percentage of total regional water use, it can be locally significant. For example, groundwater pumping for pollution containment at the Twin Cities Army Ammunition Plant has been done in partnership with the cities of New Brighton and Fridley, to prevent the spread of contamination and to provide safe drinking water to those communities.

These are generally fifth- and sixth-priority uses, and they are likely to the first curtailed during drought or other situations where there is a water use conflict.

Industrial processing – self supplied

After municipal demand, private industry uses the most water. Purposes include agricultural processing, petroleum processing, metal and non-metallic processing, sand and gravel washing and other similar uses. This use is the fifth priority water use in the state.

Between 2003 and 2012, the average daily industrial water use in the metropolitan area was approximately 26 MGD. The top three uses were for petroleum chemical processing, agricultural processing, and industrial process cooling water. Private industrial water use is distributed among approximately 190 permittees.

Small private water supply (domestic)

Minnesota statutes establish domestic water use as the highest priority of the state's water when supplies are limited (Minn. Stat., Sec. 103G.261).

Slightly less than 10% of the region’s population draws their drinking water from tens of thousands of private wells. While water use data is limited, the amount of water supplied by private domestic wells can be estimated by assuming that the population of the seven-county metro area that is not served by public water supply systems (approximately 8%) uses an average of 75 gallons per person per day. The result is an estimate of approximately 16 million gallons per day supplied by private domestic wells.

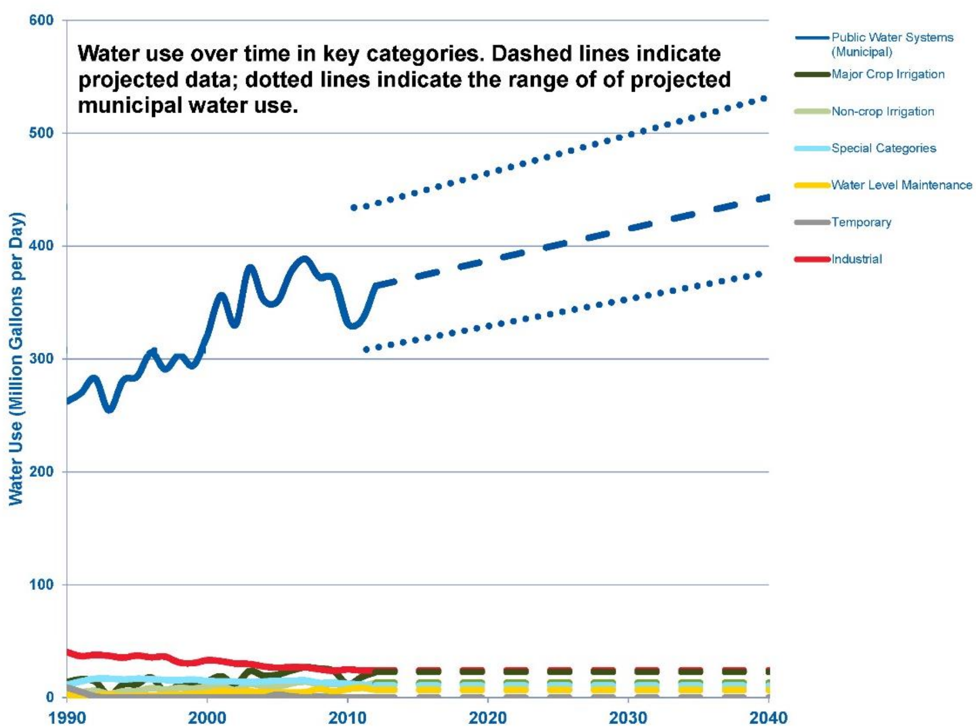
The most commonly used source of water for domestic private supplies is groundwater; which is more widely available and usually safe to drink with minimal or no treatment. Private well owners are responsible for testing water quality, taking action to prevent contamination at the wellhead or intake, and planning for back-up supplies in case of emergency. The Minnesota Department of Health (MDH) is an important resource in these efforts.

Water use is growing - future water use

The amount of water used overall has increased over time, but municipal water use is the largest and fastest growing of any water use category in the metro area. The other water use categories show various historical trends, although the quantities are not large compared to public supply.

As the region’s population and economy continue to grow, regional water use is expected to grow as well. While water demand projections are not precise, simplifying assumptions can be made to estimate a reasonable range for future water demand.

Figure 10. Historical (solid lines) and projected (dashed lines) water use for the largest water consumption categories in the Twin Cities metropolitan area. Does not include power generation, which is predominantly non-consumptive use.

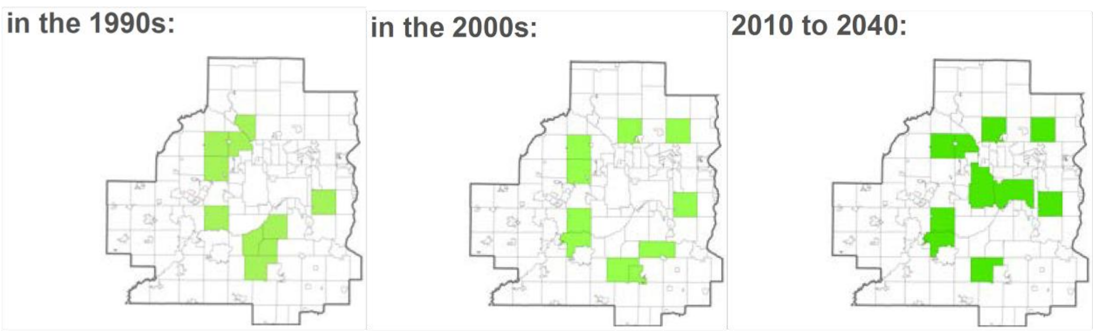


Public water supply systems - municipal water demand

Based on population projections in the Metropolitan Council's 2040 regional development framework, Thrive MSP 2040, the region's population is expected to increase by approximately 30% percent above the 2010 figure, to approximately 3.6 million. During this same period, municipal water demand is expected to increase by a similar amount and account for the majority of the increase in total regional water demand. Figure 11 highlights the top 10 growing cities by decade.

Of the metro areas' future population growth, 75% is expected to occur in communities where groundwater supplies municipal systems; 11% in communities where surface water supplies municipal systems; 12% in communities with a groundwater-surface water mix (Saint Paul Regional Water Services, Edina and Bloomington, and Burnsville and Savage); and 2% of future growth is expected in communities supplied by individual wells.

Figure 11. Top 10 growing cities in the Twin Cities metropolitan area, by decade.



The impact of this population growth on water supply was calculated using a 'per capita unit use calculation' for municipal water utilities in the seven-county metropolitan area (Metropolitan Council, 2015e). Future water demand projections are obtained by multiplying projections of future population by the estimated per capita water use:

(Projected Water Use) = (Projected Population) X (Per Capita Water Use)

Where communities provided local data, these data replaced Council estimates.

Given the variability in water use due to climatic, economic and other conditions, the Council recognizes that actual water use is likely to fluctuate around an average value by approximately 40%. This information is useful and appropriate for regional planning and modeling, but not for local water system capacity planning. For example, local water supply planning also considers peak demand in addition to average daily use. Therefore, these projections are not intended for local water system capacity planning purposes (Metropolitan Council, 2015e).

Industrial processing & commercial – self supplied

The region's total industrial and commercial water demand is expected to remain relatively constant, although the location of water use and the adoption of water conservation strategies are likely to change in ways that are difficult to predict. As more information is collected about water use by private industry and commerce, projections for future industrial water use may change. For example, the region could become more attractive for businesses moving from states facing future water shortages.

Irrigation – self supplied

Agricultural water demand is expected to remain relatively constant or increase slightly in the Twin Cities metropolitan area. Some counties, such as Dakota County, are likely to continue experiencing higher agricultural irrigation rates compared to other counties. In general, expansion of agricultural irrigation systems is assumed to be offset by improved irrigation efficiency and conversion of agricultural land to other development.

Managing and conserving water

The population and economy of the metro area are growing and demands on municipal water systems continue to increase. The metro area has enough water in the short-term, but long-term projections predict potentially significant impacts on aquifers if water continues to be consumed at current or higher rates and using current sources. A key factor in mitigating possible problems is for residents, businesses, water suppliers, and elected officials to work together to become more water-efficient.

There are many opportunities for more efficient water use and conservation across the region, and the benefits of more efficient use and water conservation extend beyond the preservation of water sources and the ecosystems and recreational water features they support. For example, water conservation may also reduce energy and treatment chemical use and offset future infrastructure investments.

The value of water conservation was a common theme at public meetings and other outreach conducted for this Master Plan. Some challenges that need to be overcome were also identified, including:

- Mitigating the impact of decreased water use on utility revenue
- Lack of funding for local education, incentive and enforcement activities
- Different conservation approaches for different users (for example, residents, industries, agricultural irrigators)
- Building public support
- Need for sub-regional and regional coordination regarding conservation targets and implementation

Municipal supply

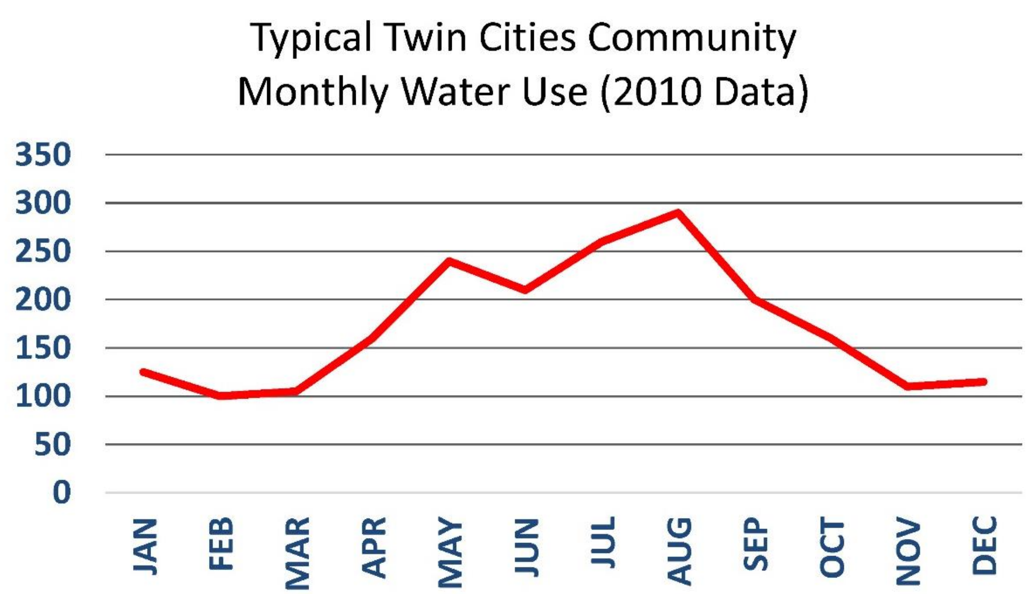
For public water suppliers, conserving water means educating customers, adopting inclined block rates with sufficiently high prices in upper tiers (which charge more per unit of water as water use increases), and enacting water conservation regulations.

Increased water efficiency and conservation may help avoid the expensive cost of adding new storage or treatment capacity. Every gallon saved is water that does not have to be pumped, treated, and delivered – and the saved water can then be reallocated to accommodate new growth or business need. In addition, water conservation may reduce the amount of wastewater that requires treatment.

Setting measurable regional goals for water conservation is useful for implementation and evaluation purposes. For example, while a challenging goal, the region could reduce its total municipal (residential, commercial and industrial) per capita water use to 90 gallons per day. This change means that the region's total 2040 water demand could be met with no regional increase in water use above 2010 amounts – existing water use could be managed to meet the region's needs. The Minnesota DNR, in partnership with the Metropolitan Council, already recommends a community goal for one part of the municipal demand: residential use of less than 75 gallons per person per day.

In most communities, reducing the growth in outdoor water use is perhaps the most valuable approach. Water systems are sized to meet maximum demand, so summer water use can drive substantial investments in infrastructure that is underused the rest of the year. In the metro area, a typical community will use up to 2.3 times more water in one summer month than during a winter month. And summer use is growing; between 1990 and 1994, the summer use was 1.6 times the winter use. The region could reduce its total water use by over 15% by simply returning to outdoor watering practices of this time period. This would conserve 16.8 billion gallons per year.

Figure 12. Seasonal municipal water use in a typical metro area community, 2010.



Private industrial and commercial

A recent survey of private industrial water users in the 11-county metropolitan area by the Minnesota Technical Assistance Program indicates that the three biggest water supply concerns, as they related to industrial water-use processes, include: water discharge regulations, water use regulations, and incoming water quality (Metropolitan Council, 2013a).

The same survey indicated that approximately 40% of industrial groundwater users do not routinely monitor water use for separate industrial processes; only total facility use is monitored. In this situation, water audits can identify a variety of opportunities for water and cost savings.

When industry and commerce do implement conservation, the benefits can be significant. For example, a small project with the Minnesota Technical Assistance Program in 2012 conducted seven one-day site assessments, identifying opportunities to save 71.9 million gallons per year. At three of those sites, changes identified through follow-up projects calculated savings of 44 million gallons annually and savings of $360,000 per year (Metropolitan Council, 2013a).

Agricultural

Agricultural water use is one of the largest water uses in Minnesota, including Dakota County in the metro area. Irrigation is a significant consumptive use of water that can adversely impact stream flows, groundwater availability, and natural ecosystems although the level at which irrigation is sustainable is still unknown.

Irrigation management is a recommended best management practice in the Agricultural Best Management Practices Handbook for Minnesota. Along with optimizing available water supplies, irrigation management can support additional objectives such as reducing non-point source pollution of surface and groundwater resources and energy use.

Conservation toolbox

The Council has developed a free on-line conservation tool (Water Conservation Toolbox) that residents, utilities, and communities can use to select an optimal mix of conservation measures that will maximize conservation in a way that makes economic sense for them.

The Conservation Toolbox includes a variety of information, including best management practices that target residential irrigation, information about sustainable conservation rate structures, and example ordinances that support water conservation.

4 Water Supply Sources

The Twin Cities metropolitan area is fortunate to have relatively abundant water resources. The Mississippi River and the region's prolific aquifers provide residents with reliable water supplies, while its rivers and lakes serve commerce, support wildlife, and offer people a variety of recreational opportunities.

No single source supplies the region's water demand, as shown in Chapter 3. Instead, a combination of sources provides the Twin Cities metropolitan area with water to meet its current and growing needs: groundwater, surface water, stormwater, and reclaimed wastewater.

This chapter describes the major water supply sources available to the region. The chapter also summarizes challenges and opportunities identified by the region's water supply managers and decision-makers. Plans to use these sources for current and future demand need to consider the issues presented in Chapter 5.

Supplementing existing sources with additional approaches

This plan recognizes that, across most of the metropolitan area, many communities rely on only one source of water. Local governments, businesses, public institutions, and private households have together invested many millions of dollars in the existing water supply infrastructure. The Metropolitan Council recognizes the value of these past investments and supports plans that leverage these existing community investments in infrastructure within the regional and local sustainable limits of water sources.

Where demand exceeds the estimated sustainable limits of current sources, as discussed under "Limitations on sources" later in this chapter, water conservation and a combination of other sources may be used to reduce demand for groundwater or augment groundwater to support demand.

Each community may consider which combination of water supply approaches work best for them. Some strategies, like water conservation, can begin immediately and eliminate the need for or buy time to consider additional options. Other strategies, like expanding surface water infrastructure, take longer to implement but can alleviate pressure on groundwater systems in areas where projected water demand exceeds the sustainable limits of groundwater sources. Much like investing, a deliberate collection of water supply sources, programs, and infrastructure will provide us with the best short and long-term water supply options.

In some areas, expansion of surface water use to supply potable water has the dual benefit of reducing groundwater withdrawals and improving the suitability of reclaimed water for industrial and irrigation uses, by reducing the use of water softeners and resulting chloride concentrations in wastewater.

In other areas, addition of groundwater wells can provide a backup source of water to communities relying solely on surface water during extreme drought or contamination events.

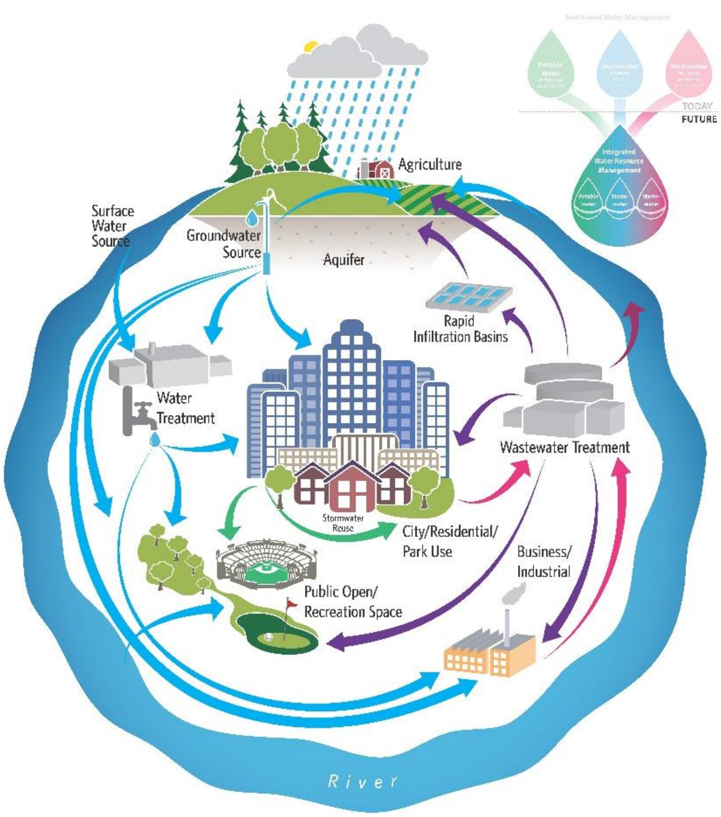
Stormwater can be collected as precipitation runs off from impermeable surfaces, such as rooftops, and stored for future use. Like groundwater wells, stormwater reuse projects can be installed as development occurs, providing a local water source as local growth occurs. Stormwater is used as a relatively minor water supply throughout the region; it is most commonly used for irrigating turf areas. While still a minor source serving non-potable needs, this source is expected to grow.

Irrigation of urban non-crop areas, such as golf courses, landscaping and athletic fields, may be especially well suited for using stormwater since they represent a significant water demand and water quality requirements are less of a concern. Based on preliminary work done in Dakota County, it appears feasible that some volume of groundwater demand for these purposes could be offset with stormwater capture and use. In the northern portion of Dakota County, these uses totaled 257 million gallons in 2010 (0.7 million gallons per day), or just over one percent of annual non-winter runoff (Metropolitan Council, 2015b).

Reclaimed wastewater has potential for both recharging groundwater and reducing potable water demand by providing an alternate source for non-potable purposes such as industrial cooling, irrigation, and toilet flushing. Year-round reuse of wastewater could include recharging groundwater, industrial cooling, and other non-potable use. Seasonal possibilities include irrigation of agricultural land, golf courses, parks, and lawns. Each type of purpose has water quality requirements that may require additional wastewater treatment before it is distributed and used.

There is no single solution for ensuring a long-term sustainable water supply across the metro area, but all solutions are likely to include some combination of the sources discussed in this chapter.

Figure 13. Water cycle illustrating opportunities for integrated water resource planning. Some of these approaches are in use already, while others may be future approaches.



Many opportunities exist throughout the hydrologic cycle to enhance and thereby expand available water supply. For example, best management practices for stormwater may enhance aquifer recharge and provide reuse opportunities.

Each of the region's water supply sources has unique benefits and obstacles. If managed together, however, they have the capacity to serve the region's water supply needs now and into the future.

The Council is committed to working with partners to protect, conserve, and utilize all sources of water in the region.

Water supply sources

The region has a diverse collection of water supply sources, as show on the map in Figure 14. They include surface water primarily supplied from the area designated as the Mississippi River source water protection area upstream of Fridley and the Vadnais Lake Chain of Lakes (blue and white stripes), groundwater from a series of aquifers distributed across the region (blue), reclaimed wastewater from several regional wastewater treatment facilities (green squares), and stormwater across the entire area.

Figure 14. Sources of water that supply potable and non-potable uses in the Twin Cities metropolitan area.

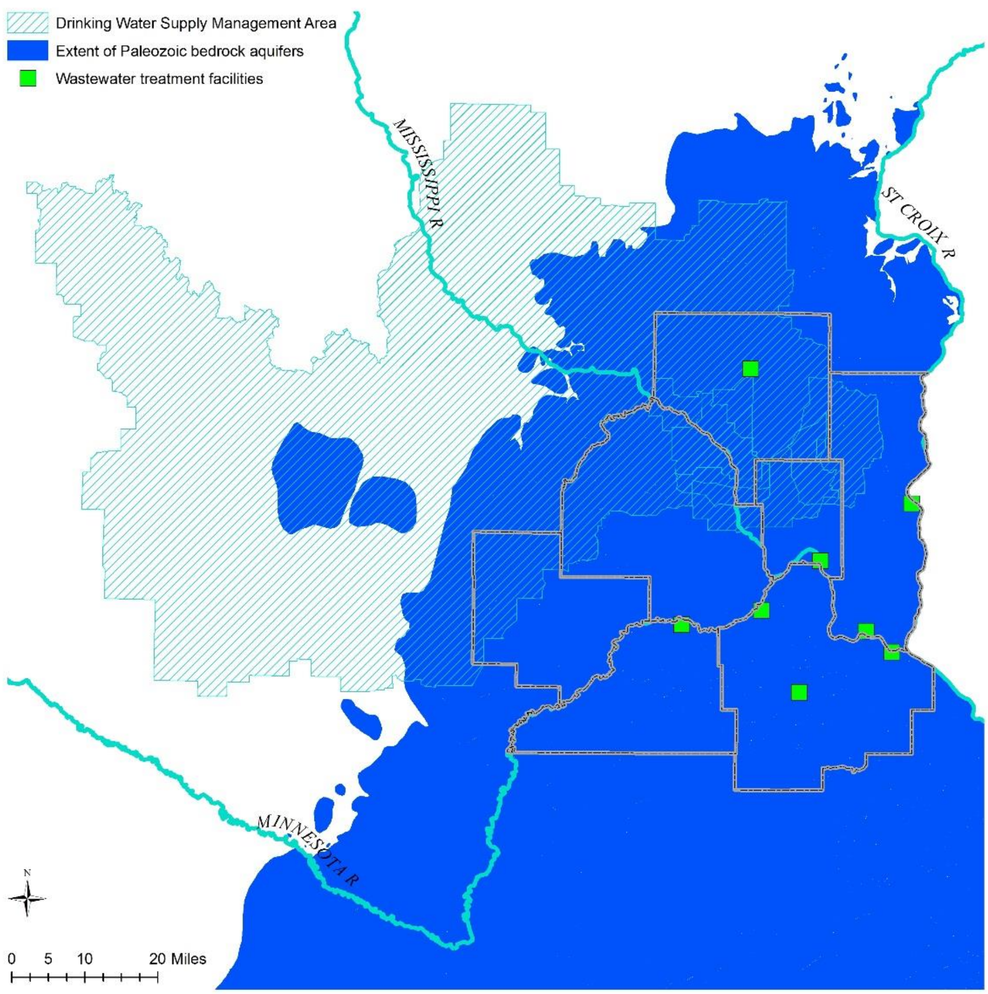


Table 2. Summary of water supply sources in the Twin Cities metro area, including key management considerations; the estimated amount of water sustainably available from sources in areas where infrastructure currently exists; or, in the case of stormwater, has current support for implementation and the number of municipal water supply systems currently supplied by each source.

Source & Management Considerations	Estimated sustainable amount available	Municipal supply systems currently using this source
Quaternary Aquifer ▪ Challenging to identify most productive sand and gravel layers ▪ First aquifer to experience changes in recharge quantity and quality ▪ Most likely of all aquifer to be connected to surface waters ▪ Treatment needs for naturally and manmade contamination varies across region ▪ Response to recharge may change along with climate, land use • Funding challenges may include project phasing opportunities, eligibility for funding sources, partnerships, etc.	About 70-90 MGD	24
Prairie du Chien-Jordan Aquifer ▪ Not available to some growing communities ▪ As the most heavily used aquifer in parts of the region, greater likelihood of water use conflict ▪ Connected to some protected surface waters ▪ Treatment needs for naturally and manmade contamination varies across region ▪ Response to recharge may change along with climate, land use • Funding challenges may include project phasing opportunities, eligibility for funding sources, partnerships, etc.	About 280-330 MGD	83
Tunnel City-Wonewoc Aquifer • Productivity varies greatly across the region and is highest where it is fractured or weathered • Connected to some protected surface waters • Treatment needs for naturally and manmade contamination varies across region • Low recharge rate in parts of the region; response to recharge may change with climate and land use • Funding challenges may include project phasing opportunities, eligibility for funding sources, partnerships, etc.	About 70-90 MGD	30
Mt. Simon-Hinckley Aquifer • Use of this aquifer is restricted by Minnesota law • Very slow recharge rate, response to recharge may change as climate and land use changes • Significant groundwater mining has occurred historically • Treatment needs for natural contamination vary across region • Funding challenges may include project phasing opportunities, eligibility for funding sources, partnerships, etc.	About 10 MGD	35

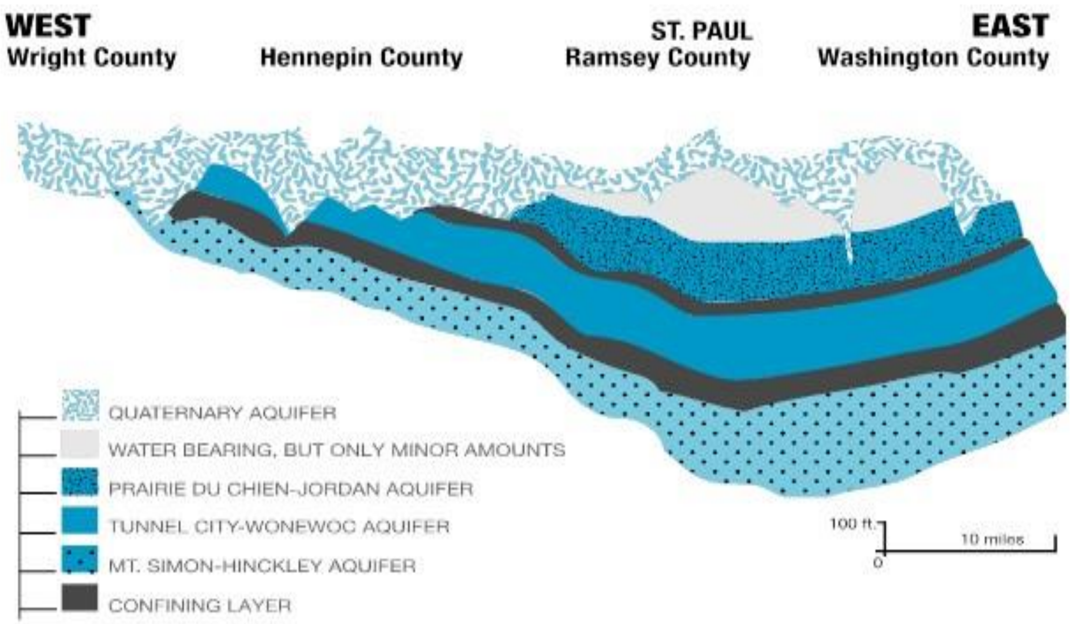
Source & Management Considerations	Estimated sustainable amount available	Municipal supply systems currently using this source
Mississippi River • Coordination with Minneapolis Water Works and St. Paul • Regional Water Services • Drought and related risk of water shortages • Vulnerability to contamination and related monitoring and treatment requirements • Limited ability to manage and protect water quality within the watershed • Limited access to source and related distribution costs • Funding challenges may include project phasing opportunities, eligibility for funding sources, partnerships, etc.	About 1,940 MGD, the flow exceeded 90% of the time at Anoka, MN	2: Minneapolis and St. Paul and the communities that they serve
Minnesota River • Drought and related risk of water shortages • Vulnerability to contamination and related monitoring and treatment requirements • Limited ability to manage and protect water quality within the watershed • Limited access to source and related distribution costs • Funding challenges may include project phasing opportunities, eligibility for funding sources, partnerships, etc.	About 320 MGD, the flow exceeded 90% of the time at Jordan, MN	0
St. Croix River • Drought and related risk of water shortages • Vulnerability to contamination and related monitoring and treatment requirements • Additional federal and state protections in place • Limited ability to manage and protect water quality within the watershed • Limited access to source and related distribution costs • Funding challenges may include project phasing opportunities, eligibility for funding sources, partnerships, etc.	About 1,290 MGD, the flow exceeded 90% of the time at St. Croix Falls, WI	0
Stormwater • Drought • Availability limited seasonally and by access to land for collection and storage • Vulnerability to contamination • Regulatory limits to protect public and environmental health • Water quality requirements for potential uses • Inconsistent watershed rules • Funding challenges may include project phasing opportunities, eligibility for funding sources, partnerships, etc.	Less than 100 MGD	All
Reclaimed Wastewater • Seasonality of some non-potable demand • Geologic limitations on the effectiveness of reclaimed wastewater water as a source for enhanced aquifer recharge • Public acceptance • Regulatory limits to protect public and environmental health • Funding challenges may include project phasing opportunities, eligibility for funding sources, partnerships, etc.	Up to 250 MGD, the average flow in regional wastewater treatment facilities	1: East Bethel, as potential non-potable water source

Limitations on sources

Groundwater

Although there are several aquifers in the region, they are not equally distributed. For example, some communities in the western metro, such as Norwood Young America – do not have access to the productive Prairie du Chien-Jordan Aquifer. Figure 15 illustrates the aquifer layers and their curved shaped beneath the Twin Cities metropolitan area.

Figure 15. Geologic cross-section of aquifers service the metro area, from east to west across the northern metro.



The amount of groundwater that can be sustainably withdrawn depends on the amount of recharge available, the rock properties that control how easily water moves through the aquifer, and human- imposed limits that have been established to protect public health, maintain ecosystem services, and reduce water use conflicts.

Recharge – the ultimate sources of water to the groundwater system – has been estimated by the Metropolitan Council, U.S. Geological Survey and Minnesota Pollution Control Agency. The range of these estimates suggest that 900 to 1,200 million gallons per day is the upper limit on the amount of groundwater available for all needs, including baseflow to surface waters, drinking water, and to support industry and commerce (Metropolitan Council, 2014d).

To understand what portion of potential recharge may be sustainably available from the groundwater system, regional groundwater flow modeling can also be used to explore approximately the limit (as an estimated range) on how much groundwater can be pumped without causing unacceptable conditions (Appendix 4). These conditions were incorporated into a regional groundwater model scenario that tests the sustainable capacity of aquifers in areas where high capacity wells already exist, under the assumptions that:

- Sustainable groundwater pumping should maintain aquifer levels consistent with safe yield conditions defined in Minnesota statutes.

- Sustainable groundwater pumping should maintain surface water by limiting withdrawals, including diversions of groundwater that supports them, to maintain protected flows and elevations
- Sustainable groundwater pumping should minimize impacts to directions of groundwater flow in areas where groundwater contamination has, or may, result in risks to the public health

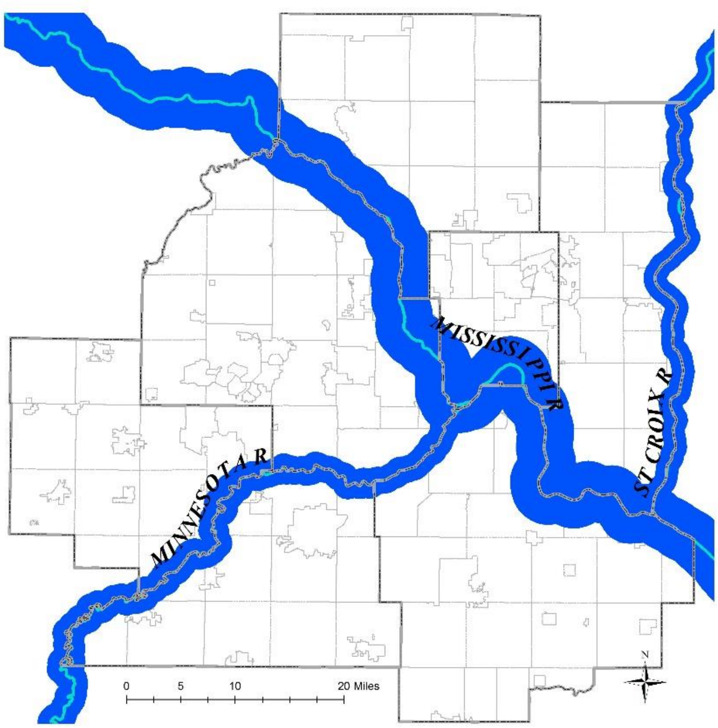
Results suggest that the region might sustainably withdraw approximately 400-500 million gallons of groundwater per day in areas where high-capacity wells currently exist (Appendix 4). However, even when groundwater withdrawals are less than that, local limitations may still exist due to proximity of sensitive local features such as neighboring wells or a trout stream.

This calculation is an estimate of sustainable withdrawals, and can be used as a guide to regional water supply management. Additional data produced by expanded monitoring and aquifer analysis can be used to refine this estimate. The estimate is most sensitive to the factors used to define sustainable conditions. This type of modeling approach may be a useful tool to evaluate how changing definitions of sustainability affect our understanding of water supply availability. Chapter 7 includes a process to continue this type of evaluation in partnership with communities and other stakeholders.

Surface water

The region's most visible water supply source is its surface water. Three major rivers, hundreds of streams and ditches, and thousands of lakes and wetlands provide varying amounts of water. This Master Water Supply Plan focuses primarily on one surface water source, the Mississippi River, but also provides information about two other large potential sources: the Minnesota River and the Saint Croix River (Figure 16).

Figure 16. The three major rivers in the Twin Cities metropolitan area, sized relative to the amount of flow that is likely to occur at least 90% of the time.



Use of the Minnesota, Mississippi and St. Croix rivers is limited by a variety of climatic, economic, water quality, regulatory, and ecological reasons.

For example, average annual flow for the Minnesota (at Jordan, MN), Mississippi (at Anoka, MN) and St. Croix (Stillwater, MN) are 4,200, 9,000, and 3,100 MGD respectively. However, flow varies considerably over time. Ninety percent of the time, flow in the Minnesota River at Jordan exceeds 320 MGD; flow in the Mississippi River at Anoka exceeds 1,940 MGD; and flow in the St. Croix River at St. Croix Falls exceeds 1,290 MGD (Dadaser-Celik and Stefan, 2009). Another way to consider low flow is the "7Q10" value. This value refers to the lowest consecutive seven-day flow that a river experiences on average at least once every 10 years, and it has been used to define low flows for the purpose of setting permit limits. The Minnesota Pollution Control Agency has established the 7Q10 value for the Minnesota River near Jordan as 175 MGD (272 cfs).

Low flow in the Mississippi River is of particular concern and is included in the State Drought Plan, which includes a matrix of drought phase triggers. When flow is less than 2,000 cubic feet per second (1,293 MGD) for five consecutive days, public water suppliers and other water users drawing from the Mississippi River implement appropriate conservation measures. Should flow fall below 1,000 cubic feet per second (646 MGD) for five consecutive days, all public water suppliers in the Twin Cities metro area implement mandatory water use reductions with the goal of reducing water use to January levels (Minnesota Department of Natural Resources, 2009).

Much discussion about these limits followed the 1988 drought. Critical flow of the Mississippi River was determined to be a flow that supports basic needs for water supply, power and navigation; a minimum flow of 554 cubic feet per second (358 MGD) is needed for these purposes (Metropolitan Council, 1990). Work done by the U.S. Geological Survey indicate that there is less than a 1% probability of flow on the Mississippi River falling below 600 cubic feet per second in any given year; the recurrence interval for flow less than 600 cubic feet per second is 100 years (Kessler and Lorenz, 2010).

Stormwater

Currently, the State of Minnesota does not have a state-specific code applicable to stormwater collection and reuse. The MPCA has developed some guidelines for the use of reclaimed water, and the Metropolitan Council has summarized these and other information in its Stormwater Reuse Guide (Metropolitan Council, 2011).

Because of its direct tie to precipitation, stormwater is not consistently available for reuse, so storage is required to ensure water is available when needed. The amount of stormwater available at any given location is also a factor of the size and amount of impervious surface in the area contributing to the site.

More work is needed to evaluate the potential for stormwater reuse across the region, but a rough estimate can be made of the amount of stormwater available for reuse, based on some simplifying assumptions:

- A one acre parking lot generates 27,000 gallons of runoff during a 1" rainfall;
- An average of six 1" rainfall events occur on average in recent years; and
- 245,909 acres of impervious area exist in the metropolitan area.

Given those assumptions, approximately 100 million gallons per day of stormwater water could be available in the region. Stormwater reuse projects are not tracked consistently through the region, so it is uncertain how much stormwater reuse currently exists.

Reclaimed wastewater

Opportunities exist throughout the region to use reclaimed wastewater as a non-potable water source. Reusing treated wastewater to supplement groundwater and surface water as sources of water to support regional growth, where economically feasible, will promote sustainability goals. Feasibility depends on site-specific factors. For instance, proximity to treatment plants, regulatory requirements, water quality needs, distribution system requirements, and the benefits of reuse from a total water perspective all contribute to feasibility. Reclaimed wastewater is one of the region's underutilized water supply sources.

The amount of reclaimed wastewater available for reuse is ultimately limited by the amount of wastewater produced and the number and size of wastewater treatment facilities. The Council currently operates eight wastewater treatment plants, with an average flow of 250 million gallons per day. The design capacity of these plants is 358 million gallons per day. Planned 2040 system capacity is 372 million gallons per day and long term (beyond 2040) is 500 million gallons per day.

The effluent quality and level of treatment varies among the existing wastewater treatment plants. Additional treatment would generally be needed to meet quality requirements for reclaimed water.

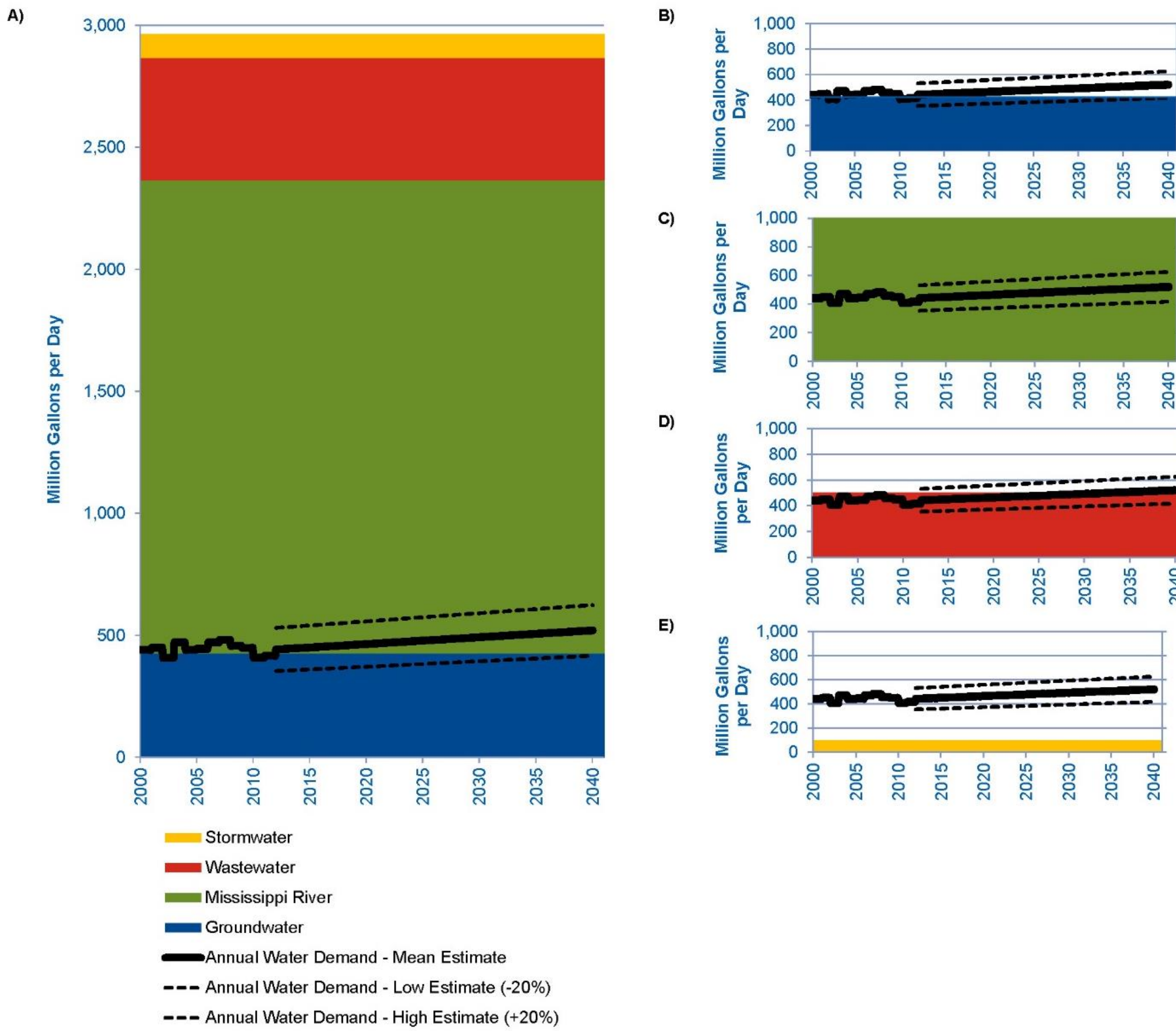
Cost is a key factor in evaluating the feasibility of wastewater reuse. In 2014, Metropolitan Council evaluated reclaimed water demand, water quality needs, and estimated costs in the Southeast Metro. Potential users included in a possible reuse scenario included Flint Hills Refinery, residential and commercial toilet flushing and irrigation in areas of growth between 2010 and 2040, and agricultural irrigation north of and east of the Empire Wastewater Treatment Plant. The treatment and distribution system incremental costs (above the existing treatment) to provide reclaimed water ranged from $5 to $10 per 1,000 gallons. Key factors driving costs are treatment requirements, distribution costs, and seasonality of use.

Estimated amount of water available to the metro area

The region can sustainably access about four billion gallons per day, considering that the metro area has access to water from several sources including stormwater, reclaimed wastewater, surface water and groundwater - and our current understanding of water supply sustainability.

Although the region generally has enough water to meet current and future demand from all available sources, each source is limited and vulnerable to a variety of factors. The only single source capable of supplying the region's demand is surface water, which is also the most vulnerable to drought and contamination.

Figure 17. Comparison of historical and projected water demand versus the estimated amount of water sustainably available from A) all available sources, B) groundwater alone, C) Mississippi River alone, D) wastewater (potential reuse for non-potable purposes), and E) stormwater (potential reuse for non-potable purposes).



5 Key Water Supply Issues

Our region is growing and our environment is changing. The region cannot take easy access to water for granted, and water supply planning should be done when there is time to develop workable solutions, not when a crisis threatens. Good planning now will keep our water supply safe and plentiful for generations to come. At the regional level, planning can provide a comprehensive look at the cumulative impacts of individual decisions.

This chapter discusses the water supply issues the region faces and how they vary across the region, including regulatory considerations, water use, conflicts and well interference, aquifer decline, surface water and ecosystem impacts, contamination, uncertainty in aquifer properties, reliability and funding.

This chapter draws on mapping, monitoring networks, and computer modeling to identify the characteristics of water supply issues in the region. This information should be refined with more locally specific information, if available, to better evaluate potential issues. The information is also summarized for each community in Appendix 1.

Water issues change across the region and through time

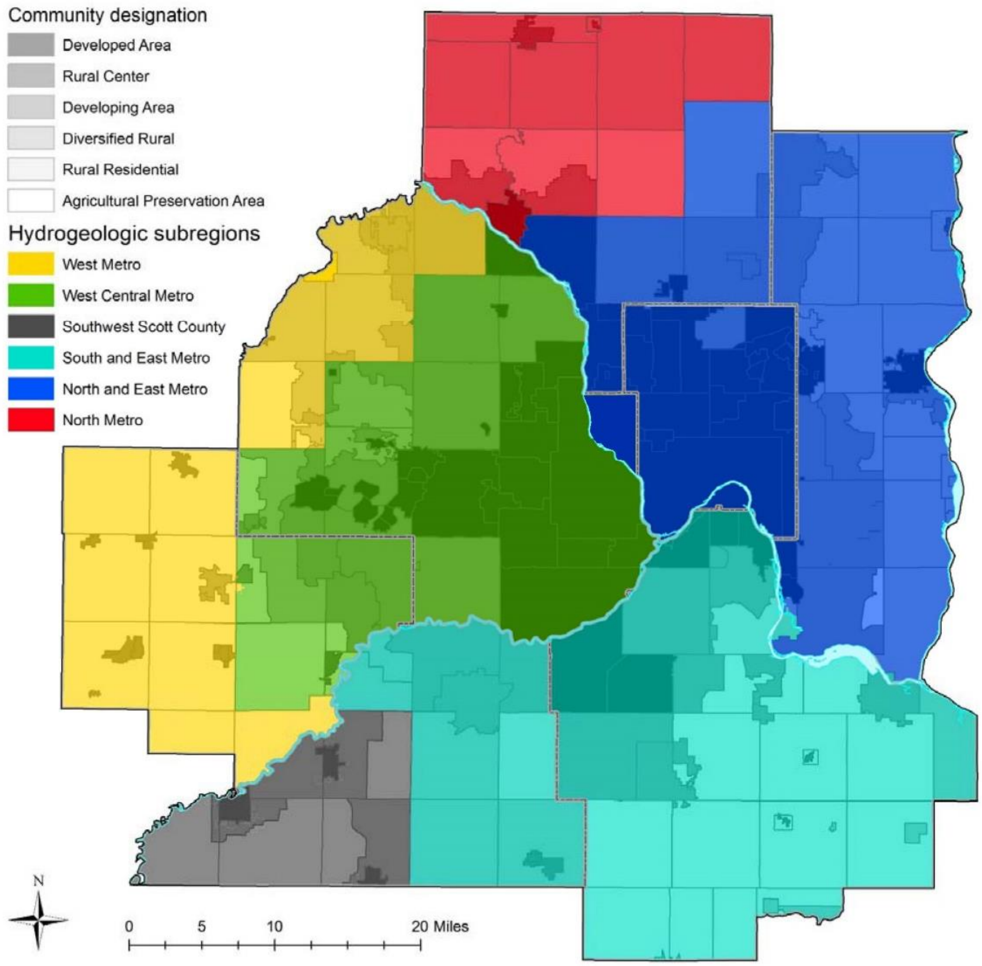
Water issues are different in different parts of the region, and they may vary over time. While water supplies – including a variety of aquifers and surface waters - are regionally abundant, they are not evenly distributed throughout the metropolitan area and may become limited over time due to hard-to-predict events like long term drought or contamination.

In addition, the state of public water supply systems varies greatly across the region. Some communities are fully served by aging water supply systems while others have just begun to develop public water supplies. Rural areas have different issues involving water supply and protection of water sources than their urban counterparts.

Our major rivers – the Minnesota, Mississippi, and St. Croix - transect the region, but most communities do not have direct access to these sources. The groundwater in the metropolitan area is not all connected – groundwater does not flow all the way from Anoka County to Dakota County and vice versa. Consequently, the amount of available groundwater is not uniform from community to community.

Figure 18 illustrates how hydrogeologic conditions and community development combine to create a patchwork of different water supply conditions across the region. Each color represents a different combination of aquifers and groundwater recharge and discharge areas. Different shading illustrates different community development patterns. Darker areas indicate communities served by public water supply systems, and lighter indicates communities mostly served by private wells.

Figure 18. Hydrogeologic conditions and community development create sub-regional differences in water supply planning issues.



The Metropolitan Council recognizes that sustainable water supply planning needs are different from community to community. The Council will work with communities to support information sharing and technical work that meets the various needs of water supply stakeholders in each of the metro area's hydrogeologic sub-regions.

Regulatory considerations

The regulatory complexity of water management in Minnesota has been identified as challenging for decades. Public water suppliers and communities have identified several challenges, including:

- Supplying, treating and distributing water to consumers in compliance with Safe Drinking Water Act standards, water appropriation permits and the well code
- Agency permit requirements that may contradict one another
- Source water protection guidance that limits stormwater infiltration, conflicting with increased requirements for onsite stormwater management
- Minnesota rules preventing use of wells for injection to enhance recharge
- Plumbing code that limits and causes confusion about how water may be reused

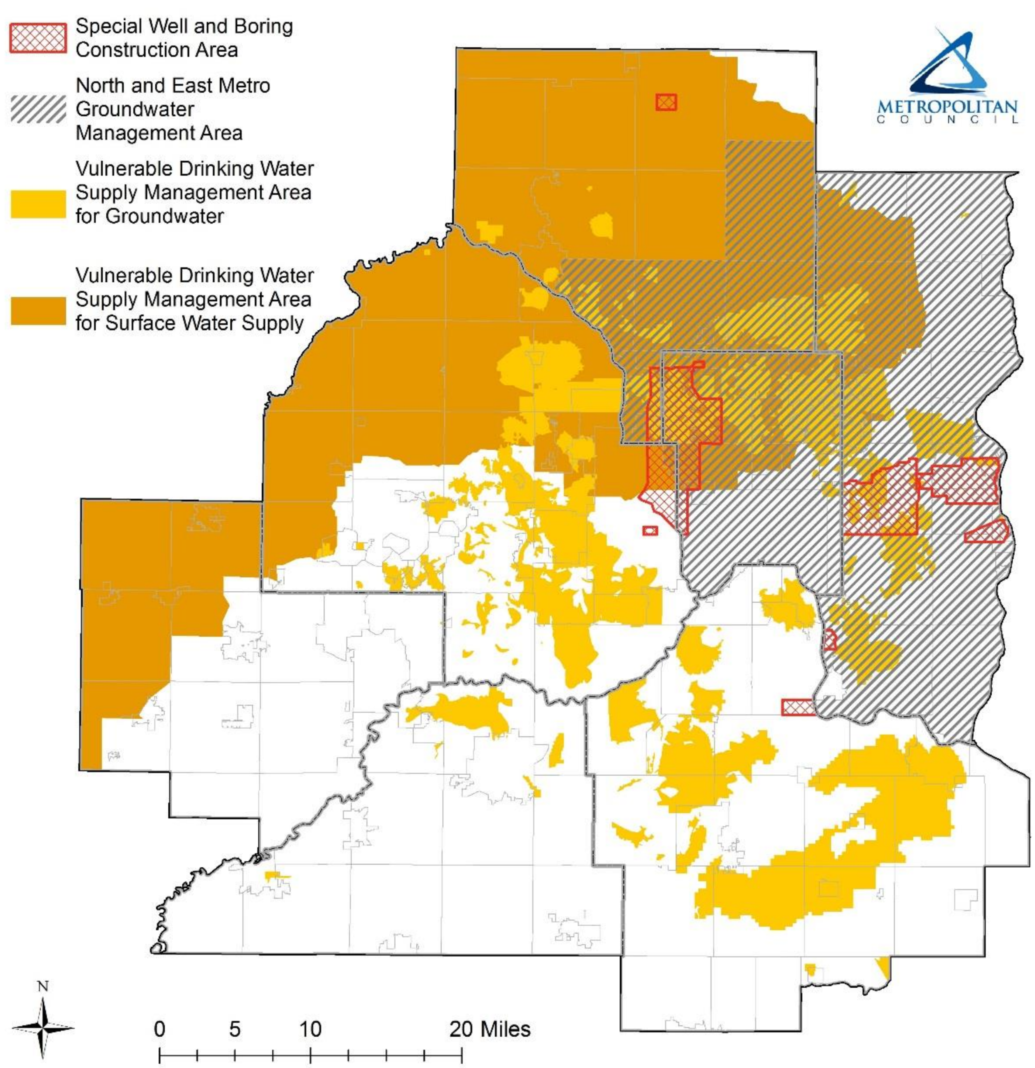
The challenges noted above may be exacerbated in the following special management areas:

- Groundwater Management Area, designated by the Minnesota Department of Natural Resources (DNR)
- Special Well and Boring Construction Areas, designated by the Minnesota Department of Health
- Vulnerable Drinking Water Supply Management Areas (DWSMAs), designated by the Minnesota Department of Health

Figure 19 illustrates DNR-designated Groundwater Management Areas (cross-hatched) and MDH-designated Special Well and Boring Construction Areas (red outlines) and Vulnerable Drinking Water Supply Management Areas for groundwater (light yellow) and surface water (dark yellow).

In these areas, special effort should be made to include all impacted agencies on planning and project teams.

Figure 19. Areas where additional regulatory conditions exist due to documented issues or vulnerability.



Managing water demand

Water demand is the driving factor for water resource planning. Water demand is shaped by various socioeconomic and climate factors, but planning and maintaining efficient systems are common goals.

The following indicators show that changes in development of water supply systems and maintenance or in demand management could result in significant water use reduction:

- Water that is not accounted for (non-revenue) makes up more than 10% of the total water use, which is a goal recommended by the American Water Works Association.
- Residential per capita water demand is greater than 75 gallons per person per day, the goal recommended by the Minnesota DNR.
- Reducing total per capita water use is a goal recommended by the DNR, but it is not decreasing.
- A ratio of maximum demand day to an average demand day of 2.6 is recommended by the DNR, but the actual ratio exceeds that level.

The challenges of water demand management vary throughout the region, primarily because of differences in level of development. For example, individual public water suppliers vary in the amount of unaccounted water they report based on inconsistent identification of the causes for unaccounted water use. For example, some communities report all non-revenue water use as “unaccounted”, while others only report water that was lost through leaks. Changes in metering systems or the age of the infrastructure can also affect estimates of unaccounted water use. New development may be associated with higher per capita use and peak summer water use as new vegetation is established. Older communities with aging infrastructure may have higher amounts of unaccounted for water use.

Water use conflicts and well interference

There are tens of thousands of wells in the region, supplying diverse users. Where water users compete, conflicts must be resolved – often a costly process. Water use conflict is defined in Minnesota rules part 6115.0740, as a condition where the available supply of water in a given area is limited by a competing demand that exceeds the reasonably available waters. However, even where there is adequate water for a proposed project, a well interference can occur if that project interferes with the ability to withdraw water from a public water supply well or private domestic well.

The following are specific indicators of increased risk of well interference:

- Documented well interference problems
- High volume water users in proximity to residential wells

Because private wells are widespread in the metro area, there is a potential for well interference for all water users. Complaints about well interferences are reported to the Minnesota DNR, which then works to resolve the issue through the process set forth in Minnesota Rules, Part 6115.0730.

Aquifer water levels

Aquifer levels are useful for providing information about groundwater flow directions, relationships between groundwater and surface water systems, and water levels near wells, so the issue of aquifer water levels is closely related to issues like water quality, relationships between surface water and groundwater relationships, and well interference. Monitoring networks provide information about current and past conditions, and modeling is a valuable tool to anticipate potential future conditions.

In several parts of the metropolitan area, historical DNR monitoring data of groundwater levels suggest long-term declines. Groundwater levels in other parts of the metro area have remained relatively constant over time. One example of long-term decline can be found in Orono, Minnesota where groundwater-level monitoring has documented declines of one foot per year in the Prairie du Chien- Jordan aquifer. However, water levels in the St. Peter aquifer in Roseville have generally trended upward since the early 1990s.

While some parts of the metro area have not yet experienced groundwater declines, existing data show that aquifer decline is an issue that needs to be addressed in parts of our region (Figure 20). Aquifer-decline issues vary throughout the region, based primarily on differences in aquifer characteristics and degree of development.

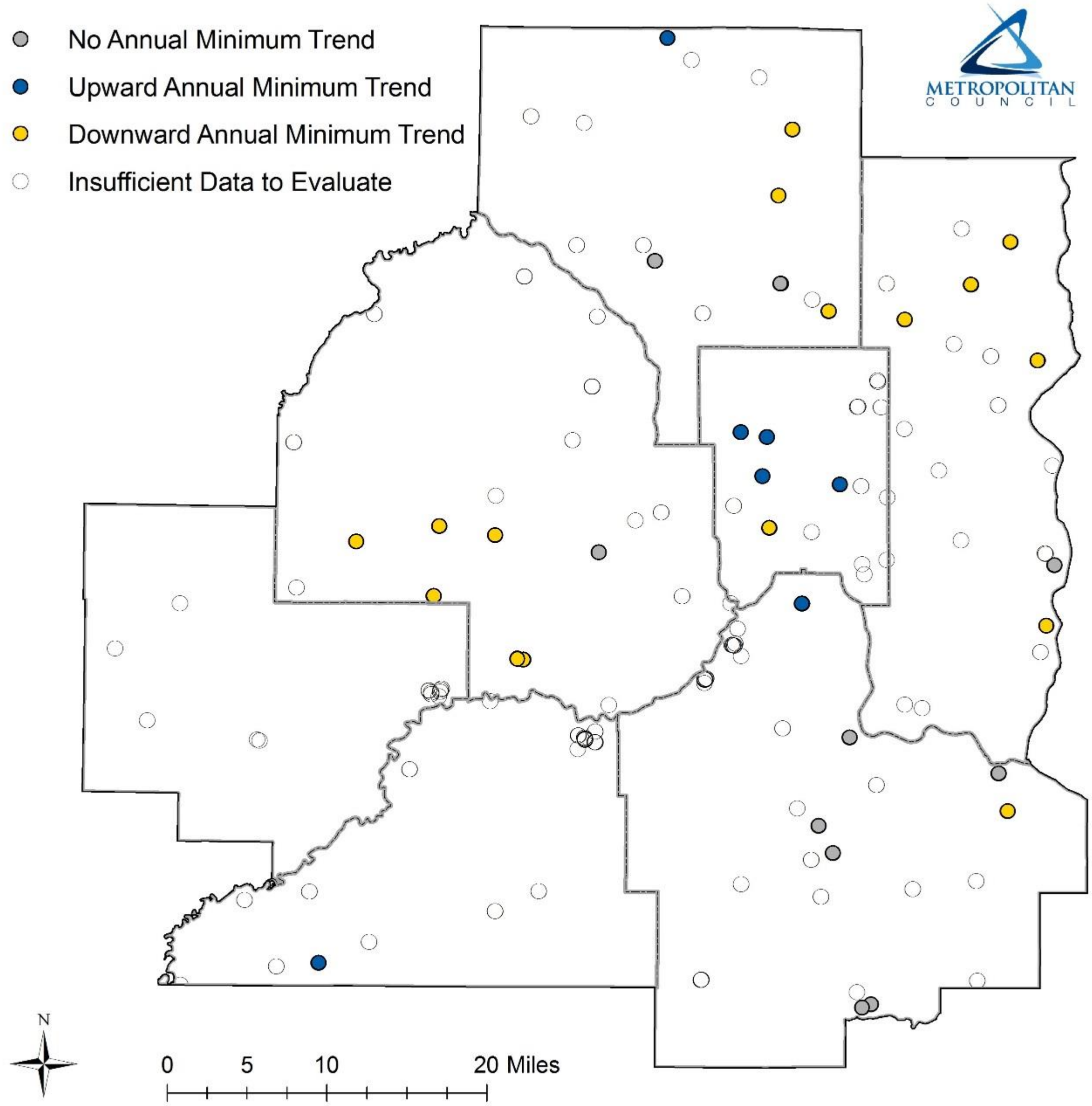
The Minnesota DNR evaluates water level impacts on confined aquifers using the definition of safe yield found in Minnesota rules, part 6115.0670. Those rules define safe yield as the amount of groundwater that can be withdrawn without degrading water quality or causing a continual decline in groundwater levels that results in a change from artesian to water table condition. For unconfined aquifers, Minnesota rules (chapter 6115) requires that withdrawal from the aquifer system cannot exceed long-term average recharge to the aquifer system. Also, Minnesota statues (chapter 103G) protects surface waters from harmful impacts to groundwater withdrawal.

The following data indicate increased risk of significant aquifer water level decline:

- DNR observation well data show a declining trend in aquifer levels, suggesting groundwater withdrawals exceed safe yield amounts, as defined above
- Regional groundwater flow modeling highlights areas where the range of projected 2040 water demand may exceed safe yield amounts, as defined above, if current use patterns and water sources are used to meet that demand. This finding may be considered a warning threshold to allow time for implementing contingency plans if water levels decline

Figure 20 is a map of DNR observation wells that monitor aquifer levels in a variety of aquifers where enough data is available for trend analysis. Trends in annual minimum water levels were developed for wells with complete records between 1993 and 2012. Blue circles indicate an upward trend in the annual minimum water level during that time period. Yellow circles show a downward trend, and white circles indicate wells without enough data to evaluate trends. This map does not identify the cause of these trends, which may represent aquifer response to climate variability or groundwater pumping or both. Regardless of the cause, however, groundwater in areas of downward trends should be reviewed regularly and water levels in nearby wells monitored to prepare for any needed management changes (State of Minnesota, 2014).

Figure 20. Active DNR observation well and trends in annual water level minima (1993 – 2012).



Regional groundwater flow modeling (Metro Model 3) is a tool that allows water supply planners to consider a range of potential future aquifer levels under a set of planned and alternative water demands and sources (Appendix 3). Metro Model 3 is a planning tool, not a regulatory tool, and it provides information to support regional planning and cooperation to ensure sustainability.

Regional groundwater modeling, which simultaneously evaluates the combined impacts of all wells in the region, suggests that our current (2015) plans for water supply are likely to cause further declines in aquifer levels.

Figure 21 is a map of Metro Model 3 model scenarios illustrating predicted aquifer declines under projected 2040 groundwater pumping conditions, which are expected to fall within a range 20% above or below the 2040 projection described in Appendix 2:

- Prairie du Chien-Jordan aquifer (left column)

- Water Table aquifer under sensitive surface waters (middle column)
- Tunnel City-Wonewoc aquifer (right column)

On the maps:

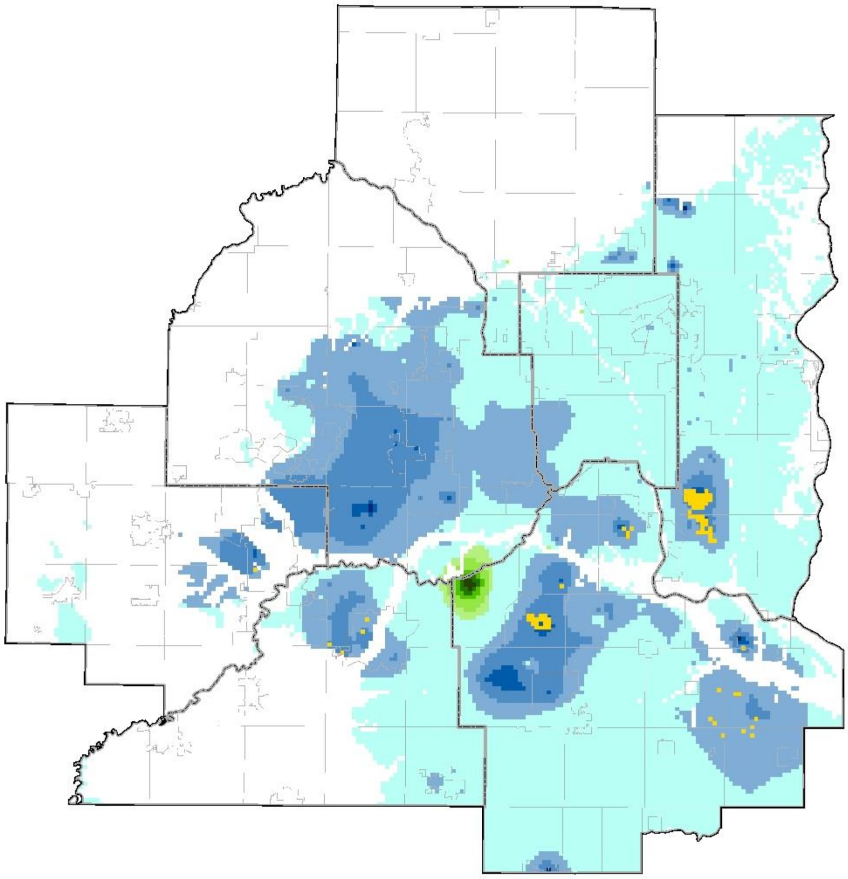
- Green areas show areas where water levels are likely to rise compared to baseline 2010 pumping conditions
- Blue-green areas illustrate places that are likely to experience relatively minor or no water level decline
- Darker blue shows areas where water levels are likely to drop the most
- Yellow illustrates where confined aquifers are especially sensitive to water level declines and where local monitoring, analysis and planning should be done to ensure that groundwater pumping does not exceed safe yield conditions, as defined in Minnesota Rules (part 6115.0630)

These model results include some uncertainty, which is discussed later in this chapter. The regional groundwater flow model, along with water demand projections, provides useful information to consider as part of regional growth planning. It is the best tool available to illustrate "the big picture" pattern of aquifer decline that may occur if 2040 demand is supplied solely by currently (2015) planned sources.

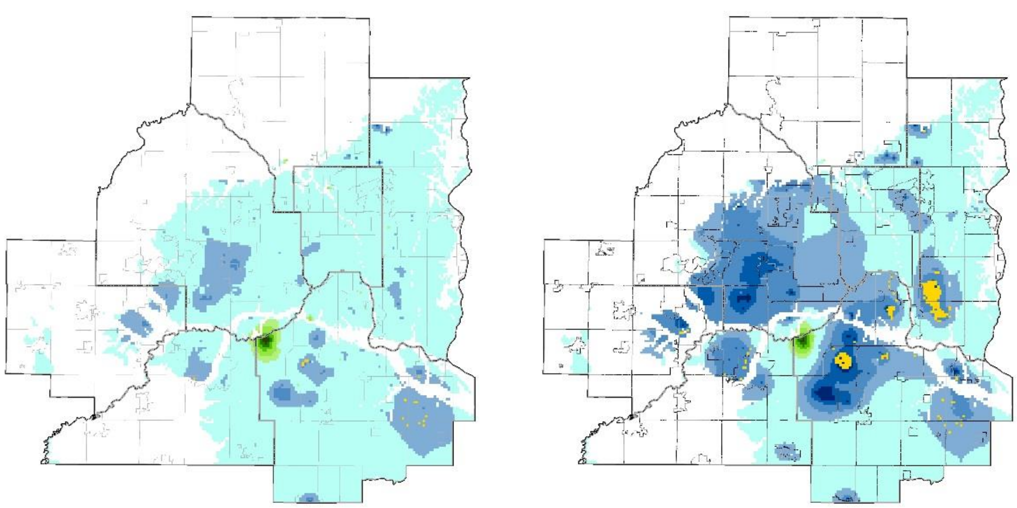
Figure 21. Potential groundwater level declines under projected 2040 pumping conditions, should future demand be met using current water supply sources. These results are based on regional groundwater flow modeling using Metro Model 3 for the Prairie du Chien-Jordan aquifer (figures 21A and 21B), the Tunnel City-Wonewoc aquifer (figures 21C and 21D), and the regional Water Table aquifer beneath potentially connected surface waters (figures 21E and 21F). The legend below applies to all maps in this figure set.

> 40 feet of rebound	5 to 10 feet of drawdown
30 to 40 feet of rebound	10 to 20 feet of drawdown
20 to 30 feet of rebound	20 to 30 feet of drawdown
10 to 20 feet of rebound	30 to 40 feet of drawdown
5 to 10 feet of rebound	> 40 feet of drawdown
< 3.28 feet (1 meter) of change	Drawdown exceeds 50% of available head

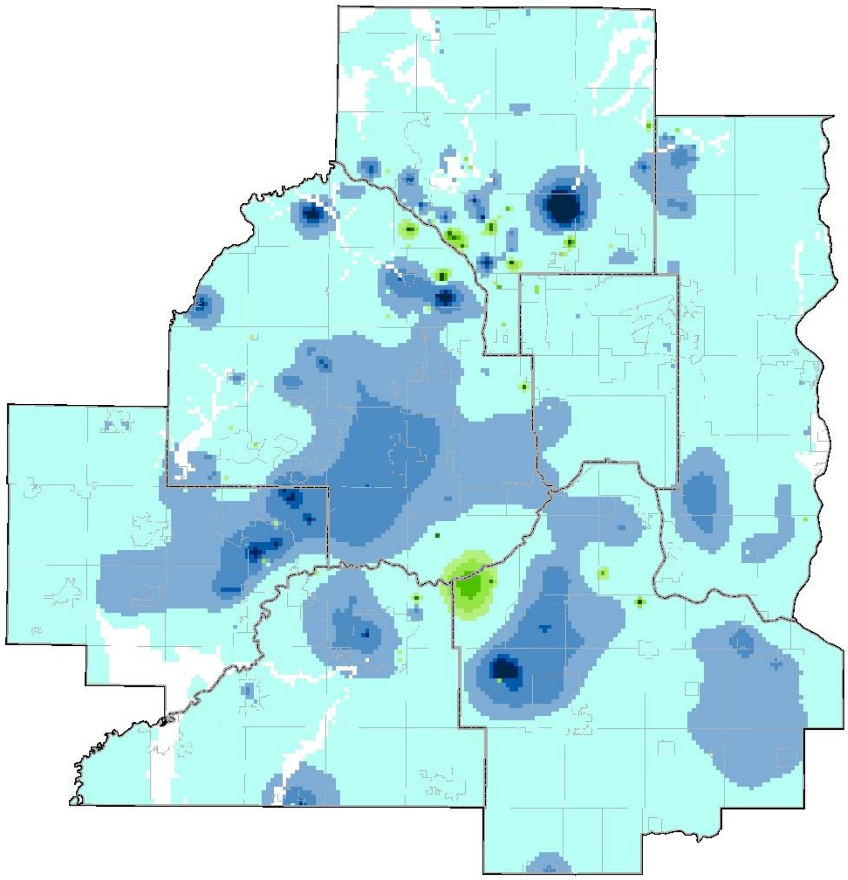
A) Drawdown in the Prairie du Chein-Jordan aquifer under average projected pumping.



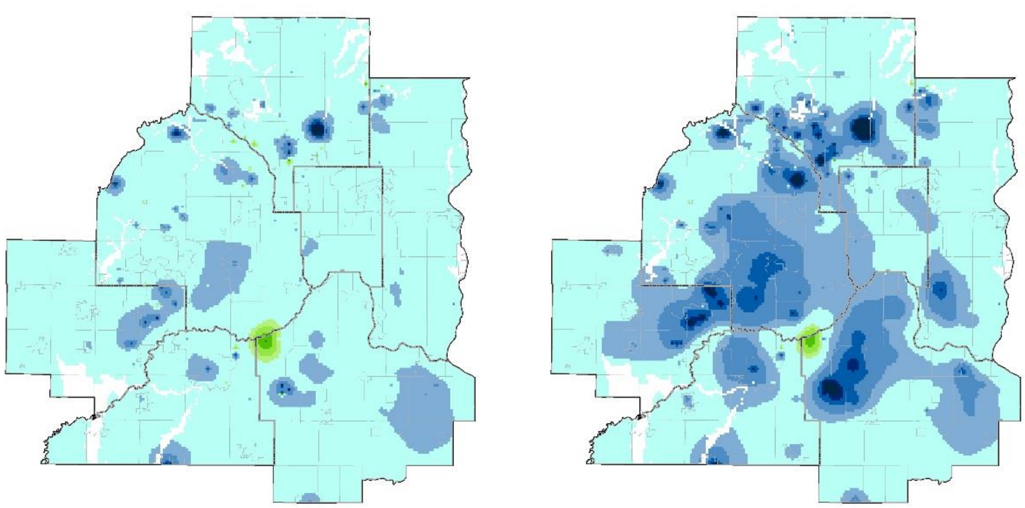
B) Drawdown in the Prairie du Chein-Jordan aquifer should under average projected pumping be reduced (map of the left) or increased (map on the right) by 20%.



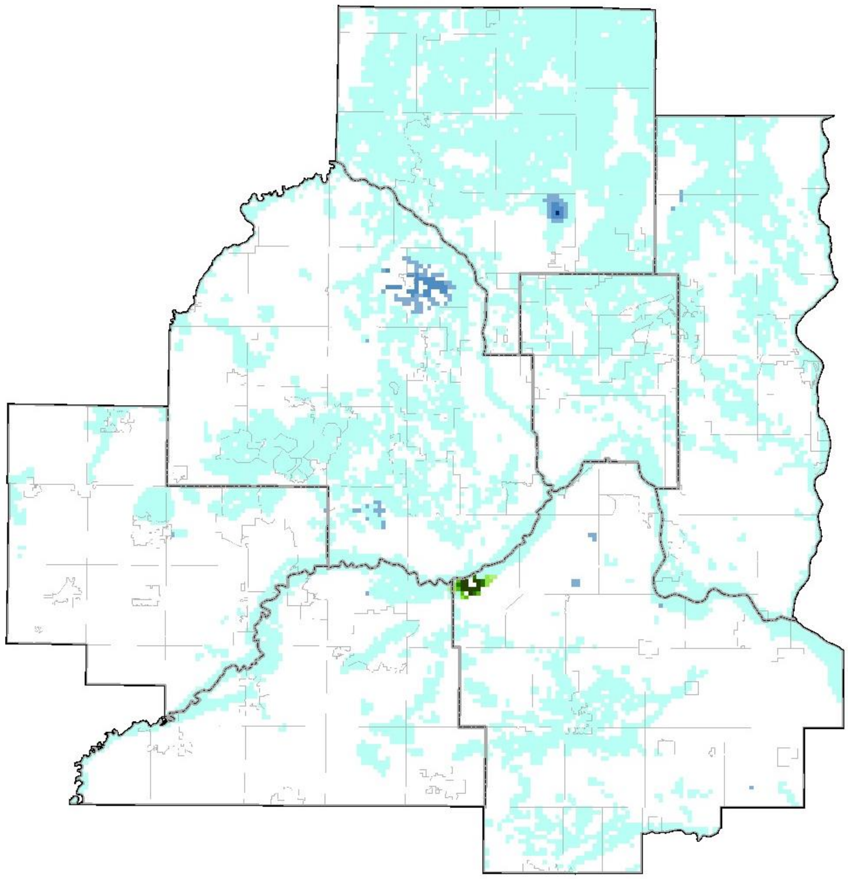
C) Drawdown in the Tunnel City-Wonewoc aquifer under average projected pumping.



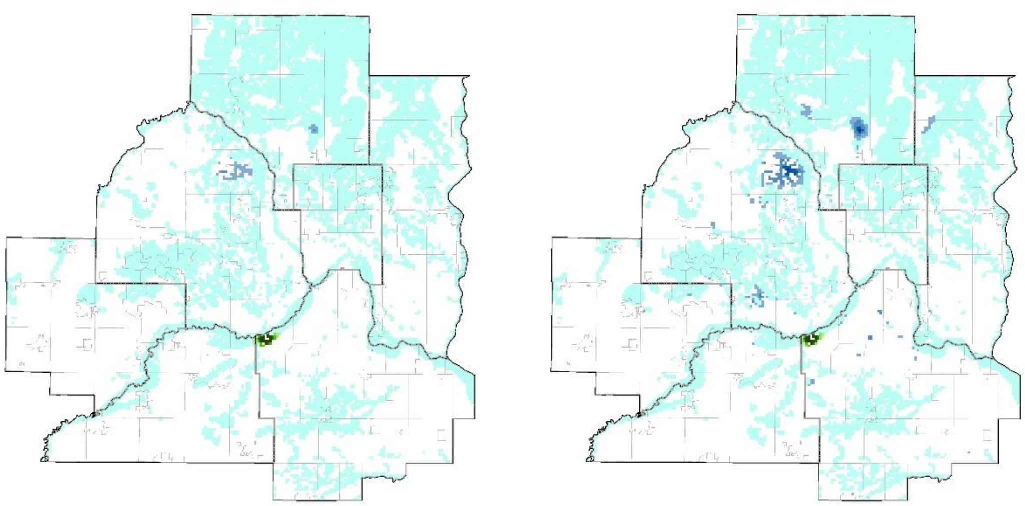
D) Drawdown in the Tunnel City-Wonewoc aquifer should under average projected pumping be reduced (map of the left) or increased (map on the right) by 20%.



E) Drawdown in the regional Water Table aquifer beneath potentially connected surface waters, under average projected pumping.



F) Drawdown in the regional Water Table aquifer beneath potentially connected surface waters under average projected pumping, should under average projected pumping be reduced (map of the left) or increased (map on the right) by 20%.



Groundwater-surface water relationships

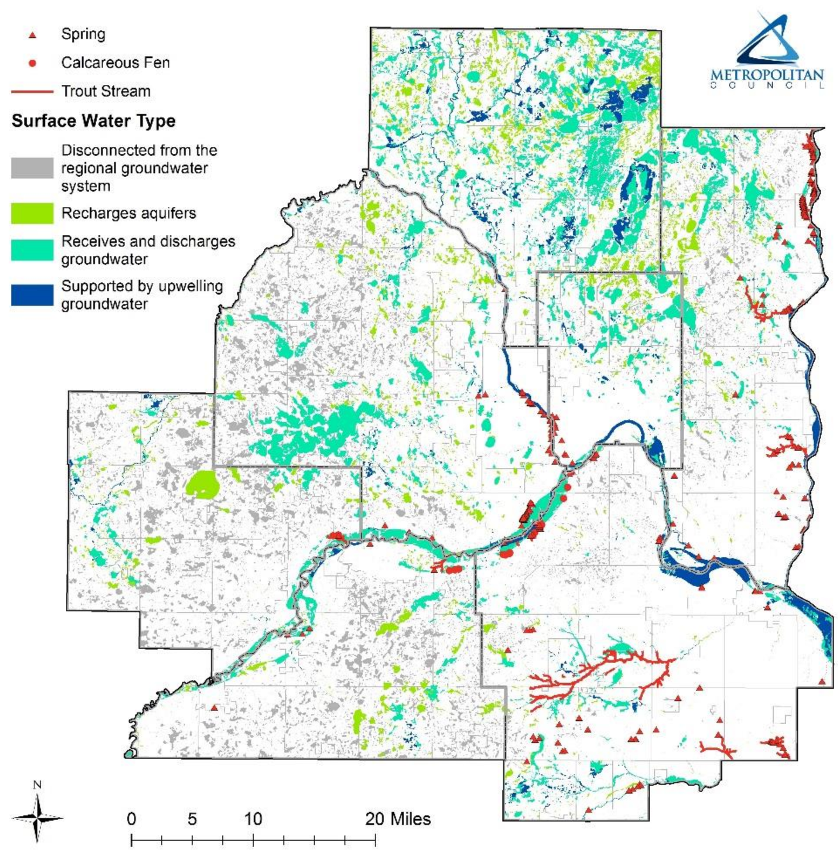
A regional evaluation of hydrogeologic conditions suggests that about half of the surface water features in the metropolitan area are likely to be directly connected to the regional groundwater flow system (Figure 22) (Metropolitan Council, 2010). When groundwater near one of these features is pumped excessively, water levels in the surface water feature may decline and water quality changes may occur.

Some examples of surface waters under the influence of groundwater include:

- Itaska Lake in Anoka County
- Seminary Fen in Carver County
- Vermillion River in Dakota County
- Lake Minnetonka in Hennepin County
- Vadnais Lake in Ramsey County
- Savage Fen, Eagle Creek and Boiling Springs in Scott County
- Valley Creek in Washington County

Surface water impacts vary throughout the region, driven by differences in the level of development and by different hydrogeologic conditions that shape groundwater and surface water interactions.

Figure 22. Surface water features likely connected to regional groundwater flow system.



Minnesota Rules, Part 6115.0670, specify that appropriation from groundwater shall be limited if the commissioner of the Minnesota DNR determines that a direct relationship of groundwater and surface waters exists such that there would be adverse impact on the surface waters. Minn. Stat., Sec. 103G.287 specifies that the applicable laws protecting surface water uses in Section 103G.285 apply to groundwater uses where there will be a negative impact on surface waters from groundwater pumping.

The following are groundwater-dependent land or surface water features at increased risk, depending on their proximity to groundwater pumping:

- State-designated trout streams
- State-designated calcareous fens
- Springs
- Surface waters where hydrogeologic conditions suggest a connection between groundwater and surface waters such that there is a potential to impact surface water levels and stream flows – these may include: rivers, lakes and wetlands

These indicators should not be considered regulatory cut-offs. Rather they are to help provide information about planning expectations, so that there are fewer surprises when permits are requested or plans are made. Where groundwater and surface water are likely to interact, additional monitoring and assessment may be needed to evaluate impacts of increased groundwater pumping or stormwater best management practices.

Water quality

For several communities, water quality is a more challenging issue that water quantity. A recent study estimated $700,000 to $12 million in costs (present values over a 20-year period) to address the increased risk of nitrate contamination of private wells (Keeler and Polasky, 2014).

Public water suppliers are responsible for providing water that meets Safe Drinking Water Act and other state requirements. The Minnesota Department of Health is the responsible agency for all public and private water quality issues. The department may test a public water supply for up to 118 different contaminants, depending on potential contamination sources, whether the system uses wells or surface water, depth to wells, geology and past test results.

Surface water and groundwater supplies are susceptible both to chronic and acute contamination from natural and human-produced sources. Spills in the Mississippi River may affect the Minneapolis Water Works and Saint Paul Regional Water Services systems. Large plumes of industrial contamination have affected many groundwater users, and nitrate contamination is a considerable issue in some parts of the metropolitan area such as Dakota County.

Chronic contamination in both surface water and groundwater can have long-term public health and economic consequences. While chronic contamination of municipal supplies can often be treated once it is discovered, treatment costs may cause significant price increases for consumers and may, in severe cases, limit use of the water source. All costs associated with treating known contaminants in a public water supply are borne by that system. Private well owners also face considerable costs when groundwater supplies are contaminated.

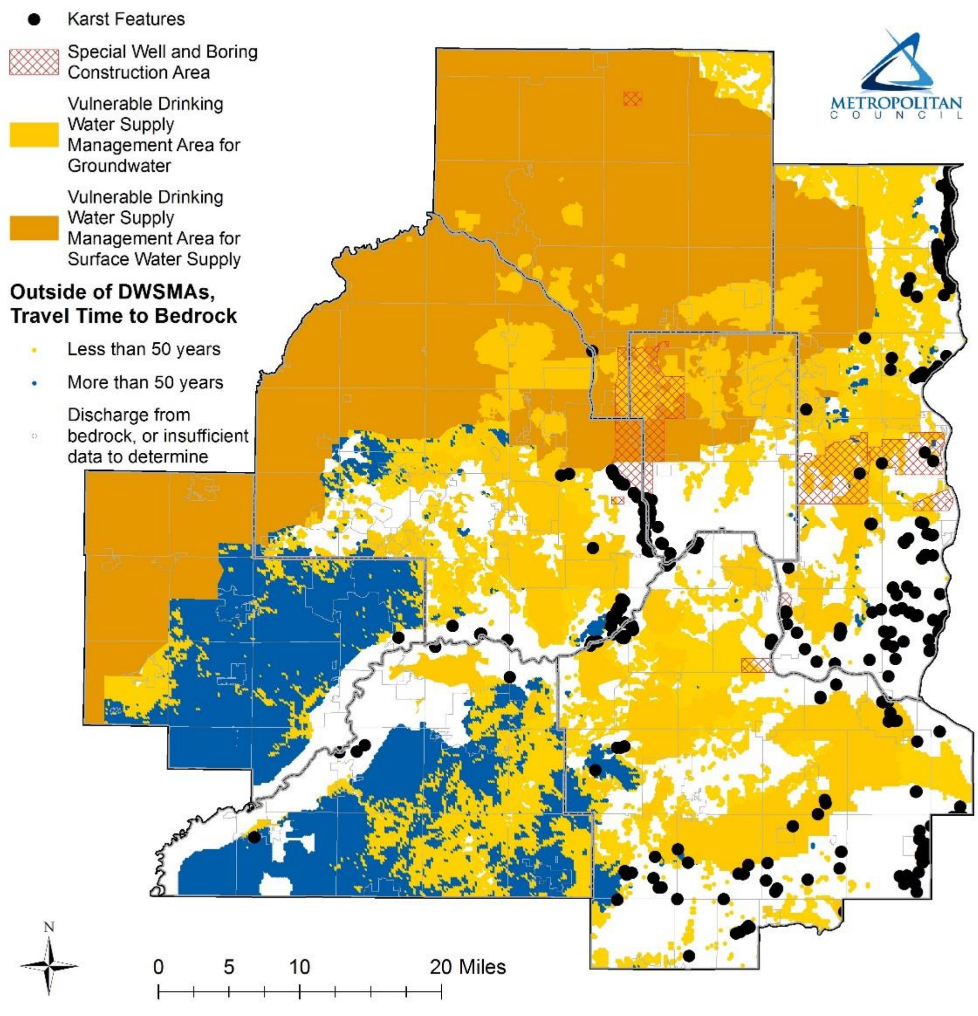
The following points are important to consider when evaluating risk of water supply contamination:

- Proximity to known areas of groundwater contamination, such as Special Well and Boring Construction Areas
- Proximity to designated Wellhead Protection Areas, Drinking Water Supply Management Areas, or Source Water Protection Areas
- Proximity to karst features such as sinkholes, which provide direct connections between land surface and underlying aquifers
- Estimated vertical travel time from land surface to bedrock aquifers

Efforts to protect and manage water supply quality (both groundwater and surface water) should consider the following, as shown in Figure 23:

- Vulnerable source water protection areas – for surface water (dark orange) and groundwater (light orange)
- Designated Special Well and Boring Construction Areas (red cross-hatched areas)
- Karst features (black dots)
- The relative amount of time it takes for spills or infiltrating stormwater to reach bedrock aquifers. Blue areas take more than 50 years; yellow areas take less than 50 years; white areas have insufficient data to evaluate

Figure 23. Characteristics of land and geologic features to be considered in protection and management efforts.



Contamination issues vary throughout the region, primarily driven by differences in hydrogeologic setting and in level of development. The most cost-effective way to address contamination is usually to prevent it through source water protection.

Uncertainty regarding aquifer productivity and extent

There is limited information about aquifer productivity and extent in parts of the region, and filling these information gaps would provide local and regional benefit. Partners such as the Minnesota Department of Natural Resource, the U.G. Geological Survey, the Minnesota Department of Health, communities and others have an important role to play in directing resources to install monitoring wells, update geologic atlases, and conduct aquifer tests.

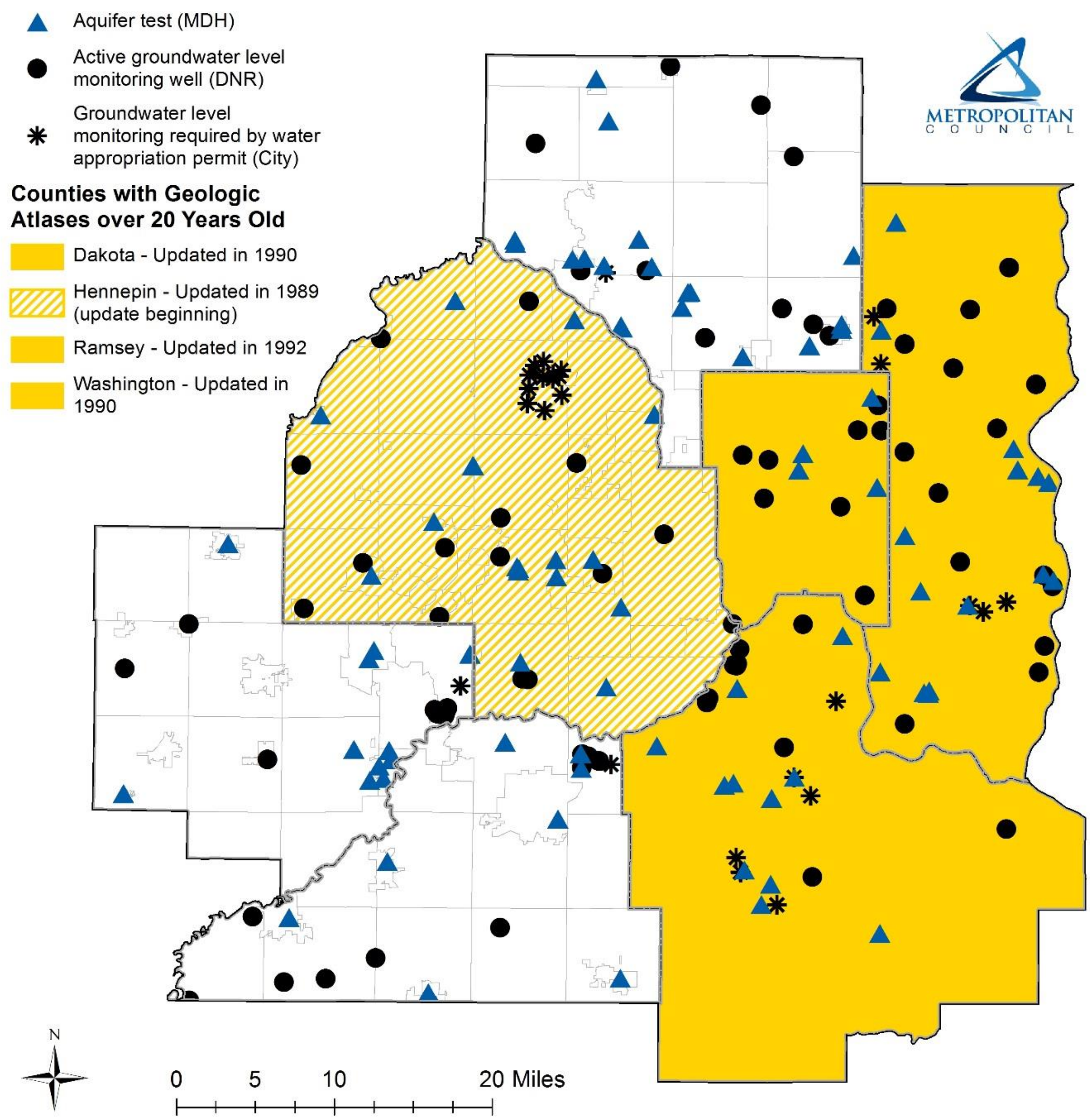
The following can indicate uncertainty about the sustainability of water supply sources:

- No aquifer test has been performed within 1.5 miles of the community
- No long-term observation well data available for areas within one mile of the community
- The most recent geologic atlas is over 20 years old

Aquifer uncertainty varies throughout the region, primarily because of differences in available data. Where wells have been drilled, for example, more data exists to support geologic mapping and other water supply assessments. Figure 24 shows the locations of:

- DNR observation wells (black circles)
- Community observation wells required as part of water appropriation permits (black stars)
- MDH aquifer tests conducted by the Minnesota Department of Health (blue triangles)
- Counties with geologic atlases that are over 20 years old (yellow)

Figure 24. Indicators of uncertainty about aquifer sustainability.



Reliability of water sources

Fifty-two communities in the metropolitan area use only one source (either groundwater or surface water) to supply all of their water demand. Major sources in the region include the Mississippi River, four major aquifers, and potentially the reuse of stormwater and wastewater.

Communities already implement federal and state regulations and programs to identify and establish protocols for protecting the safety, security and reliability of their water supplies, but there may be opportunities in some areas to improve the protection of water supplies as a priority for ensuring the reliability of water supply in the region.

The following may be indicators of reliability issues:

- Water supply system draws from only one water supply source, limiting options for back-up sources in case of emergency
- No permanent emergency interconnection exists

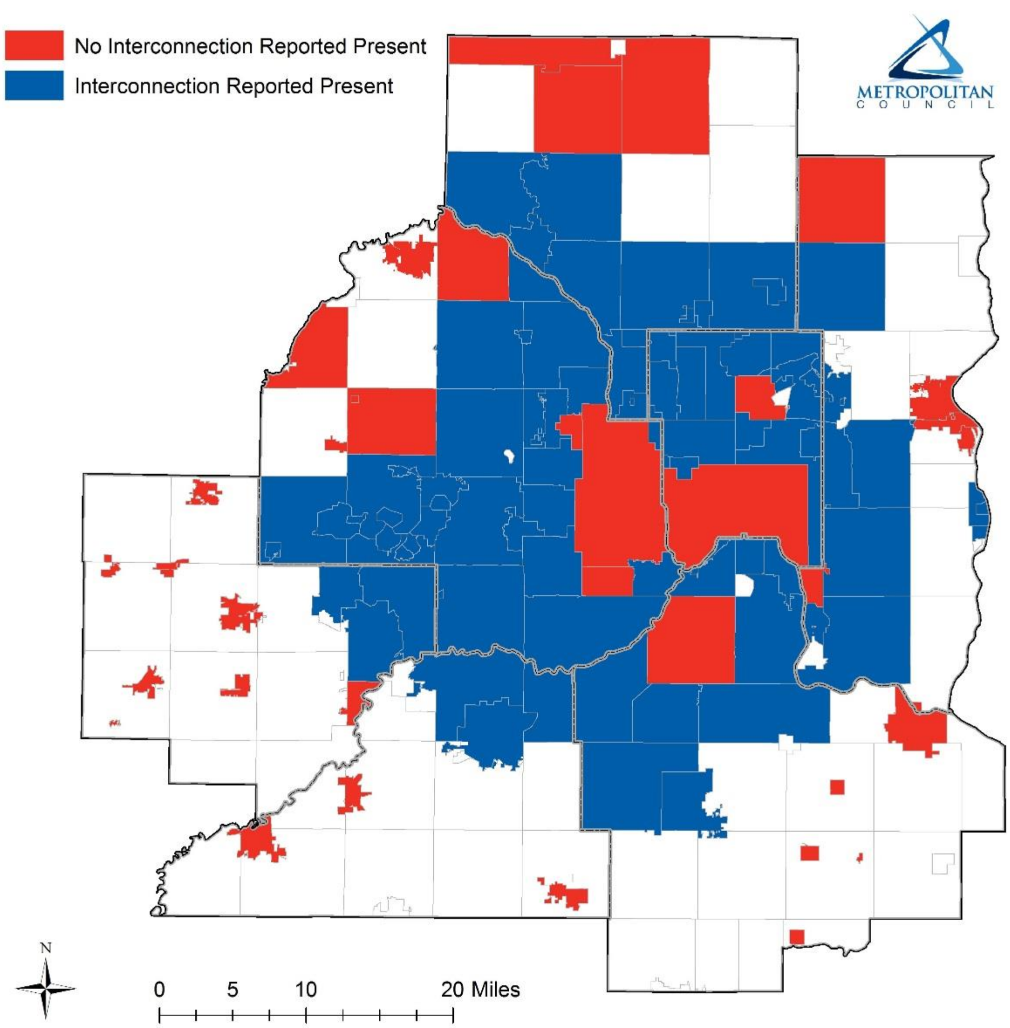
Reliability issues vary throughout the region, primarily because of differences in hydrogeologic conditions and level of development.

Figure 25 shows whether communities in the metro area have reported a connection to more than one water supply source (interconnection):

- Communities in blue have reported interconnections used for emergency and/or other purposes.
- Communities in red do not have interconnections.
- Communities in white do not have a public water supply system.

Even where community emergency interconnections exist, ongoing coordination is needed to regularly test them to ensure they will work in an emergency.

Figure 25. Reported water supply system connections between communities.



Funding/finance

High-quality drinking water and wastewater treatment systems are a critical, and costly, component of community planning. Costs include planning and design, capital costs, operation and maintenance costs, and costs to monitor and report compliance with regulatory requirements.

Going forward, these costs are expected to increase. The American Water Works Association and others have documented that water and wastewater infrastructure in North America – including Minnesota - is aging and that many communities and wastewater treatment providers must significantly increase their levels of investment in repair and rehabilitation to protect public health and safety and to maintain environmental standards.

Public water suppliers, wastewater utilities, community planners, and elected officials stress the need for financial support for infrastructure changes to achieve sustainable solutions. Some examples of challenges include:

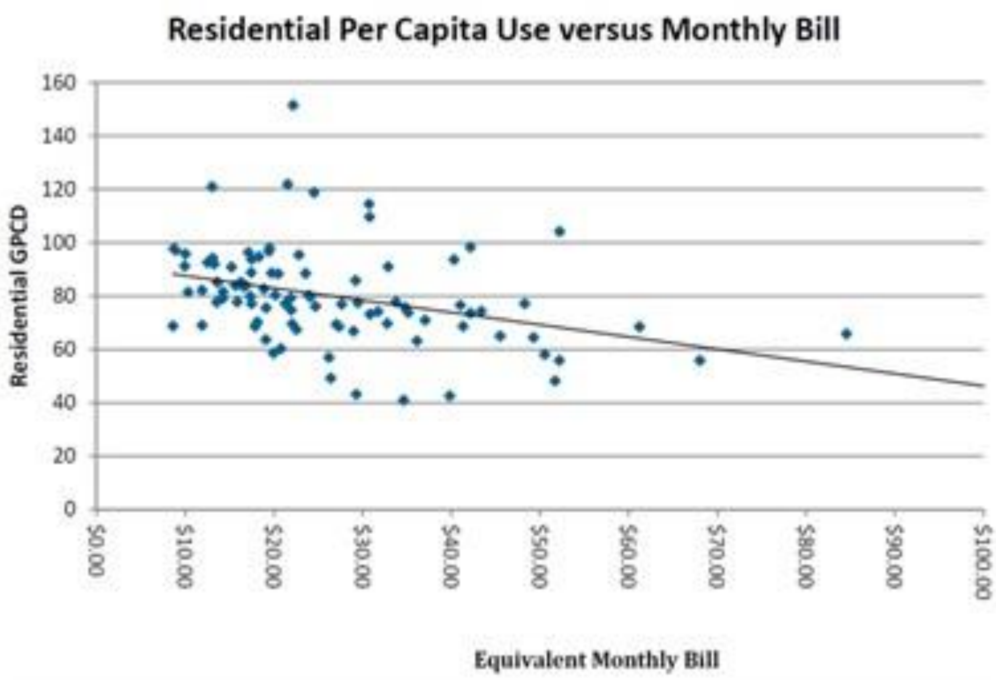
- Rebuilding and building new infrastructure
- Mitigating the revenue impact of decreased water demand, due to water conservation, on existing systems
- Addressing the need for more intense monitoring and treatment in systems with mixed water sources
- Lack of reliable and adequate funding sources for implementing many stormwater reuse opportunities

The 2015 Drinking Water Revolving Loan Fund Project Priority List illustrates the scope of the need. The list includes requests from eight metropolitan communities for over $67 million dollars to support water supply infrastructure improvements.

To finance water supply services, public water suppliers also use a variety of rate structures. A 2015 survey of public water suppliers documents the range of rate structures, provides information about how rates among communities compare, and investigates the impact that rates have on water use (Metropolitan Council, 2015d). When water rates in the metro area are normalized to one another, the monthly household bill ranges from $8.60 to $123.31, with an average of $29.10. For comparison, the monthly average retail rate per household for wastewater service in the Twin Cities metro area was $18.00 in 2011.

There is evidence that higher monthly water bills are correlated to lower residential per capita water use (Figure 26).

Figure 26. Correlation of monthly water bills to residential per capita water use.



Infrastructure costs are one of the biggest hurdles to expanding the use of surface water and reclaimed wastewater in the region. Water treatment requirements for surface water are usually higher than for groundwater, and most water users are located considerable distance from surface water and reclaimed wastewater sources. Even where the treatment costs are similar for groundwater and surface water, it is usually more financially feasible to gradually expand a groundwater supply system than to secure the up-front funding to construct a complete surface water system.

There are currently only two surface water treatment plants in the region, operated by Minneapolis Water Works and Saint Paul Regional Water Services. Investing in additional surface water treatment plants is a large cost. The Council has estimated the capital cost of a new surface water treatment plant to serve select communities in the north and east metropolitan area was estimated to be $44-$291 million dollars.

Operations and maintenance costs for such a system are estimated to be $4-$9 million per year, proportioned based on relevant Saint Paul Regional Water Services costs. Distribution costs are equally challenging. For example, an assessment of the costs and benefits of using the St. Croix River to augment White Bear Lake highlights the high costs of installing forcemain and the energy needed to pump water from the river valley up to potential users (Metropolitan Council, 2014b). In 2015, the cost to construct a 50 million gallon per day treatment plant along the Minnesota River was estimated to be $150 million (Metropolitan Council, 2015b).

Costs to collect and store large amounts of stormwater can also be costly. For example, work in Dakota County suggests that capital costs for stormwater capture and use systems for over 500,000 gallons is approximately $150,000-$1,500,000 depending on the use of stormwater ponds versus underground storage systems (Metropolitan Council, 2015b).

Key factors contributing to uncertainty

This chapter provides a regional overview of some key water supply issues. The information presented here can be used in local water supply planning and technical analyses, if work is not already underway.

The analyses conducted for this plan incorporate the best regionally available technical information to answer questions of water supply availability, and much of it was collected through local studies. The information in this chapter reflects guidance by a wide variety of stakeholders based on issues identified as important at this time.

However, uncertainty is a constant factor, several questions remain unanswered, and other questions will inevitably emerge over time. Water supply planning must be done in such a way that the plans can adapt to factors such as climate changes, technology and emerging contaminants, and changing cultural priorities and attitudes.

There are different types of uncertainties related to the issues discussed in this chapter. For instance, a distinction can be made between monitoring uncertainty and uncertainty regarding future conditions. Also, science has its limitations when dealing with complex societal problems where there are many system uncertainties, and where facts and values are intertwined. And insights may change over time as new information becomes available.

Water suppliers and planners work in a dynamic environment that requires ongoing action, even in face of less than 100% certainty. This process of "learning by doing" has also been called "adaptive management' - a structured, iterative process of decision-making, with a goal of reducing uncertainty via system monitoring.

Monitoring uncertainty

Monitoring uncertainty generally refers to how well measurements represent real world conditions. Factors that commonly contribute to monitoring uncertainty include imprecise or inaccurate measurement equipment, inadequate measurement frequency, the length of the monitoring record, and the spatial distribution of the monitoring sites.

When monitoring data is used to model hydrologic conditions, uncertainty in the data contributes to uncertainty in the model results. Informed decisions must be made about what data to include in model analyses and how to weight data with higher accuracy and precision more heavily than data with greater uncertainty.

The process to develop and calibrate the regional groundwater flow model (Metro Model 3) illustrates this approach of reducing uncertainty. For example, multiple water level datasets were used to calibrate the model including well logs reported in the Minnesota County Well Index (CWI), DNR observation wells, and synoptic water level measurements made by the DNR and USGS. Data compiled from CWI have the most inherent error; however they have the largest geographic extent. Data from synoptic water level datasets and DNR observation wells have the least amount of error, but they are not available everywhere. All data was used to calibrate the regional groundwater model, but the CWI data was not weighted as heavily as the higher quality data (Metropolitan Council 2014d).

In addition to improving analytical results, a thorough examination of monitoring uncertainty identifies gaps in information where resources can be directed. For example, the process of calibrating Metro Model 3 highlighted the importance of expanding monitoring networks to assess the connection between surface waters and the regional groundwater system.

Predictive uncertainty

The most common focus for discussions of predictive uncertainty related to this Master Water Supply Plan is the Metro Model 3 (Appendix 3) and water demand projections that the model evaluates (Appendix 2).

Metro Model 3 is a tool that supports a flexible process for water suppliers and planners to explore a wide variety of different water supply approaches under a range of potential future conditions.

Model uncertainty comes from four main factors:

1. Conceptual framework uncertainty
2. Model parameter uncertainty
3. Calibration uncertainty
4. Predictive uncertainty

Metro Model 3 predicts future aquifer conditions under a projected range of water demand. Because it is a steady-state model, it does not represent water levels for a specific day and time. Instead, it is intended to illustrate where aquifer water levels will come to equilibrium under a given water budget (recharge, pumping, baseflow). In other words, it illustrates where things will ultimately end up.

This ability to compare regional groundwater impacts under different demand and source assumptions is what Metro Model 3 was designed, conceptualized, and calibrated for. It is used as a planning tool to inform regional planning, support this Master Water Supply Plan, and assess potential impacts associated with changes in regional pumping and/or land use change.

The single biggest contributor to predictive uncertainty is uncertainty in future water demand. There is some uncertainty about how many people will live in the metro, where they will live, how much water they will use, or if sources of water will remain the same. This is where input from city administrators and engineers is critical; no one knows the city and its water supply better than the city or utility staff. Therefore, Metropolitan Council has worked closely with city staff to learn more about population, population served, per capita water use, water sources, and well locations.

Appendix 2 describes the method used to evaluate future water demand. The process included an exploration of predictive uncertainty resulting from the variability of the historical data the projection was based on and the use of different projection methods. Based on this work, water demand projections are represented as a range of future conditions.

The Metropolitan Council recognizes the error in the model compared to the real world. This error can be minimized when comparing model output to model output. For example, drawdown calculations show the change between two conditions, so the starting and ending values do not matter as much as the difference between the two conditions. Even with a model’s limitations, the Metro Model 3 is a valuable tool for informing water supply planning in the region. Table 3 summarizes appropriate uses of Metro Model 3.

Table 3. Uses for "out of the box" Metro Model 3. In some cases, the model can be used as a "back of the envelop calculation" providing a starting point for further analysis.

Acceptable	Marginally Acceptable; (use for "back of the envelop" calculations)	Not Acceptable
Compare regional scenarios	General well field placement	Localized well field optimization
Compare sub-regional scenarios	Estimate groundwater/ surface water connections	Site specific evaluations
Identify areas where more information is needed	Wellhead protection plans	Predicting time dependant water table elevations
Identify possible problem areas		

Metro Model 3 supports a flexible process for water suppliers and planners to explore a wide variety of different water supply approaches under a range of potential future conditions. This type of exercise can inform a broad range of discussions among local water supply providers and other partners about potential water supply approaches. Working collaboratively with the local providers will be the pathway to success in the area of sustainability.

Other sources of uncertainty

Uncertainty regarding predictions of future climate, technological capabilities and limitations, and future priorities are also important factors to consider when planning approaches to supply future water needs.

For example, longer growing season and increased risk of drought may change the region's water demand, sustainable limits on water supply sources, the severity and types of issues affecting the region's water supply sources, and the priorities set by decision makers.

The 2014 Minnesota State Hazard Mitigation Plan concludes that it is clear that temperatures are rising and weather patterns are changing, with an increase in severe weather events and extreme precipitation. The impacts of this change on water supplies are not fully understood, however.

Many difficult-to-predict technological changes have significant implications for sustainable water supply management. Examples include the development of new chemicals which may or may not lead to new drinking water quality standards, advancements in our water quality testing laboratories that allow contaminants to be detected at very low levels, and new water treatment technologies that may allow for increased use of water sources previously thought to be unusable.

6 Moving Toward Water Sustainability: Outcomes

The Master Water Supply Plan's goal is a sustainable water supply for the region, which supports the broader regional vision of moving toward sustainability described in *Thrive MSP 2040*.

This chapter identifies some measureable outcomes that can be tracked to monitor progress toward the goal of sustainability. These outcomes will help reduce the water supply issues identified in Chapter 5.

Sustainable water use

The region's water supplies will be considered sufficient and sustainable when:

- Sustainable amounts of groundwater are planned and used
- Demand exceeding sustainable groundwater withdrawal rates is supplied by the most feasible combination of conservation, surface water, reclaimed wastewater and stormwater reuse
- Legislative changes are made that align agency directions on all aspects of water supply

Regional groundwater modeling indicates that the maximum amount of groundwater that can be sustainably withdrawn in the region, if pumping is expanded in areas near existing high capacity wells, is approximately 400-500 million gallons per day. This method is based on currently available information about aquifer properties, groundwater-surface water interactions, and major contamination plume areas. Chapter 5 provides more detail about the uncertainty related to data availability and modeling approaches. The estimate is likely to change as more information becomes available, but it provides a starting place to consider the capacity of the region's aquifers to meet future water demand and sustain natural resources.

Sub-regional and local hydrogeologic conditions affect the amount of groundwater that can be withdrawn in different parts of the metropolitan area. Figure 18 illustrates the sub-regions. Table 4 summarizes the sub-regional estimates of sustainable groundwater withdrawal rates. Demand above these rates may require new investments – either exploration of new well fields and expanded distribution or development of new sources and/or more aggressive water conservation.

Table 4. Sub-regional estimate of sustainable groundwater withdrawal rates.

Sub-region	Estimated Sustainable Groundwater Withdrawal Rate (MGD)	Difference between Estimated Sustainable Groundwater Withdrawal Rate and 2040 Projected Groundwater Withdrawal Rate	Key types of constraints on groundwater availability
North and East	115	Approaching	Groundwater-surface water interaction, safe yield
Southeast	130	Approaching or Exceeds	Groundwater-surface water interaction, safe yield
Southwest	4	Approaching	Groundwater-surface water interaction
Northwest	140	Approaching	Groundwater-surface water interaction, safe yield
North	20	Below	Groundwater-surface water interaction
West	15	Below	Groundwater-surface water interaction

The information presented above is a general estimate of the amount groundwater sustainably available in different parts of the Twin Cities metropolitan area. This information is intended to inform regional and sub-regional planning activities and to help track progress toward regional goals. At this scale, this information is not appropriate for using in local permit decisions. More information about the method used for this estimates is in Appendix 4.

Supporting Outcomes

Water conservation

Desired Outcomes:

That, as a region, the average total municipal (including residential, commercial, and industrial) per capita water use is 90 gallons or less per person per day; the ratio of summer to winter monthly water use is equal to or less than the 1990-1994 average ratio as discussed in Chapter 3; and the per capita residential water use is equal to or less than 75 gallons per capita per day.

Based on its policy on water conservation and reuse, the Council will work with partners to identify emerging issues and challenges for the region and to work together on solutions that include the use of water conservation.

Analysis of historical and projected water use and population data shows that decreasing the average total municipal per capita water use to 90 gallons per person per day would accommodate 2040 population growth with no regional increase in water use by municipal public water supply systems.

By decreasing the summer versus winter monthly ratio to 1990s levels, the region could achieve a 15% reduction in total water use, reducing the need for infrastructure expansion for many communities.

Measures

- Regional average total municipal water use per person
- Winter versus summer water use
- Regional average residential water use per person

Increased collaboration

Desired Outcomes:

That work groups are formed and active in all hydrogeologic sub-regions and include participation by all water sectors including regulatory agencies and public and private entities, and supported by the Metropolitan Council.

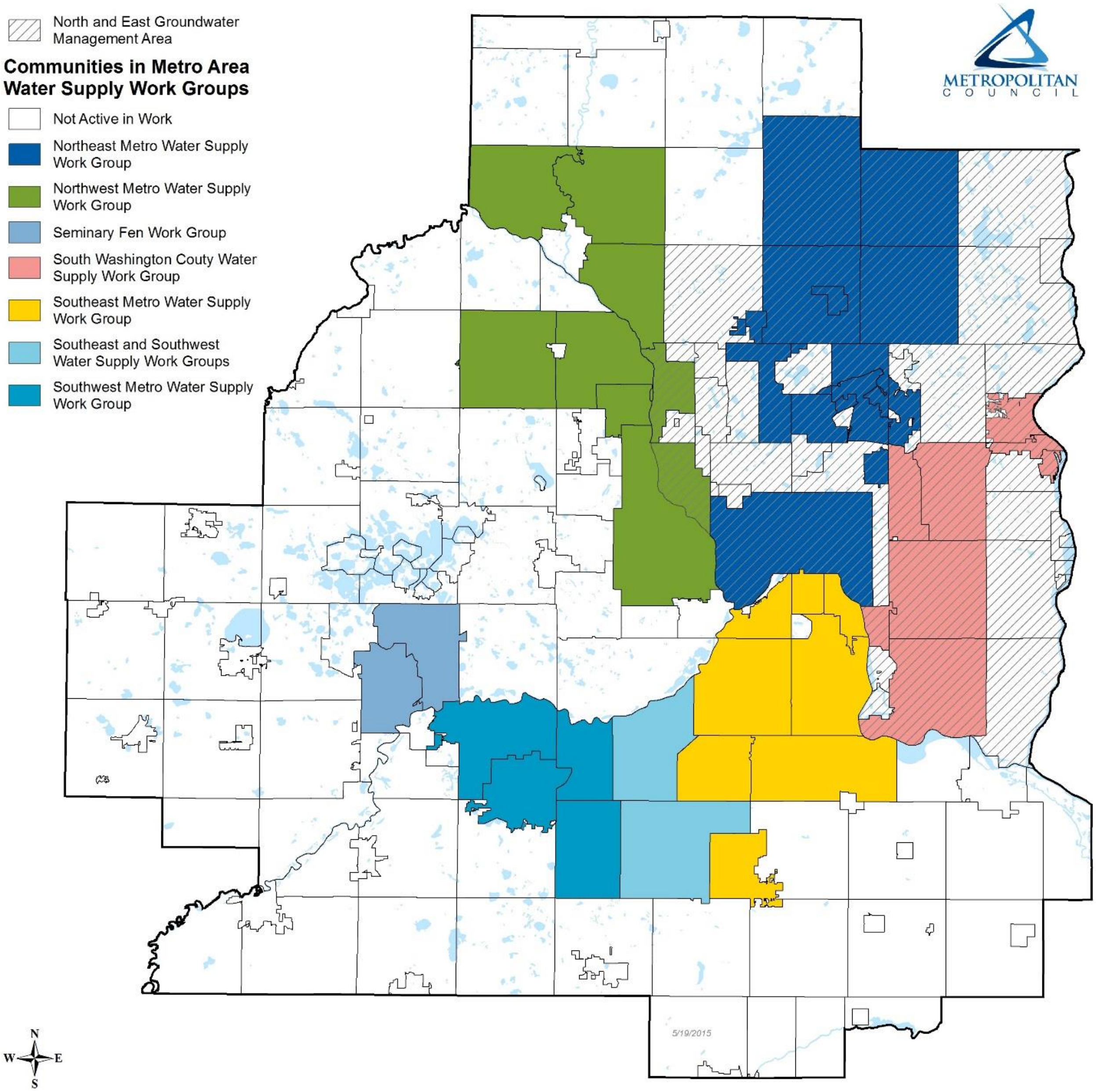
That all public water suppliers have emergency supplies through interconnectivity or multiple sources of water, including emergency connections.

As the Metropolitan Council works with local partners to identify and implement the best options for their situations, sub-regional feasibility analyses will be done, guided by local work groups, to evaluate the costs and benefits of different approaches. This information can inform local water supply plan updates, permits, environmental review documents, county groundwater plans, and source water protection plans, as appropriate. Figure 27 shows participating communities in the work groups.

Measures

- Number of partners participating in Council-facilitated work groups
- Number of partnerships reported in local water supply plans (updated on 10-year cycle)
- Number of sub-regional solutions acted on and implemented

Figure 27. Communities participating in sub-regional work groups in 2015.



Improved planning and plan implementation

Improved local planning assistance

Desired Conditions

By 2016, the Council will provide a level of technical assistance that assists communities to align their water supply plans and permitting with Council policy. Local comprehensive plans, including implementation plans that support regional water supply sustainability, will be approved by 2020.

A community's comprehensive plan is expected to accommodate the population and employment forecasts and to meet the densities specified in the Council's *Thrive MSP 2040* plan.

A community's comprehensive plan must include:

- A water supply plan that is informed by the Twin Cities metro area Master Water Supply Plan and meets the Department of Natural Resources plan requirements
- A local surface water management plan that is consistent with Minnesota Rules Chapter 8410 and Council policy and does not adversely impact the regional wastewater system, and
- A comprehensive sewer plan that is consistent with the regional wastewater system plan.

Measures

- Communication, internal and external
- Record of planning guidance provided, including workshops, presentations, planning tools provided, and other related information
- Approved community comprehensive plans
- Record of regional implementation strategies that will be completed by water supplies, as identified in approved and adopted local water supply plans

Implementation of sustainable water supply approaches

Desired Outcomes

Use of surface waters, reclaimed wastewater and stormwater for appropriate water uses becomes an option explored by communities and implemented by many.

As partners collaborate to identify and implement the best water supply options for different parts of the region, it may become clear that the least expensive, most expedient water supply options may not be sustainable. In those cases, alternative water supply approaches may be needed.

Sub-regional work groups are exploring the costs and benefits of alternative water supply approaches. Examples of existing projects and lessons learned are highlighted in Appendix 5.

Measures

- Number and types of implementation strategies planned
- Projects accomplished

Assessment and protection of source water

Aquifer levels are protected and enhanced

Desired Outcomes

Groundwater is adequately monitored across the region, and aquifer levels in all groundwater observation wells in the seven-county metropolitan area stabilize at sustainable levels.

Groundwater levels are the most direct indicator of groundwater sustainability. Trends in groundwater levels will be monitored regularly to evaluate impacts of changes in water supply management. Due to the slow recharge rates of some aquifers, it is expected that a significant delay may occur between water supply management changes and response in groundwater levels. Monitoring of groundwater levels needs to be done over the long-term.

Measure

- Trend in groundwater observation wells and piezometers, including those located at fens and trout streams, taking into account long term changes in recharge due to changes in weather patterns and climate

Source water areas are protected

Desired Outcomes:

Potential contaminant sources are reduced and/or restricted in areas identified as sources of public drinking water supplies.

Source water is protected by preventing contamination from entering sources of public drinking water at levels that present a risk to people. Potential sources of contamination are managed in the area that supplies water to a public well or surface water intake. Effective efforts are implemented to prevent pollution, such as the wise use of land and chemicals. Public health is protected and expense of treating polluted water or drilling new wells is avoided though source water protection efforts.

Measures

- Number of wells sealed in wellhead protection areas
- Planning and zoning controls for wellhead protection areas

7 Taking Action

Currently, over 100 independent water supply systems operate throughout the seven-county Twin Cities metropolitan area, and regional sustainability hinges on collaboration among these many systems. There is no simple solution, no one answer. Rather, the future of water management will involve many partnerships and enhancements to a highly complex set of systems. The approaches will be varied, they will be creative, and they will require nimble thinking.

Now is the time to be thoughtful about our water future and take action to protect our water supply. Water supply planning should not be done “after the fact,” when options are limited, more costly, or possibly more harmful to the natural environment. The plans made now for the growth and expansion of the region should lay out a combination of steps that will keep our water supply safe and plentiful for generations to come.

In partnership with key water supply stakeholders, the Metropolitan Council will help the region achieve a sustainable water supply by implementing the water supply policies of the Council’s *Water Resources Policy Plan* consistent with the principles and information provided in this Master Water Supply Plan.

This chapter provides more detail about how the policies and strategies are translated into action by the Council and partners. More information about the Council’s responsibilities and partners’ potential roles related to these actions are discussed in Chapter 8.

Approach

Providing sustainable water supplies across the region is a challenging and ongoing endeavor. Our water supplies and the resources they support are a dynamic system that changes through time. Public water suppliers, planners, scientists and engineers have been working together on this challenge for over a century (Hall et al, 1911); this will continue to be a critical effort especially with growth or change in climate.

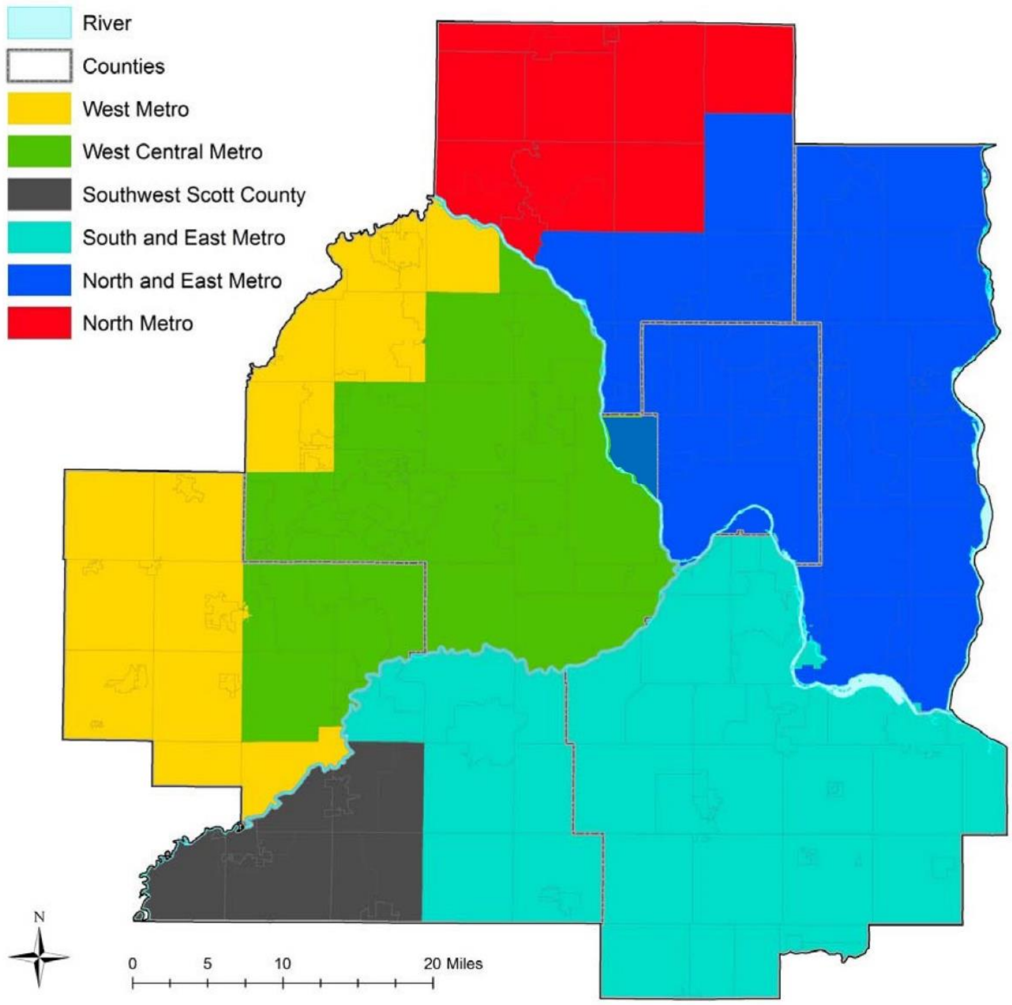
While this is an iterative process, experience shows that efforts tend to be most successful when the process includes certain steps (Table 5, Appendix 5). The Metropolitan Council’s approach to regional water supply plan implementation supports these steps by promoting a region-wide process for water supply education, sub-regional collaboration, water supply research, and technical and planning assistance.

Table 5. Steps in the Metropolitan Council's approach to support sustainable water supply planning.

Step	Council Role	Local Role
Increased Public Knowledge	Support public forums, meetings, training opportunities	Support public forums, meetings, training opportunities
Water Supply Problem Identification and Analysis	Regional and sub-regional source assessments, mapping	Local monitoring and aquifer testing and analysis, mapping
Identification of Possible Solutions	With partners, identify sustainable water supply approaches	Identify local details for each category of possible approach
Analysis of the Feasibility of Possible Solutions	Provide technical assistance	Guide analyses, provide local inputs, review results
Selection of Preferred Approaches	Bring forward approaches that provide regional benefit while serving local needs	Select approaches that serve local needs while proving regional benefit
Project Approval and Funding	Support local efforts to seek funding; commit resources as appropriate for wastewater reuse-related projects	Seek resources and request additional funding as needed
Build, Operate and Maintain	Implement wastewater reuse as appropriate	Implement approaches as appropriate

This Master Water Supply Plan recognizes that there are sub-regional and local differences in water availability and potential issues, based on factors such as aquifer extent, proximity to surface waters, natural and manmade contamination, and community development. To ensure that planning support is provided across the region's varied hydrogeologic settings, the Council has identified six sub-regional planning areas based on hydrologic boundaries and generally reflecting groupings of similar resources and other development characteristics (Figure 28). This sub-regional framework does not impose regulatory limitations or requirements; it is solely for purposes of planning and technical analysis.

Figure 28. Map of hydrogeologic sub-regions.



Funding

Funding for Master Water Supply Plan implementation strategies, identified in the *Water Resources Policy Plan* and described in more detail here, comes from multiple sources.

- The Council's property tax levy, separate from its wastewater rates, helps to support outreach and data management components of water supply-related strategies.
- Fees derived from the cost of wastewater service support water supply-related strategies are tied to meeting wastewater regulatory requirements, implementing MCES infrastructure rehabilitation and repair needs, and providing wastewater capacity for growth consistent with the Council's *Thrive MSP 2040*.
- State revenue – the Clean Water Fund in particular - supports technical projects undertaken by the Council with regard to water supply planning.

Schedule of milestones

The current state of the region's water supply has taken many years to develop; it will take many years to change. The timeline in Figure 29 illustrates the major milestones, and subsequent text provides more detail, including key milestones from each strategy.

Figure 29. Timeline of major milestones toward water sustainability.

Year(s)	Major Milestone
Ongoing	Outreach, education, data collection and analyses, tool development
2020	Sub-regional work groups established and functioning in each hydrogeologic sub-region All local water supply plans are guided by the Master Water Supply Plan, and local controls are adopted
2025	All local water plans and watershed management plans include information from the Master Water Supply Plan Information in the Master Water Supply Plan is considered in the next update of the regional development framework, Thrive MSP
2024	Master Water Supply Plan updated in coordination with the to update of Water Resources Policy Plan and to reflect updated regional development framework
2027	All wellhead protection plans include information from the Master Water Supply Plan
2021-2030	Water supply technical information is considered when planning Crow River and Northeast Area wastewater reclamation facilities
Post-2040	Water supply technical information informs East Bethel Wastewater Reclamation Facility Expansion

Progress

The 2010 Master Water Supply Plan described activities intended to meet 6 regional objectives:

1. Improve the predictive accuracy of the Twin Cities Metropolitan Area Groundwater Flow Model Version 2.00 (Metro Model 2).
2. Assess local conditions in areas where this plan predicts that issues may arise should withdrawals continue at projected levels and from traditional sources.
3. Develop a more thorough understanding of aquifer extent, capacity, and recharge, as well as long-term trends in the levels of the region's surface and groundwater systems to manage future water supply availability.
4. Develop a better understanding of the distribution of natural and manmade contaminants and source water vulnerability.
5. Guide water supply development toward regionally optimal locations and sources.

6. Incorporating new information and using updated tools will improve the evaluation of new pumping sources, locations, and pumping rates to determine regionally optimal withdrawal scenarios.

Since then, many projects have been undertaken and multiple sub-regional work groups have been formed and begun analyses of various water supply approaches. Examples include:

- Update of the Metro Model 2 to Metro Model 3
- Mapping of aquifer properties to provide better local and regional information about aquifer extent, capacity, recharge and vulnerability to contamination
- An updated Conservation Toolbox and a new Stormwater Reuse Guide

More information about these and other efforts are available on the Council website at http://www. metrocouncil.org/Wastewater-Water/Planning/Water-Supply-Planning/Studies-Projects-Workgroups- (1).aspx

One of the outcomes of previous work, particularly efforts by sub-regional water supply work groups, is the identification of remaining gaps in information and implementation tools. Some key information and tools are still needed to support the approach outlined in Figure 29 above.

New strategies

The rest of this chapter outlines strategies to address water supply needs that were identified through previous projects, by sub-regional work groups, and through the update of the *Water Resources Policy Plan*. In partnership with others, the Metropolitan Council will:

1. Collaborate with partners to update the Master Water Supply Plan
2. Review and comment on plans and permits
3. Conduct technical studies
4. Facilitate collaboration to address water supply issues
5. Promote and support water conservation
6. Investigate reusing treated wastewater
7. Support investments in water supply

For each strategy, information is provided about key partners and their possible roles and what successful achievement of the strategy might look like.

Key partners include Metropolitan Council, communities/public water suppliers, and the Minnesota Department of Natural Resources (DNR). Other partners include other agencies, counties, watersheds, academic institutions, and organizations as appropriate.

The desired achievements identified for each strategy reflect input from the region's many water supply stakeholders. However, their success is dependent on the availability of Metropolitan Council and partners' funding and staffing resources.

Strategy 1: Collaborate with partners to update the Master Water Supply Plan

The Metropolitan Council will collaborate with state agencies, watershed organizations, and community water suppliers to update the regional Master Water Supply Plan as new information becomes available and as the comprehensive development guide for the metropolitan area, *Thrive MSP 2040*, is updated. The Council promotes water sustainability through the Master Water Supply Plan, and through the review of local water supply plans, surface water management plans, comprehensive plans, and comprehensive sewer plans.

The Council's work to support collaboration and coordination is guided by Minnesota statutes 473.1565, and it supports the Council's policy on sustainable water supplies (Water Resources Policy Plan). This effort also supports community efforts to improve water supply resilience by identifying and evaluating potential water supply issues and economically and technically feasible water supply alternatives.

This collaboration with agency partners is critical to ensure inclusion of all opinions and points of view regarding the region's water supplies. For example, increased collaboration will address the issue of regulatory complexity that was repeatedly raised by stakeholders during the update of the Master Water Supply Plan. Collaboration may reduce or eliminate contradictory regulations, may better leverage program funds to support common goals, and coordinate guidance. This may help communities and water suppliers focus on actions that provide multiple water resource benefits and shift the region to a more sustainable mix of water supply approaches.

Progress will be documented through outreach event and work group meeting materials, progress reports, public comments on the draft plan, and plan approval notification.

Key partners and suggested roles

Metropolitan Council

Lead the effort to update the Master Water Supply Plan and provide staff support and public engagement opportunities, guided by policy and technical work groups, throughout the process

Communities/Public Water Suppliers

Co-lead work groups to provide guidance regarding policy and to share relevant technical information

Others

Private well owners, state agencies regulating water resources, and others as appropriate provide staff participation on policy and technical work groups to provide guidance regarding policy and to share relevant technical information

Achievements (what successful achievement of this strategy might look like)

- The Master Water Supply Plan continues to reflect regional policies and provides the most up-to-date information about the region's water supplies, emerging issues, and water supply alternatives
- Ongoing relationship building among potential partners

Strategy 2: Review and comment on plans and permits

The Council promotes water sustainability through the Master Water Supply Plan, and through the review of local water supply plans, surface water management plans, comprehensive plans, and comprehensive sewer plans. The Council will review and comment on plans that include, but may not be limited to:

- As required by Minnesota statutes, local water supply, source water protection, surface water, comprehensive sewer, and county groundwater plans
- As requested by the Minnesota DNR or other agencies, Groundwater Management Areas, water appropriation permits, and other permits

The Council's work to support water supply planning is guided by Minnesota statutes 473.1565, and it supports the Council's policy on sustainable water supplies (*Water Resources Policy Plan*).

Through this process, which includes local planning assistance, local plans will be better coordinated and will better incorporate water sustainability considerations in all areas of Council policy and actions, including overall development patterns, water management, transportation, housing, and regional parks. Progress will be documented through formal review comments.

A successful outcome of this work is that, by 2016, the Council will provide a level of technical assistance that ensures that communities clearly understand water supply-related plan and permit expectations for consistency with Council policy. Local comprehensive plans, including implementation plans that support regional water supply sustainability, will be approved by 2020. Chapter 6 provides more information.

Key partners and suggested roles

Metropolitan Council

Provide local planning assistance to communities in the development of local water supply plans, through the Local Planning Handbook, participation on planning teams, and other venues; review local water supply plan, using review criteria outlined in the Local Planning Handbook and coordinate comments with DNR, communities and others; review wellhead protection plans and share comments with MDH, communities, and water suppliers; review water appropriation permits upon request, and share comments with DNR, communities, and water suppliers; review county groundwater plans and share comments with counties, communities, and others; support DNR, communities and water suppliers in developing and implementing a plan for the North and East Metro Groundwater Management Area, and other areas as needed. May include directing technical work to fill information gaps and promote water conservation/reuse

Communities/Public Water Suppliers

Fulfill statutory obligations for water supply planning, water supply- related permits; complete local water supply plan template, with for input from neighboring and overlapping jurisdictions, adopt final plans; complete source water protection plan, with input from neighboring and overlapping jurisdiction, adopt final plans, and submit to Metropolitan Council and DNR; work with DNR in the development and implementation of a Ground Water Management Area, should one be designated; input on county groundwater plans, watershed management plans

DNR
Issue water appropriation permits and amendments, supported by a process to solicit and incorporate recommendations from partners; lead the development and implementation of Groundwater Management Area plans; approve local water supply plans; provide local technical and planning assistance to communities in the development of local water supply plans and to permit holders in the development of water appropriation permits

Others
Neighboring or overlapping jurisdictions provide input on local water supply plans, source water protection plans, county groundwater plans, permits, Ground Water Management Area plans; as a responsible agency, adopt or approve plans as required

Achievements (what successful achievement of this strategy might look like)

- Consistent and regular communication of regulatory and planning expectations
- Regional and technical and planning information exchanged by partners as part of collaborative efforts. Examples: development of local water supply plans, Groundwater Management Areas, source water protection plans, county groundwater plans, etc.
- Technical and planning assistance provides clear guidance and support for local planning. Example: Local Planning Handbook
- By 2020, updated local comprehensive plans, including water supply plans, that reflect the Master Water Supply Plan and supported by adoption of local controls and capital improvement plan
- By 2027, all wellhead protection plans reflect the Master Water Supply Plan and local water supply plans

Strategy 3: Technical studies

In partnership with others, the Council will:

- Fill gaps in technical assessments of lake, stream, river, and groundwater data.
- Maintain a regional database that contains easily accessible water quality, quantity and other water related information collected as part of the Council's monitoring programs.
- Complete technical studies to understand regional and sub-regional long-term water supply availability and demand including modeling and other approaches.
- Support community efforts to identify and evaluate the economic and technical feasibility of water supply approaches and best practices that increase water conservation, enhance groundwater recharge, and make the best use of groundwater, surface water, reclaimed wastewater, and stormwater.

The Council's work to maintain a base of technical information is guided by Minnesota statutes 473.1565, and it supports the Council's policy on assessing and protecting regional water resources (Water Resources Policy Plan). This technical information helps the Council to promote the wise use of water; better address the reliability, resiliency, security, and cost-effectiveness of the region's water supplies; and to identify sub-regional and local water sustainability solutions that balance regional needs and local objectives.

Technical information generated through these efforts will also support the other strategies outlined in this chapter. Progress will be documented through progress reports and project deliverables.

Successful outcomes of this work is may include: 1) groundwater is adequately monitored across the region, and aquifer levels in all groundwater observation wells in the seven-county metropolitan area stabilize at sustainable levels; 2) potential contaminant sources are reduced and/or restricted in areas identified as sources of public drinking water supplies. Chapter 6 provides more information.

Key partners and suggested roles

Metropolitan Council

Carry out regional and sub-regional technical studies by convening sub-regional work groups, managing consultant contracts, and provide technical expertise

Communities/Public Water Suppliers

Co-lead sub-regional work groups to shape scope of work, review interim and final deliverables

Others

Private well owners, state agencies regulating water resources, and others as appropriate participate in sub-regional work groups to shape scope of work, review interim and final deliverables

Achievements (what successful achievement of this strategy might look like)

- Better quality information and understanding of uncertainty, due to improved review of technical projects by technical advisory committees and others
- Collaborative processes are established, such as technical advisory committees, sub-regional work groups and ad hoc teams, to identify water supply data gaps, rank them and plan to address them in ways that informs decision-making. Examples of projects identified by stakeholders include:

- Identification of sub-regional indicators for desired conditions
- Identification of areas where enhanced groundwater monitoring is needed to better characterize groundwater and surface water interaction
- Evaluation of groundwater contamination, including pollution containment plans and the potential to reuse pollution containment water
- Evaluation of the effectiveness of best management practices, new water conservation technologies, and planning and zoning controls for mitigating local water supply issues
- Examples of how conservation makes financial benefit for a range of community types
- Identification of high-potential recharge areas
- Sub-regional groundwater modeling, including transient and optimization models, in all six hydrogeologic areas
- Evaluation of how stormwater reuse potential varies across the metro
- Data collection and analyses supporting revision of curve runoff numbers and stormwater, recharge, and groundwater models
- Stormwater reuse tools supported and projects implemented
- Data developed to better estimate the costs and benefits of stormwater capture and recharge projects
- Evaluation of climate change and potential impacts on the region's ability to adapt the water supply system to changing conditions
- Revision of subregional estimates of sustainable groundwater withdrawals

Strategy 4: Facilitate collaboration to address water supply issues

The Metropolitan Council will facilitate discussions on water supply issues that transcend community boundaries, though sub-regional work groups and on an ad hoc basis as needed.

This effort supports the Council's policy on sustainable water supplies (*Water Resources Policy Plan*) and helps the Council to promote the wise use of water; better address the reliability, resiliency, security, and cost-effectiveness of the region's water supplies; and to identify sub-regional and local water sustainability solutions that balance regional needs and local objectives.

Sub-regional discussions help to address the issue of water conflicts among different users, options for funding/finance, and sharing information to ensure everyone is working from the same base of the best available information.

This inclusive effort supports a common understanding of the region's water supply issues and vision, and it generates endorsement of collaborative efforts to achieve sustainability. Progress will be documented through deliverables such as work group meeting materials, public forums, and presentations to local and sub-regional organizations.

Successful outcomes of this work may include: (1) that work groups are formed and active in all hydrogeologic sub-regions and include participation by all water sectors including regulatory agencies and public and private entities, and supported by the Metropolitan Council; (2) that all public water suppliers have emergency supplies through interconnectivity or multiple sources of water, including emergency connections. Chapter 6 provides more information.

Key partners and suggested roles

Metropolitan Council

Provide staff and materials to facilitate sub-regional work groups as needed; provide staff and education materials for public forums, workshops and educational events to share findings of technical work with stakeholders develop process and tools to collect and manage data as needed.

Others

Private well owners, communities and public water suppliers, state agencies regulating water resources, and others as appropriate participate, and/or promote that water sector's participation, on sub-regional and regional work groups to provide guidance regarding policy and to share relevant technical information.

Achievements (what successful achievement of this strategy might look like)

- Improved collaboration supported in a variety of ways. Examples: training opportunities for emergency response and other issues, sub-regional work groups, identification of policies that support or inhibit implementation of alternative water supplies, etc.
- Better information about the viability of regional partnerships from both service and funding perspectives. Example efforts: technical projects, sub-regional work groups, etc.
- Increased awareness of regional, sub-regional and local water supply issues and solutions through support for educational events such as water supply displays at local events and sub-regional and regional water forums/public meetings.

- More coordinated approach to water planning and permitting among government agencies, including reduced overlap of state agency authority with regards to water management, through interagency coordination of programs and policies.
- Consistent and regular communication of regulatory and planning expectations, how the need for technical projects was identified and scoped through work group and other public meetings, and how potential solutions to water supply issues are identified
- Process employed to reach some consensus on "desired conditions" that shape definition of sustainable water supply and on possible approaches that might be implemented to achieve it
- Enhanced information and resource sharing to identify and fill gaps in monitoring networks and technical information
- Local technical work leveraged to increase the value of regional and sub-regional studies and the impact of water supply project implementation, due to resource sharing
- Enhanced information sharing and technical guidance (including lessons learned) implementing alternative water supply approaches such as water conservation, enhancing recharge, and expanding the use of groundwater, surface water and reclaimed stormwater and wastewater

Strategy 5: Promote and support water conservation

The Metropolitan Council will promote and support water conservation measures, including education, outreach and tool development.

These efforts are guided by Minnesota statutes 473.1565, and they support the Council's policy on water conservation and reuse (*Water Resources Policy Plan*) and help the Council to promote the wise use of water.

The value of water conservation was a common theme at public meetings and other outreach for this Master Water Supply Plan. Some challenges that need to be overcome were also identified, including:

- Mitigating the impact of decreased water use on utility revenue
- Lack of funding for local education, incentive and enforcement activities
- Different conservation approaches for different users (e.g. residents, industries, agricultural irrigators, schools)
- Building public support

Successful outcomes of this work include a regional average total municipal (including residential, commercial, and industrial) per capita water use of 90 gallons or less per person per day; a ratio of summer to winter monthly water use is equal to or less than the 1990-1994 average ratio; and a per capita residential water use equal to or less than 75 gallons per capita per day. Chapter 6 provides more information.

Key partners and suggested roles

Metropolitan Council

Work with partners to develop planning goals and metrics for assessing the wise use of water and water efficiency; work with partners to identify useful tools and information needs; provide support for water conservation and efficiency projects that help to meet regional goals.

Communities/Public Water Suppliers

Connect key local water users, decision-makers with information to shape water use; adopt policies, ordinances and fee structures that promote the water conservation; identify and implement demand reduction measures; showcase projects

DNR

Adopt and enforce policies to ensure permitted water users are incorporating conservation practices in their operations; provide water conservation education through existing DNR education programs.

Others

Private well owners and people using public water supplies learn about and implement, as appropriate, water demand management strategies.

Achievements (what successful achievement of this strategy might look like)

- Achievement of water conservation outcomes identified in Chapter 6
- Agency partnerships enhance information about municipal, industrial and agricultural conservation and reuse opportunities. Examples of possible partner projects may include:

    - Partnership with Minnesota Technical Assistance Program (MnTAP) to conduct water audits for industry and commerce
    - Collaborative efforts to reuse pollution containment water, where feasible
    - Partnership with USEPA WaterSense program to explore and promote supply-side and demand reduction approaches
- A grant program is initiated and supported to implement water conservation, reuse and/or cooperative water use practices
- Tools such as the Conservation Toolbox are developed, maintained and promoted
- Documented increase in water conservation awareness and implementation
- Evaluation of effectiveness of conservation best management practices for long-term reductions and for emergency/contingency planning across different community settings

Strategy 6: Investigate reusing treated wastewater

Metropolitan Council will investigate reusing treated wastewater to supplement groundwater and surface water as sources of nonpotable water to support regional growth, and when cost-effective, implement reuse.

These efforts support the Council's policy on water conservation and reuse (*Water Resources Policy Plan*).

A successful outcome of this work is that use of surface waters, reclaimed wastewater and stormwater for appropriate water uses becomes an option explored by communities and implemented by many. Chapter 6 provides more information.

Key partners and suggested roles

Metropolitan Council

Collaborate with the Plumbing Board and other partners to explore reuse opportunities; lead by example to maximize wastewater reuse within Council wastewater treatment facilities; if feasible, integrate nonpotable water systems into plans for future regional wastewater reclamation facilities – East Bethel is an example; facilitate collaboration with regulatory agencies to clarify reuse project requirements; collaborate with partners to demonstrate reuse; provide partners with technical assistance and tools such as the *Stormwater Reuse Guide*.

MPCA, MDH

Collaborate, advise, regulate

Others

Private well owners, business owners, communities and public water suppliers, state agencies regulating water resources, and others as appropriate collaborate to explore, if feasible, opportunities to reuse stormwater and wastewater.

Achievements (what successful achievement of this strategy might look like)

- Increased collaboration among the Council and state agencies on issues such as barriers to reuse, supported by efforts such as the Interagency Water Reuse Work Group. Example outcomes: identification of key implementation challenges with a nonpotable water system for toilet flushing and irrigation uses
- Increased wastewater reuse within Council wastewater treatment facilities, supported by projects such as water audits at all treatment facilities
- State regulations governing reuse are clarified
- Enhanced information about industrial reuse opportunities
- Reuse demonstrated through partnerships between Metropolitan Council and nonpotable water users
- Integrate nonpotable water systems into plans for future regional wastewater reclamation facilities.
- Wastewater investments consider regional water supply benefits
- Implement groundwater recharge and irrigation (for example, golf courses) in East Bethel and demonstrate reuse with University of Minnesota at UMore park, as demonstration projects for the region

Strategy 7: Support investments in water supply

Metropolitan Council will support cost-effective investments in water supply infrastructure to promote efficiency and sustainable use and protect the region's water supply by:

- With partners, developing criteria to identify water supply projects with regional and local benefit
- Promoting equitable cost-sharing structure(s) for regionally-beneficial water supply development projects
- Supporting cost-benefit analyses of alternative water supply options
- Identifying funding mechanisms for regionally-beneficial water supply development projects

This work is guided by Minnesota statutes 473.1565, and it supports the Council's policy on investment (*Water Resources Policy Plan*). These efforts help address the reliability, resiliency, security, and cost-effectiveness of the region's water supplies.

A successful outcome of this work is that use of surface waters, reclaimed wastewater and stormwater for appropriate water uses becomes an option explored by communities and implemented by many. Chapter 6 provides more information.

Key partners and suggested roles

Metropolitan Council

Support local effort in seeking funding for regionally beneficial infrastructure projects; provide assistance for local and sub-regional efforts to develop cost- sharing structures and other approaches to secure funding for regionally beneficial infrastructure projects by connecting local planners and sub-regional work groups with funding sources; gather information and collaborate on methods to estimate costs

Communities/Public Water Suppliers

In partnership with neighbors, lead discussion/direction to explore and implement various water supply approaches as needed; collaborate on methods to estimate costs and benefits of various approaches

Others

Private well owners, business owners, communities and public water suppliers, state agencies regulating water resources, and others as appropriate, collaborate and advise on methods to estimate costs and benefits of various approaches

Achievements (what successful achievement of this strategy might look like)

- Criteria developed to identify water supply projects with regional benefit
- Promotion of equitable cost-sharing structure(s) for regionally-beneficial water supply development projects
- Cost-benefit analyses of alternative water supply options completed, with key costs estimated in a way that allows for comparison between alternative approaches
- Funding mechanisms for regionally-beneficial water supply development projects identified
- Where feasible, interconnections among water supply systems are promoted
- Legislative funding requests for regionally-beneficial projects are supported

8 Roles and Responsibilities

Everyone – agencies, business, individuals – has a responsibility for ensuring a sustainable water supply planning. Collaborative actions are needed at the individual level, the community level, the regional level, and the state and federal level. This chapter highlights those roles and responsibilities that directly support the implementation of the Master Water Supply Plan, as defined in Chapter 7.

This Master Water Supply Plan recognizes that community public water suppliers are responsible for managing the largest category of non-consumptive water use in the metropolitan area; they are required to provide a safe and adequate supply of water.

Metropolitan Council's water supply role is to work with partners to develop a regional plan, maintain a base of technical information, provide assistance to communities in developing their local water supply plans, and to identify approaches for emerging issues.

State agencies and other organizations support sustainable use of water through permit programs, approval of local water supply-related plans, information collection and analysis activities, law enforcement responsibilities, education and technical assistance opportunities.

Sustainable water management is most successful when these efforts are coordinated. Despite an ever increasing level of coordination among the state agencies, there remains confusion among stakeholders as to who does what and where to get the information and answers they seek.

Summary of Roles

The metropolitan area's water supply management activities are divided among multiple partners; the Anoka County 2014 Water Resources Report provides an excellent summary of partner responsibilities. This Master Water Supply Plan focuses on some key partners driving the successful implementation of the plan. Other organizations provide additional support.

Key Partners

- *Private Water Supply (Well) Owners* develop, maintain and use infrastructure (primarily wells) for domestic, industrial or agricultural purposes.
- *Communities/Public Water Suppliers* provide water to customers in compliance with Safe Drinking Water Act standards, set rates to support system, develop and maintain infrastructure, monitor drinking water quality and quantity, ensure emergency procedures are in place, develop and enforce demand reduction measures (for droughts or contamination), plan for land use, water supply and capital improvements, and may regulate water use and well drilling.
- *Metropolitan Council* provides water supply and surface water planning support and direction, operates state's largest wastewater treatment system, and provides regional water quality and quantity monitoring.
- *Minnesota Department of Natural Resources* collects and analyzes information on water, regulates water use and riparian land use activities, manages public land, and approves water supply plans.

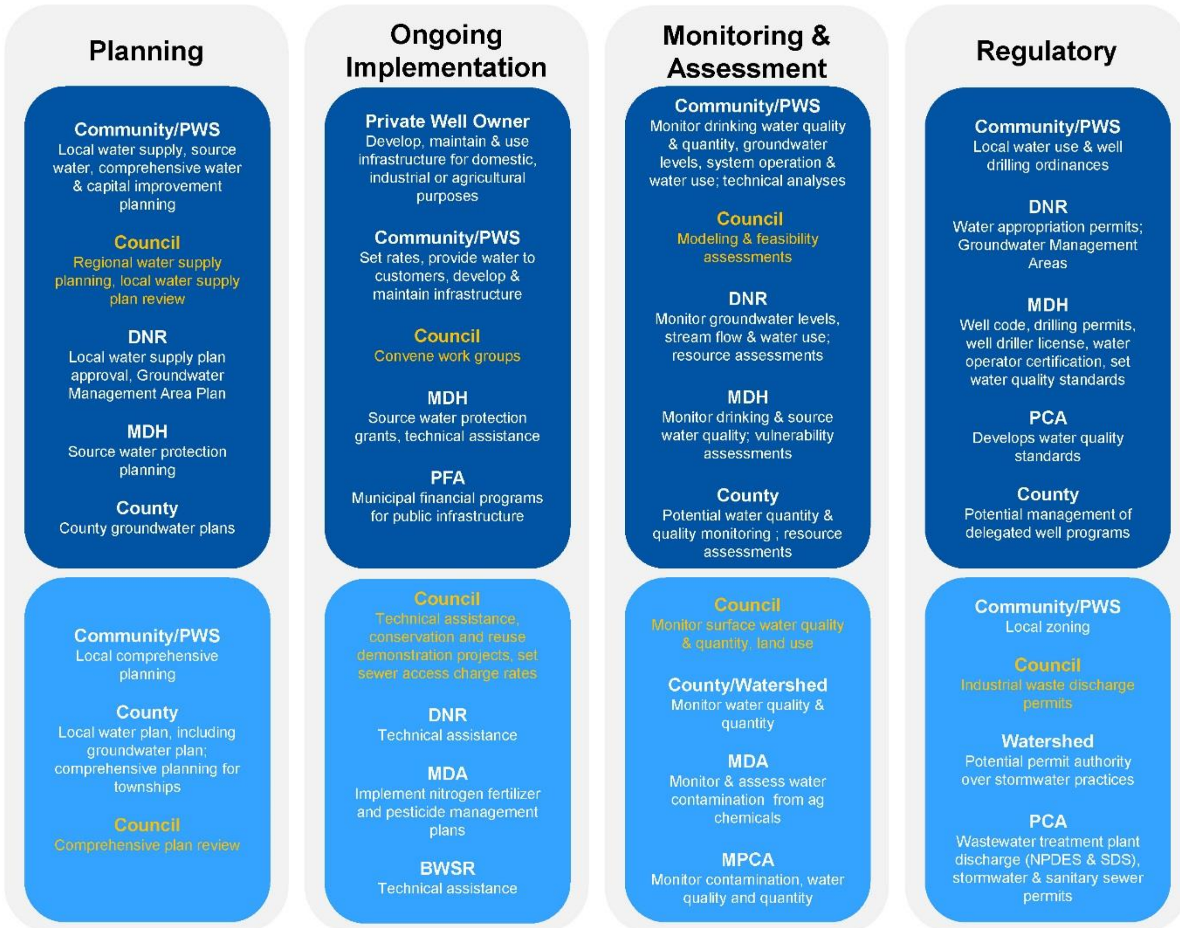
- *Minnesota Department of Health* ensures public drinking water systems protect sources and meet federal drinking water standards, regulates water well construction and sealing to protect groundwater, assesses drinking water contaminant risks to public health, licenses professions impacting drinking water, administers the Drinking Water Revolving Fund (DWRF), Source Water Protection Grants, wellhead protection plan development funding and other funding programs.
- *Minnesota Pollution Control Agency* develops water quality standards, monitors surface water and groundwater quality in non-agricultural settings, and restricts discharges of pollutants through use of permits, provides water conservation outreach through GreenSteps and other programs.
- *Minnesota Department of Agriculture* is responsible for fertilizer and pesticide regulation and management, activities include implementing the state Nitrogen Fertilizer and Pesticide Management Plans to protect groundwater; develops voluntary best management practices; monitors groundwater in agricultural settings; registers products with potential water impacts; and trains and licenses applicators.
- *Minnesota Public Facilities Authority* manages municipal financing programs to help communities build and upgrade drinking water, wastewater and storm water infrastructure.
- *Minnesota Board of Water and Soil Resources* provides resources and technical assistance to local governments, manages conservation easements, and provides oversight to local water management entities.
- *Counties* have authority to prepare and adopt groundwater plans, although most have not done so. Currently, only Washington and Dakota counties have approved plans and Carver County is in the process of approving one. Though it varies across the metro area, counties also have a role with respect to land use that includes zoning, shoreland, and mining operations.
- *Soil and Water Conservation Districts* may, if the authority is delegated by the County, prepare and adopt county groundwater plans, set priorities, address issues, and build local capacity for the protection and management of groundwater. They may also be active partners with respect to groundwater plan implementation.
- *Watershed Management Organizations* work to conserve the natural resources of the state by land use planning, flood control, and other conservation projects.
- *Minnesota Legislature* provides policy direction and, in some cases, directs funding

Coordination of these many water management activities occurs in four areas that support sustainable water supplies:

1. Planning is where information comes together in regional, sub-regional, and local commitments for prioritized, targeted, and measureable action.
2. Ongoing local implementation and support for local implementation is at the heart of the Master Water Supply Plan strategy for sustainable water supplies.
3. Monitoring and assessment determines the condition of the region’s source waters and informs future implementation actions.
4. Regulation helps ensure the best use of water resources for economic, environmental and social interests and provides for equity and fairness among water users

Figure 30 shows roles and responsibilities in water supply planning – primary ones as dark blue boxes and supporting (light blue boxes).

Figure 30. Roles and responsibilities supporting water supply planning. Dark blue activities directly support the outcomes of this Master Plan; light blue provide secondary don't directly relate to the regional outcomes in Chapter 6 but are still key water supply planning functions.



Private Water Supply (Well) Owners

Role

Regardless of size, owners of private wells and surface water intakes can take steps to use water as efficiently as possible and protect intakes or wellheads from becoming contaminated.

Responsibilities

Master Water Supply Plan implementation

- Learn about and implement, as appropriate, water demand management strategies
- Collaborate and convene with state, regional and local partners to maintain, and enhance the protection of the quality and quantity of the region's water supply (for example, participate or promote your water sector's participation on sub-regional water supply work groups)
- Partner with agencies to comply with water supply regulations and implement up-to-date best management practices for water conservation and pollution prevention

- Collaborate with Metropolitan Council and other partners to explore, if feasible, opportunities to reuse stormwater and wastewater.

Additional activities

- Develop, maintain, and use water supply infrastructure – wells and surface water intakes - for private water needs such as domestic, industrial and/or agricultural purposes
- If applicable, fulfill wastewater and stormwater management requirements

Communities/Public Water Suppliers

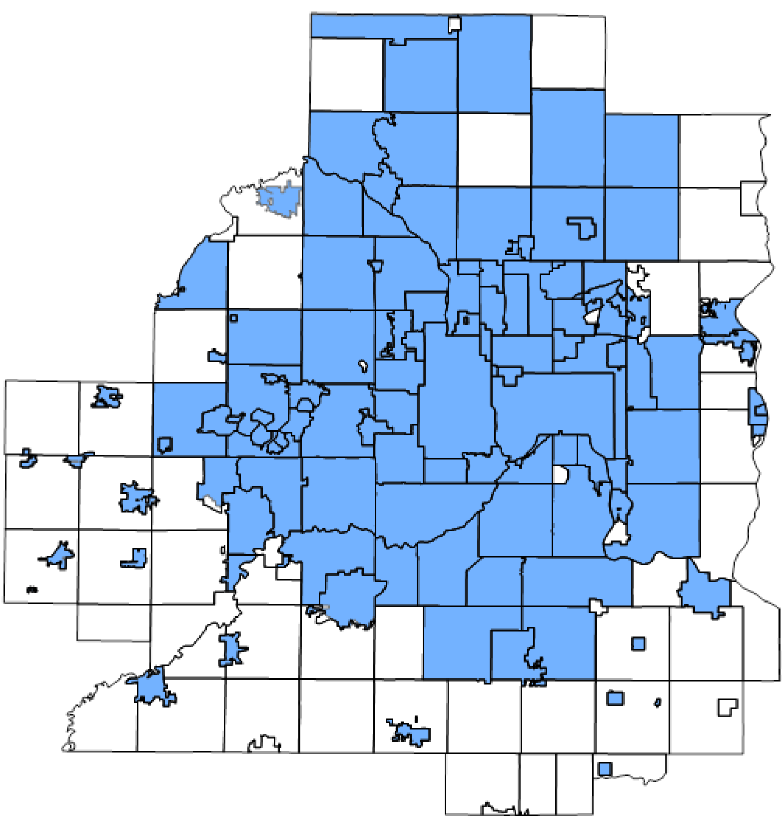
Role

The Metropolitan Council recognizes that water supply roles and responsibilities vary across the region. Some communities are fully served by public water supply systems and others have none. However, all communities can plan for sustainable water supply.

The *2014 AWWA State of the Water Industry Report* noted that communities with public water supplies are faced with two major challenges: first, conducting today's business operation and maintenance, and second, thoroughly planning for tomorrow's business operation and maintenance – including adapting to changing water demand.

Communities without public water supplies also have an important role to play, encouraging the use of environmentally sensitive development techniques and promoting best management practices for agricultural activities in order to protect the integrity of the region's water supply and the quality and quantity of surface and groundwater resource.

Figure 31. Communities with (blue) and without (white) public water supplies.



Responsibilities

Master Water Supply Plan Implementation

- Co-lead work groups; evaluate potential impacts of groundwater appropriations and work with state, regional and local partners to address issues and to reduce duplicate work.
- Comply with regulations
- Accommodate planned growth – including local controls and capital improvement programs – consistent with Council allocations of forecasted population
- Encourage the use of environmentally sensitive development techniques
- Promote best management practices for agricultural activities, where appropriate
- Prepare and implement local water supply plans that reflect this Master Water Supply Plan and source water (wellhead) protection plans, consistent with Minn. Rules Part 4720, in all communities with municipal water supply

Additional activities

- Develop and maintain water supply infrastructure, including testing of emergency interconnections as needed
- Manage finances of infrastructure, including setting water rates
- Monitor drinking water quality and quantity, groundwater levels, system operation, and water use
- Conduct technical analyses
- Develop and adopt local comprehensive plans (including the local water supply plan), source water protection plans, comprehensive water plans, and capital improvement plans
- Develop and enforce ordinances and zoning addressing issues such as water conservation, wellhead protection, mining, and well drilling within municipal water supply service areas
- Stay up to date about and implement best management practices for water conservation and pollution prevention
- Educate residents and customers about pollution prevention, water conservation, and stormwater management
- If county has an approved Groundwater Plan, then ensure that the community's water supply plan is consistent with it
- Use local zoning to promote land use that minimizes potential contaminant sources in drinking water management areas and that uses water efficiently including land use that maximizes opportunities for reuse of stormwater and/or reclaimed wastewater
- If delegated to a local board of health by the Minnesota Department of Health, manage delegated well programs for regulating of water wells, monitoring wells, and/or dewatering wells such as Minneapolis and Bloomington

Metropolitan Council

Role

The mission of the Metropolitan Council Environmental Services division is to provide wastewater services and integrated planning to ensure sustainable water quality and water supply for the region.

The role of the Council in water supply planning is to:

- Work with partners to develop a regional plan
- Maintain a base of technical information
- Provide assistance to communities in developing their local water supply plans, and
- Identify approaches for emerging issues

The Metropolitan Area Water Supply Advisory Committee and other work groups guide the Council in this work.

The Council is not a water supplier. The regional planning process has been designed and applied to ensure local water suppliers have control of and responsibility for their water supply systems.

Responsibilities

Master Water Supply Plan Implementation

- Collaborate with state agencies, watershed organizations, and community water suppliers to update the regional Master Water Supply Plan.
- Support community efforts to improve water supply resiliency by cooperatively identifying economically and technically feasible water supply alternatives.
- As required by Minnesota statutes, review and comment on local water supply plans.
- As requested by the DNR, participate on project advisory teams to provide advice and feedback on Groundwater Management Area Plans, and provide input on water appropriation permits. Metropolitan Council input will reflect Council policies and information in this Master Water Supply Plan.
- As required by Minnesota statutes, review and comment on wellhead protection and county groundwater plans.
- At the request of agency and local partners, review applicable permits.
- Facilitate discussions on water supply issues that transcend community boundaries, through sub-regional work groups and on an ad hoc basis as needed.
- Collaborate with partners to perform special studies as needed.
- Work with our partners to fill gaps in assessments of lake, stream, river, and groundwater data.
- In partnership with others, complete technical studies to understand regional and sub-regional long-term water supply availability and demand. This will include working with agencies to incorporate data collected through permitting and monitoring programs into regional and sub-regional analyses. For example, the Metropolitan Council uses data collected by DNR through the water appropriations permitting program to support regional groundwater flow modeling.
- Support community efforts to identify and evaluate the economic and technical feasibility of water supply approaches and best practices that increase water conservation, enhance groundwater recharge, and make the best use of groundwater, surface water, reclaimed wastewater, and stormwater.
- In partnership with others, research and promote low impact development, land use practices, agricultural best practices, and cooperative water use practices that minimize impacts on aquifers and maximize groundwater recharge, where practical.
- Promote and support water conservation measures, including education, outreach and tool development.
- Investigate reusing treated wastewater to supplement groundwater and surface water as sources of water to support regional growth, and when cost-effective, implement reuse.

- Support cost-effective investments in water supply infrastructure to promote sustainable use and protect the region's water supplies
- Evaluate impacts of planned growth and water demand on aquifer levels and water supply sustainability

Additional water supply-related activities

- Promote residential development patterns that protect natural resources, the quality and quantity of our water resources, and our water supply
- Monitor surface water quality and quantity
- Issue industrial wastewater discharge permits
- Monitor groundwater quality and quantity at recharge sites such as the East Bethel wastewater reclamation facility

Minnesota Department of Natural Resources

Role

The DNR plays an important role in supporting sustainable use of water through its water appropriation permit program, approval of local water supply plans, information collection and analysis activities, law enforcement responsibilities, education and technical assistance opportunities.

The DNR assists public water suppliers in developing local water supply plans to address the unique needs and resource characteristics of the individual communities. These plans are required of every public water supplier serving more than 1,000 people, but DNR staff also work closely with smaller public water suppliers that want to engage in water supply planning. DNR ensures that water use permits for public water suppliers are congruent with that community's local water supply plan. In the metropolitan area, the DNR collaborates with the Metropolitan Council on water supply planning activities. Through its local water supply plan review and approval process, the DNR ensures that local water supply plans reflect the Metropolitan Council's Master Water Supply Plan efforts.

Responsibilities

Master Water Supply Plan Implementation

- Develop a local water supply plan template and notify public water suppliers of the timeline for completing their plan
- In partnership with Metropolitan Council, review local water supply plans for consistency with regional water supply policies
- Administer the water appropriation permit program to ensure water appropriation permits are consistent with approved local water supply plans
- In partnership with Metropolitan Council, provide advice for plan development and implementation, including guidance on demand reduction methods and water conservation
- Collect, review and share data to support water supply-related mapping, modeling and management efforts, such as regional groundwater flow modeling by Metropolitan Council

Additional water supply-related activities

- Monitor groundwater and basin water levels, stream flow, and climate
- Map natural resources, including geologic atlases and ecological surveys
- Develop sustainability thresholds

- Establish Groundwater Management Areas in areas with difficult groundwater-related resource challenges, and develop and implement a plan to achieve the overall goal of long term, sustainable groundwater use in the area. Groundwater Management Area plans guide DNR actions over the timeframe of the plan.

Minnesota Department of Health

Role

The Minnesota Department of Health (MDH) has three primary areas of responsibility that relate to water supply planning:

- Regulate public water supplies under the federal Safe Drinking Water Act and state rules and statutes
- Regulate well construction including designation of special well and boring construction areas
- Assessment of drinking water contaminant risks

The MDH Drinking Water Protection Program protects public health by ensuring a safe and adequate supply of drinking water at all public water systems, which are those that serve water to the public. The MDH Well Management Program protects both public health and groundwater by assuring the proper construction of new wells and borings, and the proper sealing of unused wells and borings.

The MDH Environmental Surveillance and Assessment Program operates in collaboration with local, state, and federal environmental and health agencies and academic institutions to collect and assess data regarding exposures to chemicals and other substances that may pose health risks to the public.

Water supply planning activities include assisting public water supplies with infrastructure planning and response to drinking water contaminant issues, and planning for wellhead protection for public water supplies. A number of advisory groups provide input and advice to the MDH on drinking water issues. These include the Water Utility Council, the Advisory Council on Wells and Borings, and the Advisory Council on Water Supply Systems and Wastewater Treatment Facilities. In addition, the MDH provides technical assistance to local government, public water supply staff and the public, and access to water planning information through resources like the County Well Index.

Responsibilities

Master Water Supply Plan Implementation

- Partner with the Metropolitan Council to provide guidance to communities for considering source water protection in local comprehensive plans
- Administer the code governing wells, certify well operators, and in partnership with DNR issue permits that are consistent with DNR preliminary well screening criteria and MDH requirements

Additional water supply-related activities

- Monitor public drinking water supplies for contaminants regulated under the Safe Drinking Water Act
- Educate water suppliers about public health and drinking water, including water supply management and protection

- Assist local government, business, and the public in managing risks to and from drinking water supplies through:
    - Protecting the sources that supply drinking water to the public by mapping drinking water sources, identifying source water areas, identifying risks of impacts to water supplies
    - Supporting capacity for developing and implementing source water protection plans
    - Applying groundwater models and interpreting hydrogeology
    - Identifying interactions between groundwater and surface water
    - Identifying recharge areas
    - Identifying potential contaminant sources
    - Evaluating future water demand
    - Evaluating risk of land use changes to water quality and quantity
- Develop human health guidance
- Evaluate and communicate scientific information about the potential for health risks from exposures to newly identified health hazards in drinking water
- Identify ambient groundwater quality through initial sampling of private wells
- Collect and maintain information for the state about well construction and well logs as it relates to drinking water wells (County Well Index)
- Provide cost share funds for sealing unused wells that could become a pathway for contaminants to enter drinking water sources
- Oversee, along with the Minnesota Public Facilities Authority, the Drinking Water Revolving Loan Fund
- Delegate specific responsibilities for the regulating water wells, monitoring wells, and/or dewatering wells to local boards of health, such as Dakota County, Minneapolis, and Bloomington

Minnesota Pollution Control Agency

Role

The Minnesota Pollution Control Agency's mission is to protect and improve the environment and enhance human health.

Responsibilities

Master Water Supply Plan Implementation

- Partner with the Metropolitan Council to provide guidance to communities to consider source water protection as part of stormwater management

Additional water supply-related activities

Although MPCA is not directly responsible for water supply infrastructure or management, several activities indirectly affect water supply sources in the region:

- Monitor ambient groundwater quality as an early warning system identifying threats to the quality of shallow and vulnerable aquifers.
- Consult and provide support to the DNR for water supply concerns and dropping lake levels in the North and East Metro Groundwater Management Areas
- Participate on the Interagency Groundwater/Drinking Water collaborative team working with the Clean Water Fund

- Investigate and remediate non agricultural contaminated sites, including monitoring to assess the containment of contaminant plumes from Superfund sites, petroleum releases and closed landfills.
- Monitor the waters of the state to assess their quality, using a systematic intensive watershed approach to determine physical, chemical and biological integrity.
- Promote protection of drinking water use and identify source water protection areas in certain projects with limits on the Total Maximum Daily Load of pollutants (TMDL) and in Watershed Restoration and Protection Strategies (WRAPS)
- Maintain and update standards and rules to be consistent with other rules and statutes protecting water supply sources
- Adapt monitoring, prevention, regulation and remediation efforts for contaminants of new/emerging concern
- Identify and investigate interactions between groundwater and surface water
- Work with local government units to promote and implement best management practices that protect surface and groundwater quality
- Ensure compliance with the Minnesota Groundwater Protection Act
- Minimize and regulate pollutant discharges via permits, technical/financial assistance, and enforcement
- Provide guidance regarding siting of industrial landfills

Minnesota Department of Agriculture

Role

The mission of the department is to enhance Minnesotan's quality of life by ensuring the integrity of the food supply, the health of the environment, and the strength of the agricultural community. The Minnesota Department of Agriculture (MDA) is the lead agency for all aspects of pesticide and fertilizer environmental and regulatory functions.

Responsibilities

Master Water Supply Plan Implementation

- Partner with Metropolitan Council to provide guidance to communities to consider agricultural best management practices within source water protection areas.

Additional water supply-related activities

While MDA is not directly responsible for water supply infrastructure or management, several of its activities indirectly affect water supply sources in the region.

MDA is responsible for or involved in many water quality programs and initiatives. These include but are not limited to the following:

- Serve as lead agency for groundwater contamination from pesticide and fertilizer non-point source pollution
- Conduct monitoring and assessment of agricultural chemicals (pesticides and nitrates) in ground and surface waters
- Oversee agricultural chemical remediation sites and incident response
- Regulate use, storage, handling and disposal of pesticides
- Regulate storage, handling and disposal of fertilizer

Minnesota Public Facilities Authority

Role

The Minnesota Public Facilities Authority (PFA) is a multi-agency authority that provides municipal financing programs and expertise to help communities build public infrastructure that preserves the environment, protects public health, and promotes economic growth.

Master Water Supply Plan Implementation

- None

Additional water supply-related activities

- Administer three revolving loan funds and other programs to help local units of government fund public infrastructure projects

Program(s) funding source(s)

- State General Fund
- Clean Water Fund
- Federal Funds

Funding provided to Local Governmental Units for Implementation

- Clean Water Revolving Fund
- Drinking Water Revolving Fund

Board of Water and Soil Resources

Role

The Board of Water and Soil Resources (BWSR) is the state soil and water conservation agency, and it administers programs that prevent sediment and nutrients from entering our lakes, rivers, and streams; enhance fish and wildlife habitat; and protect wetlands.

Responsibilities

Master Plan Implementation

- None

Additional water supply-related activities

Although BWSR is not directly responsible for water supply infrastructure or management, several activities indirectly affect water supply sources in the region:

- Identify strategies for groundwater protection
- Identify potential locations for infiltration projects/BMPs that may include wetland restoration, enhancements, or creation
- Technical assistance to Soil and Water Conservation Districts
- Direct private land soil and water conservation programs through the action of SWCDs, counties, cities, townships, watershed districts, and water management organizations.
- Link water resource planning with comprehensive land use planning.
    - Approve county groundwater plans
    - Approve watershed management organization plans
- Provide resolution to water policy conflicts and issues. To implement the comprehensive local water management acts

- Provide the forum (through the board) for local issues, priorities, and opportunities to be incorporated into state public policy
- Advise local governmental units that administer for the Wetland Conservation Act
- Coordinate state and federal resources to realize local priorities

StatutoryRequirements/Authority

- Minnesota statutes chapter 103B.101
- Minnesota statutes chapters 103C, 103D, 103F
- Minnesota statutes chapters 103A.211, 103A.305, 103A.315, 103A.311
- Minnesota statutes chapters 103B.201, 103B.255, 103B.301
- Minnesota statutes chapters 103G

Counties

Role

Though their roles vary across the Twin Cities metropolitan area, counties may shape water water supply management through their planning and plan implementation functions. For example, some counties play an important role by performing land use functions – including zoning, shoreland and mining operations - for cities and townships that delegate this work to the counties.

Additionally, in 1987, metropolitan counties were given the authority to prepare and adopt groundwater plans. Groundwater plans provide counties that adopt them a mechanism to set priorities, address issues, and build local capacity to protect and manage of groundwater. Carver, Dakota, Hennepin, Ramsey, Scott and Washington counties have developed groundwater plans that were approved by the state, although not all were formerly adopted by the county. Anoka County, though not participating in the official metropolitan groundwater planning process, has prepared a “groundwater protection assessment”.

This is an important issue in the metropolitan area. Counties in the area rely heavily on their groundwater for their domestic, municipal, industrial, and agricultural water supplies. Additionally, the metropolitan area has productive aquifers, but they have limits. Development and urban sprawl can increase demands on groundwater and disrupt groundwater recharge areas.

A number of successes have come out of this planning process. Every county in the metro area has technical capacity to deal with groundwater issues at some level. Metropolitan counties with approved groundwater plans can use matching grants to implement items in their plans.

Responsibilities

Although counties are not directly responsible for water supply infrastructure or management, they may engage in several activities that indirectly affect water supply sources in the region.

Master Water Supply Plan Implementation

- In close coordination with cities that develop their own groundwater plans, write, coordinate, and administer county groundwater plans that reflect the Master Water Supply Plan
- Review local water supply plans and recommend Metropolitan Council approval, if a county groundwater plan has been adopted (persuant to Minnesota statutes 473.859, subd. 6)

Additional water supply-related activities

- Convene local stakeholders to ensure and enable coordination with respect to groundwater issues and activities
- Conduct comprehensive planning for townships (except Ramsey and Hennepin)
- Establish and enforce standards to prevent contamination of groundwater
- If delegated to a local board of health by the MDH, manage delegated well programs for regulating water wells, monitoring wells, and/or dewatering wells, such as in Dakota County
- Coordinate monitoring networks and monitoring groundwater and surface water quality and quantity
- Regulate individual sewage treatment systems, if a program exists
- Regulate feedlots
- Enforce building codes
- Monitor water resources
- Test private wells
- License solid and hazardous wastes
- Provide well sealing grants and technical assistance
- Educate the public, businesses, organizations and others about water appropriation and conservation
- Identify sensitive areas that may be vulnerable to adverse water supply impacts

Soil and water conservation districts

Role

Soil and Water Conservation Districts (SWCDs) are local units of government that manage and direct natural resource management programs at the local level. Districts work in both urban and rural settings, with landowners and with other units of government, to carry out a program for the conservation, use, and development of soil, water, and related resources.

One crucial niche districts fill is that of providing soil and water conservation services to owners of private lands.

Responsibilities

SWCDs provide needed technology, funding and educational services. Counties and Soil and Water Conservation Districts may collaborate or delegate all responsibilities to one or the other.

Master Water Supply Plan Implementation

- If delegated authority by the County, write, coordinate, and administer county groundwater plans, if they are developed, that reflect the Master Water Supply Plan; otherwise, an SWCD can be an active partner with respect to Groundwater Plan development and implementation
- Review local water supply plans and recommend Metropolitan Council approval, if a County Groundwater Plan has been adopted pursuant to Minnesota statutes 473.859, subd. 6

Additional water supply-related activities

- Monitor groundwater and surface water resources
- Promote best management practices that protect and enhance water supplies, particularly in rural areas

Watershed management organizations

Role

The organization of watershed management responsibilities varies across the metropolitan area. Watershed management may occur through Watershed Management Organizations (WMOs), Watershed Districts, or counties. Regardless of the management structure, watersheds work to conserve the natural resources of the state by land use planning, flood control, and other conservation projects using sound scientific principles for the protection of public health and welfare and wise use of the natural resources.

In the metro area, watershed activities are guided by the Metropolitan Area Surface Water Management Act (Minnesota statutes 103B.201 to 255), which requires watersheds to prepare and implement watershed management plans.

Responsibilities

Master Plan Implementation

Although watersheds are not directly responsible for water supply infrastructure or management, several activities may indirectly affect water supply sources in the region.

- Incentivize low-impact development practices to reduce irrigation and increase infiltration
- Use communication media to disseminate information about source water protection
- Monitor groundwater-surface water connections

Additional water supply-related activities

Watersheds have the option to engage in water supply management, shaped by Minnesota statutes and rules. If this option is pursued, responsibilities might include:

- Fund water supply protection activities (well sealing, for example)
- Support stormwater infiltration approaches that protect and enhance groundwater
- Monitor groundwater and surface water quality and quantity to evaluate water supply sustainability
- Issue permits for water appropriations, if the watershed management organization has permitting authority
- Complete a watershed management plan that is consistent with the Minnesota Rules 8410
- If a county has an approved groundwater plan, ensure that the community's own groundwater plan is consistent with it.

Funding sources for implementation

Drinking water infrastructure

For building or maintaining infrastructure for drinking water, there are several funding options available to municipalities and drinking water utilities. These include traditional revenue generating methods such as utility water rates, and other customer fees and charges for specific benefits or services.

Large capital projects often require multiple funding sources to finance projects and minimize the impact on user rates. Projects of this type can be financed through municipal revenue bonds, which are generally paid for over time by water rates, or with other sources, including low-interest loans or grants that may be available through state and federal programs.

Several programs relevant to water utilities in Minnesota are described below in Tables 6 and 7. Some of the funding programs target small communities and rural areas, and may have limited applicability in more urbanized areas. These qualifications are noted, where possible.

Table 6. Funding sources for drinking water infrastructure.

Topic	Program Detail
Program	**Rural Development, U.S. Department of Agriculture**
Objective	Provide loans and grants for development of water systems in rural areas and towns with a population of 10,000 or less.
Applicant	Public entities, non-profit organizations, and Indian tribes. Several areas in the seven-county metropolitan area are ineligible.
Uses	Construction, land acquisition, legal fees, engineering fees, capitalized interest, equipment, initial operation and maintenance costs, project contingencies, and any other cost that is determined by the Rural Development program to be necessary for the completion of the project. Projects must be primarily for the benefit of rural users.
Population	Less than 10,000 in rural areas.
Terms/ Conditions	Must show that applicant is unable to secure funds at affordable rates otherwise. Rates are set quarterly. Loans are made based on the applicant's authority and the life expectancy of the system's project.
Website	http://www.rurdev.usda.gov/UWP-dispdirectloansgrants.htm
Program	**Small Cities Development Grant Program**
Objective	Provide grants to help cities and counties with funding for public infrastructure. Benefits individuals and households with low and moderate incomes, eliminates urgent threat to public health or safety.
Applicant	Cities, township and counties. In seven-county metropolitan area, only Carver County and Scott County are eligible.
Uses	Public facility improvements, including wells, water towers, distribution systems.
Population	Cities with population of 50,000 or less. Counties with population of 200,000 or less.

Topic	Program Detail
Terms/ Conditions	Maximum grant is $600,000. Must benefit low and moderate-income persons or households. Timeline to complete projects is normally 30 months.
Website	http://mn.gov/deed/government/financial-assistance/community- funding/
Program	**Drinking Water Revolving Fund, Minnesota Department of Employment and Economic Development**
Objective	Provide loans to help communities build drinking water storage, treatment and distribution systems to comply with standards in the Safe Drinking Water Act.
Applicant	Cities, counties, townships, sanitary districts or other governmental subdivisions responsible for providing public drinking water. Projects must be on the MDH Project Priority List (PPL) and the Public Facility Authority's Intended Use Plan (IUP). Must be certified by MDH before loan approval.
Uses	Allowable costs include land costs, site preparation, construction, engineering, equipment and machinery, bond issuance, and certain fees and contingency costs. Projects that are primarily to serve growth are not eligible
Population	No cap or minimum. Rate discounts may apply for applicants with populations less than 2,500.
Terms/ Conditions	Discounted loan rates. Loans are amortized up to a maximum of 20 years or up to 30 years if the average annual resident cost would exceed 1.2% of median household income.
Website	http://www.mn.gov/deed/government/public-facilities/funds-programs/drinking-

Storm water infrastructure

There are several potential funding sources for local stormwater infrastructure projects. These may include user rates and charges, grants, or low-interest loan programs. Revenues generated from stormwater utility fees and charges can be used to fund capital projects.

Similarly, watershed districts (and some water management organizations) can fund capital projects with revenues collected through their taxing authority, or through special fees. Additional opportunities may be available to public entities through either community partnerships or partnerships among a combination of public and private entities. In some cases, granting organizations will support nonprofit, nongovernmental or educational programs, but are restricted from directly funding government operations.

Community partnerships, where a school, non-profit, or other similar organization is the primary grant applicant and the governmental agency is a partner or subrecipient, may open other granting opportunities where the costs and implementation responsibilities could be shared between organizations. Often, collaborative arrangements, multidisciplinary or public-private partnerships, and the involvement of community stakeholders are supported by granting organizations.

Table 7 below summarizes two state programs that could potentially be used to finance stormwater projects in Minnesota. Some programs focus on water quality improvement projects, so water quality benefits of any candidate project would have to be clearly demonstrated.

Table 7. Funding sources for stormwater infrastructure

Topic	Program Detail
Program	Point Source Implementation Grant Program,
Objective	Provide grants to local units of government to assist with the cost of wastewater or stormwater projects. Projects should be focused on water quality.
Applicant	Cities, counties, townships, sanitary districts. Must be on the MPCA's Project Priority List (PPL).
Uses	Build, repair and improve public wastewater or stormwater systems. Must address an issue involving the total maximum daily load (TMDL) of identified pollutants.
Population	No cap or minimum.
Terms/ Conditions	Provides grants for up to 50% of eligible costs up to $3 million.
Website	http://www.mn.gov/deed/government/public-facilities/funds-programs/point-source-grants.jsp
Program	**Projects and Practices, Board of Water and Soil Resources (BWSR) Clean Water Fund (CWF) grants**
Objective	Provide grants for on-the-ground projects and practices that will protect or restore water quality in lakes, rivers or streams, or will protect groundwater or drinking water. Must be consistent with approved state or local water management document or plan.
Applicant	Soil and Water Conservation Districts, Watershed Districts, Watershed Management Organizations, Counties, Cities, and joint powers board of these organizations.
Uses	Eligible activities can consist of structural practices and projects, non-structural practices and measures, project support, and grant management and reporting.
Population	No cap or minimum.
Terms/ Conditions	Requires minimum 25% nonstate match. Minimum request of $30,000

Topic	Program Detail
Website	http://www.bwsr.state.mn.us/cleanwaterfund/FY12_BWSR_CWF_Policy_Final.pdf
Program	**Targeted Storwwater Grant, Metropolitan Council**
Objective	Provide grants for projects that serve as visual demonstration projects, are easy to replicate, focus on highly urbanized areas, include long-term monitoring and provide information on challenges and opportunities.
Applicant	Soil and Water Conservation Districts, Watershed Districts, Watershed Management Organizations, Counties, Cities, and joint powers board of these organizations.
Uses	Stormwater management demonstration projects
Population	No cap or minimum
Terms/ Conditions	Contact Metropolitan Council for more information
Website	None

Other sources

Other sources, although more difficult to secure, include special appropriations from state or federal government. These include the State and Tribal Assistance Grant (STAG) program administered by the regional offices of the U.S. Environmental Protection Agency, or other infrastructure funding included in special legislation or appropriations.

In the past, these funds have, in the past, helped to finance a portion of the costs associated with water infrastructure projects. Projects that are selected for special funding provisions often demonstrate collaborative approaches to resource or infrastructure challenges, and present solutions with regional benefits. Financial hardship to the affected communities or rate payers may also be considered, among other criteria.

Shared water infrastructure projects have secured special funding consideration in Minnesota in the past. The Joint Powers Water Board, a shared utility that serves Albertville, Hanover and Saint Michael secured approximately $1 million in grant money to establish a joint utility in 1977. The Burnsville/ Kraemer Quarry water project received $5.5 million in state funding in 2008 for construction of a new water treatment plant that serves the Cities of Burnsville and Savage. Rural water systems in Minnesota have also secured federal and state funding for capital improvements and expansion.

The size and scope of major infrastructure projects often require a combination of funding sources, which can include rate payer-generated funds, bonds, low-interest loans, or grants. Many of the loan or grant programs require some component of matching funds; pursuing a diversified financing strategy is recommended to maximize opportunities, and minimize the impact on rate payers. As supply and resource availability issues continue to emerge in the region, a shared-system approach to water supply may provide both supply reliability and a framework for equitable resource use, as well as economic opportunities.

9 Annotated Bibliography

AMERICAN WATER WORKS ASSOCIATION. 2014. AWWA STATE OF THE WATER INDUSTRY REPORT.

The American Water Works Association (AWWA) has been formally tracking issues and trends in the water industry since 2004 through the State of the Water Industry (SOTWI) study. The Association continues to conduct this annual survey in order to: identify and track significant challenges facing the water industry, provide data and analyses to support water professionals as they develop and communicate strategies to address current issues, discover and highlight potential problems or concerns on the water industry's horizon, and inform decision makers and the public of the challenges faced by the industry.

ANOKA COUNTY COMMUNITY HEALTH AND ENVIRONMENTAL SERVICES. 2014. WATER RESOURCES REPORT. ANOKA COUNTY: ANOKA, MN.

This report addresses the environmental health issues identified for Anoka County. Natural resources management, environmental protection and environmental health protection share many goals. For example, the protection and management of Mississippi River water quality is a goal of a natural resources program such as the Clean Water Act, and a public health program including the Safe Drinking Water Act. This report will be used to address environmental health issues identified in Anoka County through the Community Health Services assessment and planning process, and will be incorporated into the Community Health Improvement Plan (CHIP). Appendix A provides a detailed summary of the authority and responsibility for water resources management, including information about federal, state and local entities. ***Website***

BARR ENGINEERING COMPANY. 2015 (DRAFT). TECHNICAL MEMORANDUM TO METROPOLITAN COUNCIL: METRO PUMPING OPTIMIZATION 3.

This technical memorandum describes the optimization of pumping in the seven-county metropolitan area. The goal of the optimization was to maximize total pumping from existing wells while meeting constraints on baseflow, hydraulic head, and flow direction as specified by the Metropolitan Council. The optimization uses the steady-state version of the Twin Cities Metropolitan Area Groundwater Flow Model, Version 3.0 (Metro Model 3; Metropolitan Council, 2014).

DADASER-CELIK, FILIZ AND STEFAN, HEINZ G.. 2009. STREAM FLOW RESPONSE TO CLIMATE IN MINNESOTA, PROJECT REPORT NO. 510. UNIVERSITY OF MINNESOTA, ST. ANTHONY FALLS LABORATORY. PREPARED FOR LEGISLATIVE CITIZENS COMMITTEE ON MINNESOTA RESOURCES. ST. PAUL, MN.

The variability of stream flows in Minnesota, and the relationship between stream flows and climate are the focus of this report. We analyze historical flow records of Minnesota streams to determine how much frequency and magnitude of flows have been affected by climate and land use changes. Flow duration analysis, high and low flow ranking, and flood frequency analysis were applied to recorded mean daily stream flows, 7-day average low flows, and annual peak flows. Data from 36 gauging stations located in five river basins of Minnesota (Minnesota River, Rainy River, Red River of the North, Lake Superior, and Upper Mississippi River Basins) covering the 1946-2005 period were used. ***Website***

DICKINSON, MARY ANN. 2014. THE REAL RELATIONSHIP BETWEEN CONSERVATION AND RISING WATER RATES. DOWNLOADED FROM NATIONAL GEOGRAPHIC WEBSITE ON APRIL 29, 2015 AT HTTP:// VOICES.NATIONALGEOGRAPHIC.COM/2014/10/05/THE-REAL-RELATIONSHIP-BETWEEN- CONSERVATION-AND-RISING-WATER-RATES/

This article discusses three reasons why water efficiency is a smart investment for both utilities and consumers and not solely a revenue buster as is currently perceived:

- Water rates will rise regardless of whether water conservation occurs.
- Water efficiency has been proven to actually slow down the increases in consumer rates.

Efficiency is often the cheapest source of new supply and can help avoid the expensive costs of adding new storage or treatment capacity. ***Website***

HALL, C.W. ET AL. 1911. GEOLOGY AND UNDERGROUND WATERS OF MINNESOTA. WORK DONE IN COOPERATION WITH THE MINNESOTA STATE BOARD OF HEALTH. UNITED STATES GEOLOGICAL SURVEY: WASHINGTON D.C.

The purpose of this investigation was to determine to the fullest extent practicable the principal facts in regard to the underground waters – their quantity, head, mineral content, sanitary conditions, and their depths below the surface – as well as the best methods for drilling to the them and finishing wells for their utilization and to consider all other questions relating to their recovery for human use. ***Website***

KEELER, BONNIE L. AND STEPHEN POLASKY, 2014, LAND-USE CHANGE AND COSTS TO RURAL HOUSEHOLDS: A CASE STUDY IN GROUNDWATER NITRATE CONTAMINATION. ENVIRONMENTAL RESEARCH LETTERS 9 074002. IOP SCIENCE PUBLISHING LTD. PUBLISHED JUNE 30, 2014.HTTP:// IOPSCIENCE.IOP.ORG/1748-9326/9/7/074002/ARTICLE

Loss of grassland from conversion to agriculture threatens water quality and other valuable ecosystem services. Here we estimate how land-use change affects the probability of groundwater contamination by nitrate in private drinking water wells. We find that conversion of grassland to agriculture from 2007 to 2012 in Southeastern Minnesota is expected to increase the future number of wells exceeding 10 ppm nitrate-nitrogen by 45% (from 888 to 1292 wells). We link outputs of the groundwater well contamination model to cost estimates for well remediation, well replacement, and avoidance behaviors to estimate the potential economic value lost due to nitrate contamination from observed land-use change. We estimate $0.7–12 million in costs (present values over a 20 year horizon) to address the increased risk of nitrate contamination of private wells. Our study demonstrates how biophysical models and economic valuation can be integrated to estimate the welfare consequences of land-use change. ***Website***

KESSLER, ERICH AND LORENZ, D.L., 2010, LOW-FLOW CHARACTERISTICS OF THE MISSISSIPPI RIVER UPSTREAM FROM THE TWIN CITIES METROPOLITAN AREA, MINNESOTA, 1932-2007: U.S. GEOLOGICAL SURVEY SCIENTIFIC INVESTIGATION REPORT 2010-5163, 14 P

The U.S. Geological Survey, in cooperation with the Metropolitan Council, conducted a study to characterize regional low flows during 1932–2007 in the Mississippi River upstream from the Twin Cities metropolitan area in Minnesota and to describe the low-flow profile of the Mississippi River between the confluence of the Crow River and St. Anthony Falls. Probabilities of extremely low flow were estimated for the streamflow-gaging station (Mississippi River near Anoka) and the coincidence of low-flow periods, defined as the extended periods (at least 7 days) when all the daily flows were less than the 10th percentile of daily mean flows for the entire period of record, at four selected streamflow-gaging stations located upstream. The likelihood of extremely low flows was estimated by a superposition method for the Mississippi River near Anoka that created 5,776 synthetic hydrographs resulting in a minimum synthetic low flow of 398 cubic feet per second at a probability of occurrence of 0.0002 per year. ***Website***

KLOPROGGE, PENNY, ERONENE VAN DER SLUIJS AND ARJAN WARDEKKER. 2007. UNCERTAINTY COMMUNICATION: ISSUES AND GOOD PRACTICE. COPERNICUS INSTITUTE – RESEARCH INSTITUTE FOR SUSTAINABLE DEVELOPMENT AND INNOVATION, UNIVERSITEIT UTRECHT: UTRECHT, THE NETHERLANDS.

Dealing with uncertainty is essential because assessment results regarding complex environmental issues are of limited value if the uncertainties have not been taken into account adequately. A careful analysis of uncertainties in an environmental assessment is required, but even more important is the effective communication of these uncertainties in the presentation of assessment results. This report explores the issue of uncertainty communication in detail, and contains more detailed guidance on the communication of uncertainty. ***Website***

MAUPIN, M.A., KENNY, J.F., HUTSON, S.S., LOVELACE, J.K., BARBER, N.L., AND LINSEY, K.S.. 2014. ESTIMATED USE OF WATER IN THE UNITED STATES IN 2010: U.S. GEOLOGICAL SURVEY CIRCULAR 1405.

This report, “Estimated use of water in the United States in 2010,” is the 13th in a series of U.S. Geological Survey (USGS) Circular reports that have been published every 5 years since 1950. The 60-year span of national reports represents the longest compilation record of water-use data by a Federal agency in the United States. ***Website***

METROPOLITAN COUNCIL. 2010. EVALUATION OF GROUNDWATER AND SURFACE-WATER INTERACTION: GUIDANCE FOR RESOURCE ASSESSMENT: TWIN CITIES METROPOLITAN AREA, MINNESOTA. PREPARED BY BARR ENGINEERING. METROPOLITAN COUNCIL: SAINT PAUL, MN.

This project provides a screening method to identify areas where groundwater withdrawals are most likely to have an impact on surface waters. In these areas, further characterization of the groundwater- surface water connection may be an important part of local water supply development. This study was conducted to: (1) prioritize surface water features for impact monitoring and resource assessment and (2) recommend monitoring and analysis techniques that will provide early warning to water supply managers to help avoid impacts on surface water features from groundwater pumping. ***Website***

METROPOLITAN COUNCIL. 2011. STORMWATER REUSE GUIDE. PREPARED BY CDM SMITH. METROPOLITAN COUNCIL: SAINT PAUL, MN.

The Metropolitan Council Stormwater Reuse Guide introduces effective alternative techniques for stormwater reuse for the purpose of reducing demand on Twin Cities metropolitan area potable water supplies. Tailored for city planners, engineers, and green thinkers, the Guide provides step-by-step instructions that describe how to bring a stormwater reuse project from concept, to assessment, to implementation. A stepwise series of tools are provided to characterize the source stormwater, identify the intended use, assess the feasibility of the concept, and then select and implement the appropriate collection, storage, treatment, and distribution components of the project. The Guide is designed to be visually appealing and easy to navigate, both electronically and on paper. ***Website***

METROPOLITAN COUNCIL. 2013A. ASSESSING THE OPPORTUNITY AND BARRIERS FOR WATER CONSERVATION BY PRIVATE INDUSTRIAL WATER USERS: FOR THE TWIN CITIES METROPOLITAN AREA. PREPARED BY THE MINNESOTA TECHNICAL ASSISTANCE PROGRAM. METROPOLITAN COUNCIL: SAINT PAUL, MN.

This project supports the intent of the Metropolitan Council to better understand the industrial water use needs of private well water users in an eleven county area including Anoka, Carver, Chisago, Dakota, Hennepin, Isanti, Ramsey, Scott, Sherburne, Washington, and Wright counties. Through this project, the Metropolitan Council and MnTAP will identify opportunities for industrial water conservation as well as factors that motivate implementation of operational changes to capture water conservation savings. The project will fill an existing knowledge gap in water conservation data in the metropolitan area. Data gained from this project will be used in water supply planning projections for the metropolitan area. Private industrial water users will receive site-specific water conservation recommendations. ***Website***

METROPOLITAN COUNCIL. 2013B. GROUNDWATER DIGEST. METROPOLITAN COUNCIL: SAINT PAUL, MN.

This digest explains how groundwater “works” and why it is important to the region. ***Website***

METROPOLITAN COUNCIL. 2014A. ASSESSING THE OPPORTUNITY AND BARRIERS FOR WATER CONSERVATION BY PRIVATE INDUSTRIAL WATER USERS. PREPARED BY MINNESOTA TECHNICAL ASSISTANCE PROGRAM (MNTAP). METROPOLITAN COUNCIL: SAINT PAUL, MN.

This project supported the intent of the Metropolitan Council to better understand the industrial water use needs of private well water users in an eleven county area including Anoka, Carver, Chisago, Dakota, Hennepin, Isanti, Ramsey, Scott, Sherburne, Washington, and Wright counties. Through this project, the Metropolitan Council and MnTAP worked to identify opportunities for industrial water conservation as well as factors that motivated implementation of operational changes to capture water conservation savings. The project helped to fill an existing knowledge gap in water conservation data in the metropolitan area. Data gained from this project will be used in water supply planning projections for the metropolitan area. Private industrial water users received site-specific water conservation recommendations and will continue to be followed up with through at least 2015 to see if additional assistance is useful. ***Website***

METROPOLITAN COUNCIL. 2014B. FEASIBILITY ASSESSMENT OF APPROACHES TO WATER SUSTAINABILITY IN THE NORTHEAST METRO. PREPARED BY SHORT ELLIOTT HENDRICKSON INC. METROPOLITAN COUNCIL: SAINT PAUL.

The Metropolitan Council retained Short Elliott Hendrickson Inc. (SEH) to complete this technical assessment of the capital and operational costs, as well as the potential benefits, of alternative approaches to water supply in the northeast metro area. The report also looks specifically at the direct augmentation of White Bear Lake with water from the major rivers in the region. This study has been carried out with input from and engagement with local stakeholders, including community public water utilities, through a water supply work group. This group continues to meet regularly to discuss the study along with other water supply topics of importance to group members.

METROPOLITAN COUNCIL. 2014D. TWIN CITIES METROPOLITAN AREA REGIONAL GROUNDWATER FLOW MODEL, VERSION 3.0. PREPARED BY BARR ENGINEERING. METROPOLITAN COUNCIL: SAINT PAUL, MN.

This report summarizes the result of work to update the regional groundwater flow model, which meets the requirements of Minn. Stat., Sec. 473.1565 calling for the Council to engage in planning activities which must include "development and maintenance of a base of technical information needed for sound water supply decisions including surface and groundwater availability analyses, water demand projections, water withdrawal and use impact analyses, modeling, and similar studies".

The report is organized into six major sections. The introduction provides an overview of the Council and the need for the project. The next five sections discuss methods and results. ***Website***

METROPOLITAN COUNCIL. 2015. CONSERVATION TOOLBOX. PREPARED BY CDM SMITH. METROPOLITAN COUNCIL: SAINT PAUL, MN.

This online tool supports efforts to conserve water.

METROPOLITAN COUNCIL. 2015B. REGIONAL FEASIBILITY ASSESSMENTS: TECHNICAL ANALYSIS SUPPORTING LONG-TERM RELIABILITY AND SUSTAINABILITY OF WATER SUPPLIES IN THE TWIN CITIES METROPOLITAN AREA. PREPARED BY HDR. METROPOLITAN COUNCIL: SAINT PAUL, MN.

Metropolitan Council recognition of water supply planning as an integral component of long-term regional and local comprehensive planning has led to the implementation of a number of projects to provide necessary technical information to form the basis for sound water supply decisions. This Regional Feasibility Assessments study will inform the Council and the participating communities about the potential to diversify water sources to support a sustainable and reliable long-term regional water supply in the Twin Cities Metropolitan Area.

Alternative water supply approaches evaluated include:

- Enhanced recharge
- Surface water
- Groundwater
- Stormwater

METROPOLITAN COUNCIL. 2015C. *THRIVE MSP 2040*. METROPOLITAN COUNCIL: SAINT PAUL, MN.

Under state law, the Council prepares a long-range plan for the Twin Cities region every 10 years. *Thrive MSP 2040* sets the policy foundations for systems and policy plans developed by the Council: the Transportation Policy Plan, the *Water Resources Policy Plan*, the Regional Parks Policy Plan, and the Council's first Housing Policy Plan update in nearly 30 years.

METROPOLITAN COUNCIL. 2015D. WATER BILLING AND CONSUMPTION ANALYSIS: WATER USAGE PRACTICES IN 189 CITIES AND TOWNSHIPS IN THE TWIN CITIES METROPOLITAN AREA, MINNESOTA. PREPARED BY CDM SMITH. METROPOLITAN COUNCIL: SAINT PAUL, MN.

This project included collection and dissemination of data regarding water costs and conservation programs in the seven-county metropolitan area, including:

- Evaluating all water rate structures of the communities in the seven-county metro area. The information on rates by community was correlated with community per capita values, peaking ratios, and other water use characteristics.
- Evaluating all water conservation programs in the communities in the seven-county metro area.
- Developing and analyzing water use characteristics by community and sector to determine trends in water use, including inter-community comparisons. ***Website***

METROPOLITAN COUNCIL. 2015E. FEBRUARY 13, 2015 MEMO TO TWIN CITIES METROPOLITAN AREA WATER SUPPLIERS: WATER DEMAND PROJECTION METHOD AND PRELIMINARY RESULTS.

This memorandum provides a summary of the methods used to project water demand for the public water supply systems in the Twin Cities Metropolitan Area. This work is being done in support of the regional Master Water Supply Plan update that is currently in progress. Presented are the data sources used, assumptions made, and exceptional cases and how they were addressed.

MILLER, T.P., J.R. PETERSON, C.F. LENHART, AND Y. NOMURA. 2012. THE AGRICULTURAL BMP HANDBOOK FOR MINNESOTA. MINNESOTA DEPARTMENT OF AGRICULTURE.

The purpose of this handbook is to present the findings of a comprehensive inventory of agricultural Best Management Practices (BMPs) that address water quality impairments in Minnesota. This handbook provides water quality practitioners with the information necessary to identify suitable agricultural BMPs for agricultural watershed in Minnesota. ***Website***

MINNESOTA DEPARTMENT OF HEALTH. 2014. AQUIFER TEST DATABASE DESIGN DOCUMENTS.

These are database design documents generated by the Aquifer Test Workgroup whose members included representatives of Federal, State and Local Agencies. This database is designed to satisfy the needs of the various groups to track aquifer tests performed in Minnesota. These tests are primarily conducted on high-capacity wells but may include tests of other types of wells such as those used for domestic supply, or groundwater contamination. The purpose collecting and managing the information is to provide robust scientifically-justified support to decision-makers at all levels to promote the wise use of water resources and protect drinking water and the environment. This database is a filing system for all data collected during a test, not just a list of calculated aquifer properties.

MINNESOTA DEPARTMENT OF HEALTH. 2015. COUNTY WELL INDEX. HTTP://WWW.HEALTH.STATE.MN. US/DIVS/EH/CWI/.

The CWI database contains basic information, such as location, depth, and static water level, for wells drilled in Minnesota. The database contains construction and geological information from the well record (well log) for many wells. CWI Online also provides mapping of wells onto aerial photos, allowing users to visually identify well locations. ***Website***.

MINNESOTA DEPARTMENT OF HEALTH – WELL MANAGEMENT. SPECIAL WELL AND BORING CONSTRUCTION AREAS (FORMERLY KNOWN AS SPECIAL WELL CONSTRUCTION AREAS AND BEFORE THAT "WELL ADVISORIES"). HTTP://WWW.HEALTH.STATE.MN.US/DIVS/EH/WELLS/SWCA/. ACCESSED FEBRUARY 26, 2015.

Minnesota Department of Health website describing Special Well and Boring Construction Areas. A Special Well and Boring Construction Area is sometimes also called a well advisory. It is a mechanism which provides for controls on the drilling or alteration of public and private water-supply wells, and monitoring wells in an area where groundwater contamination has, or may, result in risks to the public health. The purposes of a Special Well and Boring Construction Area are to inform the public of potential health risks in areas of groundwater contamination, provide for the construction of safe water supplies, and prevent the spread of contamination due to the improper drilling of wells or borings. ***Website***

MINNESOTA DEPARTMENT OF NATURAL RESOURCES. 1989. DROUGHT OF 1988. SAINT PAUL, MINNESOTA.

The 1988 drought broke long-standing records; strained water use controversies; enhanced public concern about water resources; and generally challenged the energies, talents and perseverance of water managers and the public at large.

Little could be done to manage natural disasters such as the 1988 drought; however impacts can be managed and minimized. Although drought impacts are very damaging to some industries and the environment, it also creates the opportunity to learn and improve future ability to manage such crises. ***Website***

MINNESOTA DNR - DIVISION OF FISHERIES. 2002. MINNESOTA TROUT STREAMS [MAP]. SCALE NOT GIVEN. MARCH 2002. HTTP://DELI.DNR.STATE.MN.US (DECEMBER 2014)

This layer shows legally designated trout streams and trout stream tributaries as identified in Minnesota Rules Chapter 6264. See http://www.revisor.leg.state.mn.us/arule/6264/0050.html for legal descriptions and restrictions associated with designated trout waters. This data layer is a subset of the DNR 24K streams layer, a statewide streams-hydrography data set cooperatively developed amongst many units of government within Minnesota.

MINNESOTA DNR - DIVISION OF ECOLOGICAL RESOURCES - NATURAL HERITAGE & NONGAME RESEARCH PROGRAM, 2008. CALCAREOUS FENS - SOURCE FEATURE POINTS [MAP]. SCALE NOT GIVEN. AUGUST 2008. HTTP://DELI.DNR.STATE.MN.US (DECEMBER 2014)

Pursuant to the provisions of Minnesota statutes, section 103G.223, this database contains points that represent calcareous fens as defined in Minnesota rules, part 8420.1020. The calcareous fens in this shapefile correspond to the fens listed in Identification Order No. 08-001, which was published in the State Register on June 2, 2008 (32 SR 2148-2154). The current list of fens is posted on the DNR web site at http://files.dnr.state.mn.us/publications/waters/calcareous_fen_list_nov_2009.pdf

Minnesota DNR - Division of Waters. 2009. Minnesota Statewide Drought Plan. Saint Paul, MN.

This plan provides a framework for preparing for and responding to droughts to minimize conflicts and negative impacts on Minnesota's natural resources and economy. ***Website***

Minnesota Department of Natural Resources. 2013. Permit Information Report: Active Permit Information (Excel spreadsheet file).

Minnesota water use data were gathered from permit holders who report the volume of water used each year. Permit information reports are generated directly from the main database files. The Permit Information Report was updated 2/4/2013. ***Website***

Minnesota Department of Natural Resources. 2015a. Cooperative Groundwater Monitoring. http://www.dnr.state.mn.us/waters/cgm/index.html (August 30, 2015)

Since 1944, DNR has managed a statewide network of water level observation wells (obwells). Data from these wells are used to assess ground water resources, determine long term trends, interpret impacts of pumping and climate, plan for water conservation, evaluate water conflicts, and otherwise manage the water resource. Soil and Water Conservation Districts under contract with DNR measure the wells monthly and report the readings to DNR. Readings are also obtained from volunteers at several locations.

Hydrographs, well descriptions and water level data are available for each well in the Ground Water Level Observation Well Database. ***Website***

Minnesota Department of Natural Resources. 2015b. MNDNR Permitting and Reporting System. 2015, http://www.dnr.state.mn.us/mpars/index.html (August 30, 2015)

The MNDNR Permitting and Reporting System is an online system for water use reporting, permit applications, permit change requests, and well construction preliminary assessment requests. MPARS is designed to benefit DNR's permit holders and applicants with a simple, convenient and easy-to-use system. ***Website***

Minnesota Department of Public Safety – Division of Homeland Security and Emergency Management. 2014. Minnesota State Hazard Mitigation Plan 2014. Minnesota Department of Public Safety: St. Paul, MN.

The State All Hazard Mitigation Plan represents the efforts of the state of Minnesota in fulfilling the responsibility for hazard mitigation planning. The purpose of this Plan is to identify the State's major hazards, assess the vulnerability to those hazards, and take steps to reduce vulnerability using the technical and program resources of Minnesota agencies. The Plan identifies goals and recommended actions and initiatives for state government to reduce and/or prevent injury and damage from hazardous events. The intent of the plan is to provide unified guidance for ensuring coordination of recovery-related hazard mitigation efforts following a major emergency/disaster, and to implement an on-going comprehensive state hazard mitigation strategy intended to reduce the impact of loss of life and property due to disasters. ***Website***

Minnesota Geological Survey. 2011. Distribution of Vertical Recharge to Upper Bedrock Aquifers, Twin Cities Metropolitan Area. Minnesota Geological Survey: Minneapolis, MN.

This report summarizes work performed by the Minnesota Geological Survey (MGS) in partial fulfillment of work as described under contract 10I021 between the University of Minnesota and the Metropolitan Council. The goal of this investigation was to provide datasets that would assist the Metropolitan Council with regional ground water planning. Specifically, vertical travel times were calculated from a regional water table surface to bedrock in order to gain a better understanding of recharge to upper bedrock aquifers in the extended Twin Cities Metropolitan Area (TCMAx). A focus of this investigation, therefore, was on the permeability of unconsolidated sediments overlying the bedrock surface, and the regional distribution of vertical hydraulic gradient.

Minnesota Pollution Control Agency. 2014. Water Governance Evaluation: Update 2014 – Recommendations to streamline, strengthen, and improve sustainable water management. Minnesota Pollution Control Agency: St. Paul, MN.

This report is a follow-up to the 2013 Water Governance Evaluation, prepared by the Minnesota Pollution Control Agency (MPCA) in collaboration with the other state water management agencies at the direction of the Legislature. This 2014 progress report focuses on:

- initiatives that have been completed or are in progress
- new initiatives that the group has identified; and
- issues in need of further legislative action or direction

Website

State of Minnesota. 2014. Clean Water Fund Performance Report: A Report of Clean Water Funds Invested, Actions Taken, and Outcomes Achieved. Minnesota Pollution Control Agency: St. Paul, MN.

The Framework includes a set of performance measures that will convey the most meaningful information about clean water activities to key audiences across Minnesota. These performance measures generally fall into the following categories:

- Environmental and drinking water measures to track whether our water is getting cleaner
- Partnership and leveraging measures to track local government and citizen actions supported by the Clean Water Fund
- Organizational performance measures to track state government-led actions supported by the Clean Water Fund
- Financial measures to track how much and where Clean Water Fund money is being spent

The Framework also describes the connection between short-term activities and long-term results. The multi-agency Team grouped the measures into three other categories: financial investments, actions taken, and outcome measures. Together these measures track how Clean Water Fund investments result in actions taken and ultimately, clean water outcomes achieved.

In the early years of the Clean Water Fund, more progress will be reported in short-term actions taken than long term outcomes. ***Website***

University of Minnesota, Department of Geology and Geophysics; Minnesota DNR - Division of Waters. 2003. Karst Feature Inventory Points [map]. Scale Not Given. January 2003. http://deli.dnr.state.mn.us (December 2014)

Since the early 1980s, the Minnesota Geological Survey and Department of Geology and Geophysics at the University of Minnesota have been mapping karst features and publishing various versions of their results in the form of 1:100,000 scale County Geologic Atlases. In the mid 1990s, the Minnesota Department of Natural Resources was assigned responsibility for the hydrogeology portions of the County Atlases and is now responsible for the karst mapping. Dalgleish and Alexander (1984),

Alexander and Maki (1988), Witthuhn and Alexander (1995), Green and others (1997), Shade and others (2001), and Tipping and others (2001) published sinkhole distribution maps for Winona, Olmsted, Fillmore Counties, Leroy Township, Pine and Wabasha Counties respectively.

Published Atlases of Washington, Dakota, and the counties of the Twin Cites Metro area contain limited information on sinkhole occurrences. This karst feature database of Southeastern Minnesota has been developed to allow sinkhole and other karst feature distributions to be displayed and analyzed across existing county boundaries in a GIS environment. The karst inventory points are point features such as sinkholes, springs, and stream sinks.

U.S. Geological Survey. 2015. National Water Information System: Web Interface. USGS Current Conditions for Minnesota. URL: http://waterdata.usgs.gov/mn/nwis/uv? (May 2015)

This website provides data about historical and current stream conditions. ***Website***

10 Glossary

Abandoned Well

Any well (drinking water, oil and gas, etc.) which is not used for a long period of time, is not maintained properly, and/or is not properly sealed when its useful life is over.

Acre-foot

Enough water to cover an acre of land one-foot deep (i.e., 325,851 gallons, or 43,560 cubic feet).

Adaptive Management

A process for continually improving management policies and practices by learning from the outcomes of management actions.

Agricultural Area

Communities that encompass areas with prime agricultural soils that are planned and zoned for long-term agriculture. Maximum allowable density is 4 units/40 acres.

Approach

The high-level category of water supply projects that could be applied at the sub-regional level to improve the sustainability of the Twin Cities metropolitan area water supply. For example, water conservation is an approach.

Appropriation

Use of water permitted by the Minnesota Department of Natural Resource. Except for some exempted purposes, a water use (appropriation) permit from DNR is required for all users withdrawing more than 10,000 gallons per day or 1 million gallons per year.

Aquifer

Rock or sediment that is saturated and able to transmit economic quantities of water to wells and surface waters. Minnesota Administrative Rules 6115.0630 defines aquifer as any water-bearing bed or stratum of earth or rock capable of yielding groundwater in sufficient quantities that can be extracted.

Aquitard

A water-saturated sediment or rock whose permeability is so low it cannot transmit any useful amount of water.

Artesian Aquifer

See confined aquifer. An aquifer with a confining layer at the top, causing the groundwater to be under pressure. Minnesota Administrative Rules

6115.0630 defines artesian aquifer or a confined aquifer as a water body or aquifer overlain by a layer of material of less permeability than the aquifer. The water is under sufficient pressure so that when it is penetrated by a well, the water will rise above the top of the aquifer. A flowing artesian condition exists when the water flow is at or above the land surface.

Artesian Well

A well drilled in a confined aquifer where the elevation of the well water (i. e., potentiometric surface) is above the top of confined aquifer. If this well flows at the land surface without mechanical pumping, it is a flowing artesian well.

Available Head

An informal term to specify the amount of decline in water level that can occur in a confined aquifer before artesian conditions change to water table conditions. For the purposes of the Master Water Supply Plan, “available head” is defined as the difference in elevation between an aquifer’s long-term average water level, as predicted by the Metropolitan Council’s groundwater flow model, and ten feet above the top of the upper bedrock surface of that aquifer.

Baseflow

The amount of water in a stream, lake or wetland that is supplied by groundwater. This is also referred to as dry weather flow.

Basin

Minnesota Administrative Rules 6115.0630 defines a basin as a depression capable of containing water which may be filled or partly filled with waters of the state. It may be a natural, altered, or artificial depression.

Benchmark

A measurable water resource condition against which historic, current, and projected conditions can be compared to evaluate the sustainability of the region’s water supplies.

Beneficial Use

Use of a [water] resource that includes, but is not limited to, domestic (including public water supply), agricultural, commercial, industrial, water- based recreational uses and the propagation and growth of aquatic life.

Best Management Practices

A set of recommendations pertaining to the development and maintenance of varied land uses, aimed at limiting the effects of development, such as soil erosion and stormwater runoff, on the natural environment. See the Council’s *Urban Small Sites Best Management Practices Manual* for specific examples of Best Management Practices.

Calibration

The process of using historical data to estimate parameters in a groundwater model, hydrologic forecast technique, routings, and unit hydrographs.

Capita

Latin for ‘person’.

Community Public Water Supply

Community public water supplies serve at least 25 persons or 15 services connections year-round, which includes municipalities, manufactured mobile home parks, etc. These systems are required to provide a safe and adequate supply of water under the federal Safe Drinking Water Act. Also known as a *public water supply system*.

Cone of Depression

A cone-shaped depression of the water table.

Confined Aquifer

An aquifer with a confining layer at the top, causing the groundwater to be under pressure. Minnesota Administrative Rules 6115.0630 defines artesian aquifer or a confined aquifer as a water body or aquifer overlain by a layer of material of less permeability than the aquifer. The water is under sufficient pressure so that when it is penetrated by a well, the water will rise above the top of the aquifer. A flowing artesian condition exists when the water flow is at or above the land surface.

Confining Unit

A hydrogeologic unit of impermeable or distinctly less permeable material bounding one or more aquifers and is a general term that replaces aquitard.

Conjunctive Use

The coordinated management of surface water and groundwater supplies to maximize the yield of the overall water resource. An active form of conjuctive use utilizes artificial recharge, where surface water is intentionally percolated or injected into aquifers for later use. A passive method is to simply rely on surface water in wet years and use groundwater in dry years.

Conservation

The management of natural resources to prevent waste, destruction or degradation.

Consumptive Use

Minnesota Administrative Rules 6115.0630 defines consumptive use or consumption as water withdrawn and not directly returned to the same waters as the source for immediate further use in the area.

Density

The number of dwelling units per net residential acre of land.

Developable Land

Land that is suitable as a location for structures and that can be developed free of hazards to, and without disruption of, or significant impact on, natural resource areas.

Diversified Rural

Communities that are home to a variety of farm and nonfarm land uses including very large-lot residential, clustered housing, hobby farms, and agricultural uses. Located adjacent to the Emerging Edge Suburban communities, the Diversifies Rural designation protects rural land for rural lifestyles today with the potential of becoming urbanized after 2040. Maximum allowable density is 1-2.5 units for existing lots, and 1 unit/10 acres where possible.

Drawdown

The lowering of the water table in and around a pumping well. It is the difference between the pumping water level and the original water level.

Drinking Water supply Management Area

A drinking water supply management area (DWSMA) is the Minnesota Department of Health approved surface and subsurface area surrounding a public water supply well that completely contains the scientifically calculated wellhead protection area and is managed by the entity identified in a wellhead protection plan. The boundaries of the drinking water supply management area are delineated by identifiable physical features, landmarks or political and administrative boundaries.

Emerging Suburban Edge

Cities, townships and portions of both that are in early stages of transitioning into urbanized levels of development. In the majority of these communities, less than 40% of the land has been developed. Parts of Emerging Suburban Edge communities are in the MUSA and all have a minimum average net density of 3-5 units/acre.

Essential Use

Nonessential use is defined by Minn. Stat. 103G.291 as water that is used for drinking, cooking, cleaning or sanitation (i.e. domestic water use).

Equity

Equity is defined in *Thrive MSP 2040* as just and fair inclusion where all can participate and prosper.

Equitable Development

Equitable development is an approach to creating healthy, vibrant, communities of opportunity. Equitable outcomes come about when smart, intentional strategies are put in place to ensure that low-income communities and communities of color participate in and benefit from decisions that shape their neighborhoods and regions.

Evapotranspiration

Loss of water from the soil both by evaporation from the soil surface and by transpiration from the leaves of the plants growing on it. Factors that affect the rate of evapotranspiration include the amount of solar radiation, atmospheric vapor pressure, temperature, wind, and soil moisture.

Forecast

In *Thrive MPS 2040*, a calculation of growth in population, households and jobs based on data about current conditions (e.g., the 2010 Census) that is extrapolated into the future.

Full Build-Out

Having absolute development under the proposed future land use and the guidelines of the 2040 Comprehensive Plan Update (see Ultimate Build Out).

Geologic Formation

Rocks or unconsolidated deposits that form a unit and may be dominated by a certain type of deposit or rock, or may have some other common feature.

Greywater

Domestic wastewater that does not contain human wastes such as tub, shower, or washing machine water.

Groundwater

Water stored in the pore spaces of rock and unconsolidated deposits found in the saturated zone of an aquifer (compare to surface water). Minnesota Administrative Rules 6115.0630 defines groundwater as subsurface water in the saturated zone. The saturated zone may contain water under atmospheric pressure (water table condition), or greater than atmospheric pressure (artesian condition).

Hydrology

Science dealing with the properties, distribution, and flow of water on or in the earth.

Hydraulic Conductivity

A measure of the permeability of the porous media. It is commonly measured in feet per day (ft/day).

Hydraulic Gradient

The change in an aquifer's water level elevation over a given distance.

Impermeable

Material that does not permit fluids to pass through it.

Impervious

The ability to repel water or not let water infiltrate.

Infiltration

1. The seepage of water from land surface down below the root zone. This water may move horizontally through the soil toward nearby streams, wetlands, and lakes – becoming baseflow. Or this water may move vertically down to recharge deeper regional aquifers.
2. The seepage of groundwater into sewer pipes through cracks or joints in the pipes.

Infrastructure

Fixed facilities, such as sewer lines and roadways; permanent structures.

Integration

The incorporation of all planning aspects (e.g., land use, transportation, housing, water resources, and natural resources) into decisions about development.

Investments, Regional Investments

Investments made by the Metropolitan Council into regional infrastructure.

Karst

Topography formed over limestone, dolomite or gypsum and characterized by sinkholes, caves, and significant rapid underground drainage. The Minnesota Pollution Control Agency (MPCA) recognizes portions of southeastern Minnesota as a karst area, including all or parts of these metropolitan area counties: Dakota, Hennepin, Ramsey, Scott and Washington. In these counties, the MPCA recommends treating the following geologic units as karst aquifers: Platteville Formation, St. Peter Formation, and the Prairie du Chien Group.

Local Comprehensive Plan

Plans for local land use and infrastructure. Counties, cities and townships are required to have their local comprehensive plans reviewed by the Metropolitan Council to ensure that they are consistent with metropolitan system plans. (Compare with *comprehensive plan.*)

Local Government

Municipal units of government, such as counties, cities and townships.

Metro Model

The Twin Cities metropolitan area regional groundwater flow model. The current modeling effort builds upon the Minnesota Pollution Control Agency's 2000 *Metro Model*. The current Metro Model (version 3) is used to evaluate the groundwater impacts of current and projected groundwater withdrawals. Information provided by the Metro Model helps set regional goals, screen for future risks, and evaluate/compare the regional impact of different water supply approaches.

Metropolitan Area Water Supply Advisory Committee

The 2005 Minnesota State Legislature passed a measure that directs the Metropolitan Council to carry out planning activities addressing the water supply needs of the Twin Cities metropolitan area. To assist the Council in its planning activities, the legislature established the Metropolitan Area Water Supply Advisory Committee. The Advisory Committee, which was instrumental in the development of the Metropolitan Area Master Water Supply Plan, meets regularly to discuss plan implementation and other relevant water supply topics.

Metropolitan Development Guide

The collection of regional plans that includes *Thrive MSP 2040* and the policy plans for the regional systems: transportation, wastewater and water quality, regional parks and open space.

Metropolitan Land Planning Act

Minnesota Statute 473 directing the Council to adopt long-range, comprehensive policy plans for transportation, airports, wastewater services, and parks and open space, and authorizing the Council to review the comprehensive plans of local governments.

Metropolitan Urban Service Area (MUSA)

The area, in which the Metropolitan Council ensures that regional services and facilities under its jurisdiction are provided.

Model

A model is any device that represents an approximation of a field situation. A mathematical groundwater model, such as Metro Model 3, simulates groundwater flow indirectly by means of a governing equation thought to represent the physical processes that occur in the system, together with equations that describe heads or flows along the boundaries of the model.

Multifamily Housing

Residential structure with two or more separate dwelling units.

Nitrate

Used generically for materials made of nitrogen and oxygen; sources include animal wastes and some fertilizers.

Nonconsumptive Use

Nonconsumptive use is water withdrawn and directly returned to the same waters as the source for immediate future use in the area. Compare with *consumptive use*.

Nonessential Use

Nonessential water uses defined by Minn. Stat. 103G.291 include lawn sprinkling, vehicle washing, golf course and park irrigation and other nonessential uses. Nonessential use refers to water that is not used for drinking, cooking, cleaning or sanitation (i.e. nondomestic water use). Compare with *essential use*.

Nonurban Land Uses

Residential, commercial or industrial land uses that are not found in the urban area, and where urban services are unavailable. (Compare with *urban land uses.*)

Observation Well

A non-pumping well used for observing the elevation of the water table or piezometric surface.

On-site Septic System

System for disposing and treating human and domestic waste at or near the location where the waste is generated, such as a septic tank and soil absorption system or other system, allowed by state and city when access to the municipal sewer system is not required of feasible.

Open Space

Public and private land that is generally natural in character. It may support agricultural production, or provide outdoor recreational opportunities, or protect cultural and natural resources. It contains relatively few buildings or other human-made structures. Depending on the location and surrounding land use, open space can range in size from a small city plaza or neighborhood park of several hundred square feet, corridors linking neighborhoods of several acres to pasture, croplands or natural areas and parks covering thousands of acres.

Option

Water supply project that could be applied at the sub-regional level to implement an approach to water supply sustainability. Options were developed as part of the Master Plan to better quantify the costs and benefits of implementing sustainable water supply approaches.

Ordinance

A law or regulation set forth and adopted by a governmental authority, usually a city or county.

Peak Use (Demand)

The maximum water demand occurring in a given period, such as hourly or daily or annually.

Per Capita Use

Water use per person.

Permeability

Ability of a rock or unconsolidated deposit to transmit water through connected spaces between grains. The size and shape of the spaces controls how easily water flows.

Pollutant

An impurity (contaminant) that causes an undesirable change in the physical, chemical, or biological characteristics of the air, water or land that may be harmful to or affect the health,

Porosity

Volume of open pore space between particles of clay, silt, sand, gravel, cobble or within rock in a geologic formation.

Prediction

Prediction quantifies the response of a system to future events.

Pressure Head

Height of the water column due to aquifer pressurization.

Projection

A projection indicates what future values for the unknown would be if the assumed patterns of change were to occur. They are not a prediction that the unknown will change in this manner. A projection simply indicates a future value for the unknown if the set of underlying assumptions occur.

Public Water System

Community public water supply systems serve at least 25 persons or 15 services connections year-round, which includes municipalities, manufactured mobile home parks, etc. These systems are required to provide a safe and adequate supply of water under the federal Safe Drinking Water Act. Also known as a *community public water supply system*.

Recharge

The natural or manmade infiltration of surface water into the zone of saturation. For the purposes of regional recharge modeling using the SWB model, recharge is the portion of infiltration that moves from the unsaturated sediment below the root zone into the underlying aquifers (saturated zone).

Recharge Area

An area where surface water from rainfall, snowmelt or other sources seeps through the soil into the saturated zone.

Redevelopment

Any proposed expansion, addition, or major façade change of an existing building, structure, or parking facility.

Regional Infrastructure

Infrastructure pertaining to any of the Council's systems: wastewater, transportation, and parks and open space (See also *regional systems.*)

Regional Systems

Systems for which the Metropolitan Council is the responsible planning and operating authority. They include wastewater services, transportation, parks and open space, and airports. (See also *regional infrastructure*.)

Reuse

Reuse of water already authorized by a permit is exempt to water appropriation permit requirements.

Runoff

The rainfall, snowmelt, or irrigation water flowing that has not evaporated or infiltrated into the soil, but flows over the ground surface.

Rural Centers

Local commercial, employment, and residential activity centers serving rural areas in the region. These small towns are surrounded by agricultural lands and serve as centers of commerce to those surrounding farm lands. The density is 3-5 units/acre.

Rural Residential Area

Communities that have residential patterns characterized by large lots and do not have plans to provide urban infrastructure. Maximum allowable density is 4 units/40 acres.

Safe Yield

Amount of groundwater that can be withdrawn from an aquifer system without degrading the quality of the aquifer and without allowing the long- term average withdrawal to exceed the available long-term average recharge to the aquifer system. Minnesota Administrative Rules 6115.0630 defines "Safe yield for water table condition" as the amount of groundwater that can be withdrawn from an aquifer system without degrading the quality of water in the aquifer and without allowing the long term average withdrawal to exceed the available long term average recharge to the aquifer system based on representative climatic conditions. Minnesota Administrative Rules 6115.0630 defines "Safe yield for artesian condition" as the amount of groundwater that can be withdrawn from an aquifer system without degrading the quality of water in the aquifer and without the progressive decline in water pressures.

Saturated Zone

Zone with only water in the interconnected spaces.

Simulation

The imitative representation of the functioning of one system or process by means of the functioning of another, such as a computer simulation of groundwater flow.

Soil Moisture

Moisture contained in the soil above the water table, including water vapor.

Source Water Protection

Source water refers to water from streams, rivers, lakes or underground aquifers that is used for drinking. There are three primary parts to Minnesota's Source Water Protection Program, administered by the MN Department of Health:

1. Wellhead Protection

2. Source Water Assessments

3. Protection of Surface Water Intakes

Special Well and Boring Construction Area

A Special Well and Boring Construction Area is sometimes also called a well advisory. It is a mechanism which provides for controls on the drilling or alteration of public and private water supply wells, and monitoring wells in an area where groundwater contamination has, or may, result in risks to the public health. The purposes of a Special Well and Boring Construction Area are to inform the public of potential health risks in areas of groundwater contamination, provide for the construction of safe water supplies, and prevent the spread of contamination due to the improper drilling of wells or borings.

Specified Flow

Cumulative depletion of groundwater that results in greater than 15% reduction of groundwater base flow, as represented by average August flow rate.

Stormwater

Surplus surface water generated by rainfall that does not seep into the earth but flows overland to flowing or stagnant bodies of water. (See also *runoff.*) DNR defines stormwater more specifically as runoff from impervious surfaces.

Stormwater Reuse

The collection and use of stormwater runoff that is reclaimed for specific, direct, and beneficial uses. The term is also used to describe water that is collected on-site and utilized in a new application. It is also called rainwater harvesting, rainwater recycling, or rainwater reclamation. The Minnesota Department of Natural Resources more specifically defines stormwater reuse as the secondary use of water for a purpose other than what it was originally appropriated for.

Sub-region

A Metropolitan Council Water Supply Planning management area defined to ensure that technical analyses are distributed equitably throughout the region, reflect all the varied water supply conditions/environments, and that sustainability issues and approaches are distributed in a targeted way.

Suburban Area

Communities that saw their primary era of development during the 1980s and early 1990s. Suburban communities also include places that were once resort destinations along Lake Minnetonka and White Bear Lake and along the St. Croix River. Suburban communities are in the MUSA and have a minimum average net density of 5 units/acre.

Suburban Edge

Communities that have experienced significant residential growth beginning in the 1990s and continuing to the 2010s. At least 40% of the land in these communities is developed, but significant amounts of land remain for future development. Suburban Edge communities are in the MUSA and have a minimum average net density of 3-5 units/acre.

Superfund Site

A Superfund site is an uncontrolled or abandoned place where hazardous waste is located, possibly affecting local ecosystems or people.

Surface Water

Water on the earth's surface exposed to the atmosphere such as rivers, lakes and creeks. (Compare with *groundwater.*)

Sustainable Development

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.

Sustainable Water Use

Use of water that does not harm ecosystems, degrade water quality, or compromise the ability of future generations to meet their own needs.

Technical Assistance

Aid provided by Council staff to local governments to implement *Thrive MSP 2040*, including the Master Water Supply Plan.

Transpiration

Loss of water from a plant, mainly through the stomata of leaves.

Ultimate Build-out

Having absolute development under the proposed future land use and the guidelines of the 2040 Comprehensive Plan Update (see Full Build Out).

Unconfined Aquifer

Aquifer without a confining layer at the top and a lack of pressure that allows the water level to easily rise and fall.

Unsaturated Zone

Area below the land surface that contains a mixture of air and water.

Urban Area

Communities that are adjacent to the Urban Center communities and have seen considerable development and growth along highways. Urban areas are in the MUSA and have a minimum average net density of 10 units/acre.

Urban Center

Communities that include the largest, most centrally located and most economically diverse cities of the region. Urban centers are in the metropolitan urban service area (MUSA) and have a minimum average net density of 20 units/acre.

Wastewater

Water carrying waste from domestic, commercial, or industrial facilities together with other waters that may inadvertently enter the sewer system through infiltration and inflow.

Wastewater Treatment Plant

A facility designed for the collection, removal, treatment, and disposal of wastewater generated within a service area.

Water Cycle

The path that water takes through its various states – vapor, liquid, solid – as it moves throughout the ocean, atmosphere, groundwater, lakes and streams.

Water Table

The elevation at which the pore water pressure is at atmospheric pressure.

Wellhead Protection Area

The fundamental goal of wellhead protection (WHP) is to prevent contaminants from entering public wells. To accomplish this goal, public well owners must first determine where the water supplying their well(s) is coming from—this area is called the WHP area (WHPA). It can also be thought of as the recharge area to the public well and is ultimately the area to be managed by the public water supplier, as identified in the WHP plan.

Acronyms and Initialisms

CFS – Cubic Feet per Second

DNR – Department of Natural Resources (of Minnesota) DWSMA – Drinking Water Supply Management Area GPCD – Gallons per Capita (Person) per Day

GPM – Gallons per Minute

LPA – Local Planning Assistance department of the Metropolitan Council

MAWSAC – Metropolitan Area Water Supply Advisory Committee MCES – Metropolitan Council Environmental Services division MDNR – Minnesota Department of Natural Resources

MDA – Minnesota Department of Agriculture MDH – Minnesota Department of Health MGD – Million Gallons per Day

MPCA – Minnesota Pollution Control Agency PCA – Pollution Control Agency (of Minnesota) PWS – Public Water System

SDWA – Safe Drinking Water Act

SWBCA – Special Well and Boring Construction Area

WHPA – Wellhead Protection Area

WHPP – Wellhead Protection Plan

Appendix 1: Water Supply Profiles

Purpose

This appendix provides a general overview of local and sub-regional water supply conditions including in the seven-county Twin Cities metropolitan area: water use, source, and potential issues.

The information in each water supply profile is generally based on regional information and does not necessarily provide a complete representation of the local water supply system and management efforts. This information should be considered along with more locally specific characteristics, as they are available, to verify and/or evaluate potential issues.

The profiles provide a useful starting place for local planning and can be used in several ways, including:

- To inform community water conservation programs by helping to target large water use categories
- To complete local water supply plans in a way that considers Metropolitan Council policy and the Master Water Supply Plan
- To inform water supply-related permit applications and environmental review documents
- To provide a sub-regional picture of water supply-related issues in an area, such as a group of communities, or in a county or watershed

Target Audiences

- Sub-regionSub-regional work groups focused on water supply and water resources issues
- Community planning staff
- Public water supply utility staff
- County planners
- Watershed planners

Methodology and Supporting Data

The following pages describe the sources of data and analyses done to summarize the following:

- Overview of the water systems and use in the community
    - Number of DNR-permitted wells and surface water intakes that provide water
    - Average annual water withdrawn from different sources
    - Available options to meet current and future water demand

- Municipal water use
    - Water treatment
    - Rate structure
    - Amount of municipal water used for different purposes
    - Historical winter, summer, and annual average water use
    - Projected water use
- Potential water supply issues that may be addressed in plans and permits
- Potential actions to include in plans and programs

Overview of water systems and use in the community

Information about the current status of the community's water system came from a review of past local water supply plans, data submitted to the MN Department of Natural Resources (DNR) as part of the water appropriation permit program, and information submitted to the MN Department of Health (MDH) and stored in the Minnesota Drinking Water Information System (MNDWIS).

The information was updated in August 2015 based on information provided through the public review process for this Master Water Supply Plan.

Available approaches to meet current and future demand

The list of available options for water supply sources was developed through a public outreach process that included input by sub-regional work groups. The list is the same in every water supply profile, because these options – in different combinations – are available across the entire region.

More information about stakeholder discussions is available in Chapter 1 of the Master Water Supply Plan. More information about each of these options is described in Chapter 4 of the Master Water Supply Plan.

Number of active public and private DNR-permitted wells and surface water intakes that provide water to residents and businesses in the community

Information about the number of active high capacity wells and intakes with water appropriation permits came from the Minnesota DNR Permitting and Reporting System (MPARS), and the data reflect information submitted as of July 28, 2015.

The number of active municipal public water supply and non-municipal DNR water appropriation permit installations were counted for each major water source in every community, county, watershed, and sub-region in the 7-county Twin Cities metropolitan area.

The following water source categories were used:

Mt. Simon-Hinckley aquifer

DNR water appropriation permit installations with the following aquifer descriptions were assigned to this category: Mt. Simon-Hinckley and Mt. Simon-Fond du Lac.

Prairie du Chien-Jordan aquifer
DNR water appropriation permit installations with the following aquifer descriptions were assigned to this category: Jordan, Prairie du Chien, and Prairie du Chien-Jordan.

Quaternary aquifers
DNR water appropriation permit installations with the following aquifer descriptions were assigned to this category: Quaternary Buried Artesian, Quaternary Buried Unconfined, and Water Table.

Tunnel City-Wonewoc aquifer
DNR water appropriation permit installations with the following aquifer descriptions were assigned to this category: Tunnel City, Tunnel City-Wonewoc, and Wonewoc.

Multi-aquifer or minor aquifers
This category includes relatively minor aquifers and wells with records that indicate the well is open to more than one aquifer. DNR water appropriation permit installations with the following aquifer descriptions were assigned to this category: Eau Claire, Eau Clair-Mt. Simon, Jordan-Mt. Simon, Jordan-St. Lawrence, Jordan-Wonewoc, Mt. Simon-Fond du Lac, Platville-St. Peter, Prairie du Chien-Eau Claire, Prairie du Chien-St. Lawrence, Prairie du Chien-Tunnel City, Prairie du Chien-Wonewoc, Precambrian, St. Lawrence-Eau Claire, St. Lawrence-Mt. Simon, St. Lawrence-Tunnel City, St. Lawrence-Wonewoc, St. Peter, St. Peter-Jordan, St. Peter-Prairie du Chien, St. Peter-St. Lawrence, St. Peter-Tunnel City, Tunnel City-Eau Claire, Tunnel City-Mt. Simon, Wonewoc-Mt. Simon, Wonewoc-Eau Clair, and Wonewoc-Eau Claire-Mt. Simon.

Surface water
DNR water appropriation permit installations with the following resource code was assigned to this category: Surface Water. This includes water from major rivers, as well as from ditches, lakes, quarries/mines, and dug pits/ponds.

Amount of water used annually, on average, by water appropriation permit holders in key water use categories
Information about water use in major categories came from MN Department of Natural Resources water appropriation permit database, the State Water Use Data System (SWUDS). The average water use between 2003 and 2012 is reported here. This is consistent with the water use represented by Metro Model 3 (Metropolitan Council 2014d). Water use is reported by source for key water use categories.

Sources include: Other (multi-aquifer wells and minor aquifers), Tunnel City-Wonewoc aquifer, Mt. Simon-Hinckley aquifer, Prairie du Chien-Jordan aquifer, Quaternary aquifers, and Surface Water.

Key water use categories include: municipal, irrigation, industrial/commercial, other (which includes, where it exists, pumping for pollution containment), and water level maintenance.

Municipal Water Use

Municipal water treatment

Information about municipal water treatment was taken from the MN Department of Health database, called the Minnesota Drinking Water Information System (MNDWIS).

Rate structure

Information about the community's water rate structure came from a 2014 survey of municipal water rates in the 7-county Twin Cities metropolitan area (Metropolitan Council, 2015d).

Permitted amount in 2012

Information about the amount of permitted water use in 2012 came from the MN Department of Natural Resources water appropriation permit database, the State Water Use Data System (SWUDS). This value represents the amount of water approved by the Minnesota Department of Natural Resources in the community/public water supplier's water appropriation permit.

Reported use in 2012

Information about the amount of water used by the community/public water supplier in 2012 came from the MN Department of Natural Resources water appropriation permit database, the State Water Use Data System (SWUDS). This value represents the amount of water withdrawn from various sources, as reported by the community/public water supplier to the MN Department of Natural Resources as part of the water appropriation permit reporting process.

Residential water use per person in 2012

Information about the amount of residential water use per person in the community in 2012 came from the MN Department of Natural Resources water appropriation permit database, the State Water Use Data System (SWUDS). This value represents the amount of water sold for residential purposes divided by the estimated population served by the municipal water supplier. These values are reported by the community/public water supplier to the MN Department of Natural Resources as part of the water appropriation permit reporting process.

It is important to note that each community categorizes residential water use differently, so this value is not well-suited for comparing communities to one another. For example, some communities may define water use by apartment buildings or nursing homes as residential water use while others may consider these to be commercial water uses.

Water use by major categories in 2012

Information about the amount of water used by the community/public water supplier for major water use categoriesin 2012 came from the MN Department of Natural Resources water appropriation permit database, the State Water Use Data System

(SWUDS). A pie chart illustrates the amount of public water supply used for residential, industrial, commercial, irrigation, and non-revenue purposes.

Non-revenue water use may include water that is unaccounted for reasons such as discrepancies in meter readings, leaks, or due to unmetered use for washing community vehicles or watering community property.

Historical municipal water use in the community

Historic water use information came from the MN Department of Natural Resources water appropriation permit database called the State Water Use Data System (SWUDS). Summer water use is represented by the month with the highest water use (usually July or August) and winter water use is represented by the month with the lowest water use (usually January or February).

Projected water use

Projected water use was developed by the Metropolitan Council with input from public water utility and community staff. The process is described in Appendix 2 of this Master Water Supply Plan. Some highlights are summarized below.

Population Served

Population served represents the number of people receiving water from the municipal water supply system. If the community sells water to a neighbor, the population served may be larger than the population of the community.

2020, 2030, and 2040 population served was projected by Metropolitan Council with input from communities. Values in this table should be assumed to range within 20% above and below the projection.

Total Population

Total population represents the total number of people who live in the community. 2020, 2030 and 2040 total population projections, which were revised July 8 of 2015, were taken from *Thrive MSP 2040*.

Projected Average Daily Water Use (Million Gal./Day), Plus or Minus 20%

Projected average daily water use represents the total amount of municipal water used in a year by the community for purposes that include residential, commercial, industrial, serving neighbors, and non-revenue purposes, divided by 365 days.

2020, 2030, and 2040 average daily water use was projected by Metropolitan Council with input from communities. Values in this table should be assumed to range within 20% above and below the projection.

Total Per Capita Water Use (Gallons per Person per Day)
Total per capita water use represents the average daily water use by the community (see description above), divided by the population served (see description above).

This value represents more than water used by residents in their homes; it also includes commercial, industrial, irrigation, and residential use. This value should not be used to compare communities against one another, because it is strongly shaped by community differences in the composition of commercial, industrial and residential users.

2020, 2030, and 2040 total per capita water use was projected using the method described in Appendix 2 of the Master Water Supply Plan.

What per capita water use would be, if population grew without changing total water use:
This value illustrates how much water demand may have to be reduced, on a per person basis, to supply the community's future population with the same amount of water.

2020, 2030, and 2040 total per capita water use, assuming total water use remains at 2011 levels, was determined by dividing 2011 total water use reported in the MN Department of Natural Resources SWUDS database by the 2020, 2030, and 2040 population served (see description above).

Water resource plans and permits that address the following issues support more sustainable water supplies:

Local studies may be underway or completed to provide more information about these issues.

The issues identified here are generally based on regional information and can be refined for more local, site specific characteristics to better evaluate vulnerability.

Local water supply plans, permit requests, and environmental review documents should acknowledge potential issues and discuss actions to explore them further using more local information.

Regional information used to identify potential water supply issues came from several sources. The criteria and data sources used to identify each potential issue are described here:

Potential for water use conflicts and well interference

Due to the pervasiveness of private wells, the potential for well interference has been identified as a potential water supply issue throughout the region.

Potential for significant decline in aquifer water levels

This issue was included on a water supply profile if one or more of the following conditions were met:

- DNR reports a declining trend in annual minimum water levels at an observation well within 1.5 miles of the community, county, sub-region, or watershed. Observation wells located less than 1.5 miles away *but* across the Minnesota, Mississippi, or St. Croix rivers were not used. Trend information was taken from the *2014 Clean Water Fund Performance Report.*
- Regional groundwater flow modeling of the likely range of 2040 water demand, assuming currently planned sources are used, suggests that available head will drop by more than 50% over at least 60 acres (250,000 m^2) in one or more aquifers in the area of interest. Details about the Metropolitan Council's water demand projection process can be found in Appendix 2 of this Master Water Supply Plan; details about the modeling process can be found in Appendix 3.

Potential for impacts of groundwater pumping on surface water features and ecosystems

- A trout stream is located within 5 miles of the community, based on mapping published by MN Department of Natural Resources (MN Department of Natural Resources, 2002). Trout streams located less than 1.5 miles away *but* across the Minnesota, Mississippi, or St. Croix rivers were not used.
- A fen is located within 5 miles of the community, based on mapping published by MN Department of Natural Resources (MN Department of Natural Resources, 2008). Fens located less than 1.5 miles away *but* across the Minnesota, Mississippi, or St. Croix rivers were not used.
- A spring is located within 1.5 miles of a community, based on mapping published by the University of Minnesota and the MN Department of Natural Resources (University of Minnesota and Minnesota DNR, 2003)
- Surface waters within 1,000 feet of the community are likely to be directly connected to the regional groundwater system, based on regional screening by Metropolitan Council (Metropolitan Council, 2010).

Significant vulnerability to contamination

- Minnesota Department of Health has designated a Special Well and Boring Construction Area has been designated within the community Minnesota Department of Health, 2015)
- A Drinking Water Supply Management Area (DWSMA) has been designated by the Minnesota Department of Health and one or more communities; all or part of the DWSMA has been designated as vulnerable
- A sinkhole (karst) has been mapped within 1.5 miles of the community (University of Minnesota and Minnesota DNR, 2003). Sinkholes located less than 1.5 miles away *but* across the Minnesota, Mississippi, or St. Croix rivers were not used.

- The estimated vertical travel time from land surface to the regional water table is less than 50 years, based on hydrogeochemical mapping done by the Minnesota Geological Survey (Minnesota Geological Survey, 2011)

Significant uncertainty about aquifer productivity and extent

- No aquifer test or groundwater monitoring wells exist within 1.5 miles of the area of interest (Minnesota Department of Health, 2014). Aquifer tests located less than 1.5 miles away *but* across the Minnesota, Mississippi, or St. Croix rivers were not used.
- The most recent county geologic atlas is over 20 years old
- No DNR or community groundwater level observation wells are located within 1.5 miles of the area of interest (Minnesota Department of Natural Resources, 2015a, b)

Regulatory Considerations

- A Groundwater Management Area has been designated by the MN Department of Natural Resources

As appropriate, incorporate the following actions into plans and programs, consistent with your organization's roles and responsibilities:

The actions discussed here may already be underway or completed, and information may be available from local public water suppliers, planners, or water resource managers.

Information about recommended action was developed by Metropolitan Council in partnership with state agencies, particularly DNR, and under the guidance of the Metropolitan Area Water Supply Advisory Committee and a community technical work group.

Local work underway or completed:

The profiles include information submitted by communities during the public comment period for this Master Water Supply Plan about local work that is underway or has been completed.

TEMPLATE Water Supply Profile

Overview of water systems and use in the community

The community owns and operates their own municipal water supply system. Private wells supply additional water demand to some users.

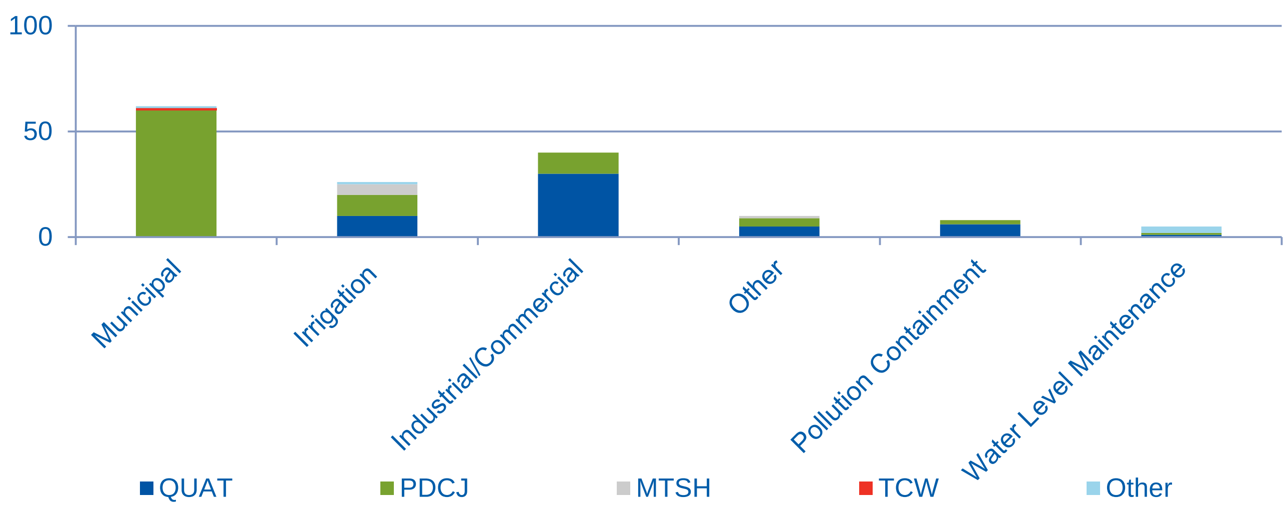
Available approaches to meet current and future demand

1. Conservation
2. Groundwater sources
3. Stormwater reuse
4. Reclaimed wastewater
5. Enhanced recharge
6. Surface water sources

Number of active public and private DNR-permitted wells and surface water intakes that provide water to residents and businesses in the community

Source	Municipal Wells or Intakes in the Community	Non-Municipal Wells or Intakes in the Community	Municipal Wells or Intakes Outside the Community
Mt. Simon-Hinckley Aquifer	0	2	1
Prairie du Chien-Jordan Aquifer	16	10	2
Quaternary Aquifer	0	2	3
Tunnel City-Wonewoc Aquifer	0	0	5
Multi-aquifer or Minor Aquifer	0	0	6
Surface Water	0	0	7

Amount of water used annually, on average, by water appropriation permit holders in key water use categories



Municipal water use

Municipal water treatment: Disinfection, Fluoride, Iron/Manganese Sequestration

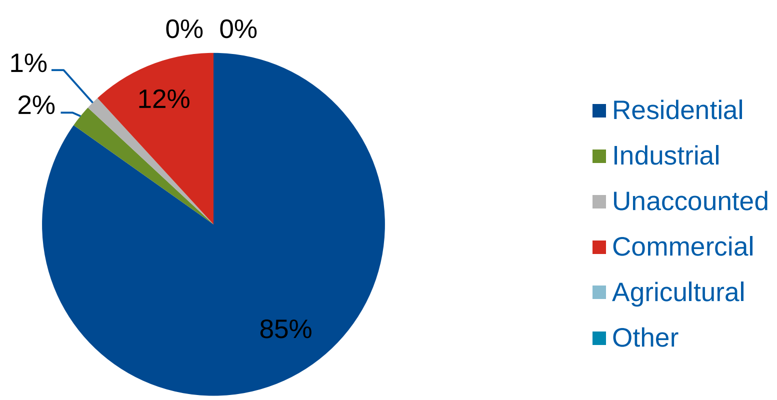
Rate structure: Increasing block

Permitted amount in 2012: 3,267 million gallons/year (8.95 million gallons/day)

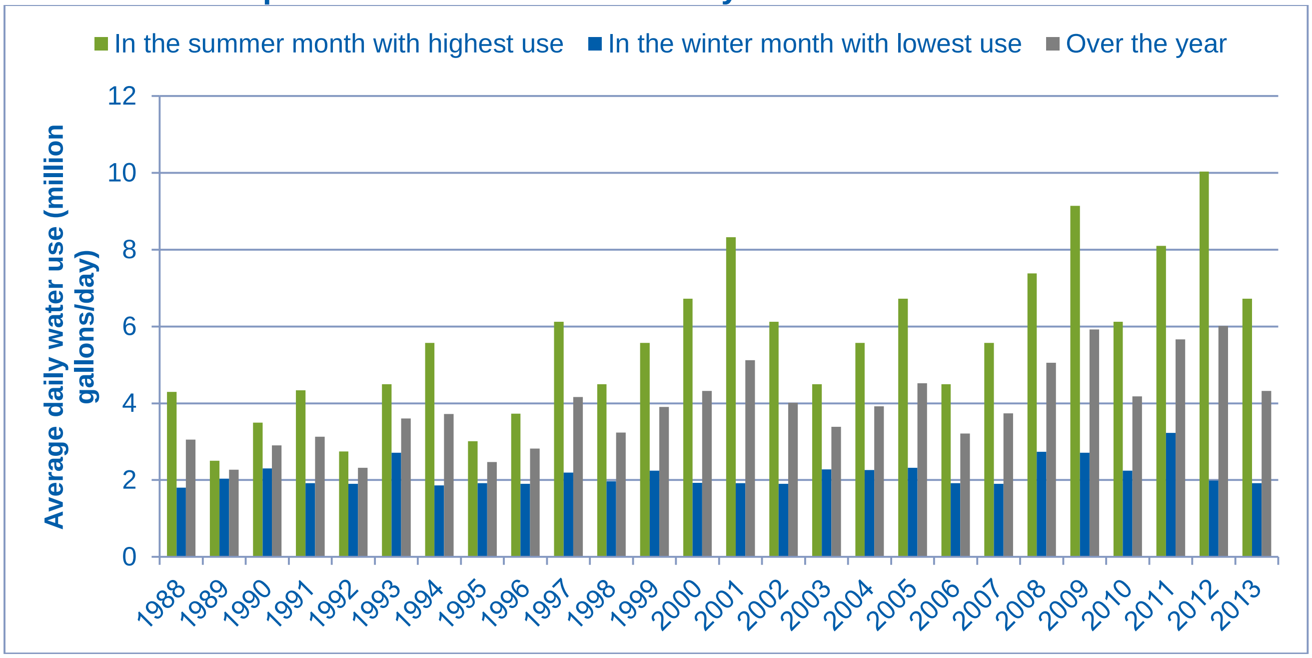
Reported use in 2012: 3,267 million gallons/year (8.95 million gallons/day)
Note: this may be higher than permitted amount if, for example, water is purchased from a neighbor)

Residential water use per person in 2012: 78 gallons per person per day

Water use by major categories in 2012



Historical municipal water use in the community



Projected municipal water use

	2020	2030	2040
Population Served	42	42	42
Total Population	74,000	84,000	87,200
Projected Average Daily Water Use (Million Gal./Day), Plus or Minus 20%	42	42	42
Total Per Capita Water Use (Gal./Person/Day)	0	0	0
What per capita water use would be, if population grew without changing total water use:	95	84	81

Water resource plans and permits that address the following issues support more sustainable water supplies:

- State and federal requirements, such as Safe Drinking Water Act standards, conditions identified on water appropriation permits issued by the DNR, water quality permits issued by the MPCA and others
- Potential for water use conflicts and well interference
  - Due to the pervasiveness of private wells in the metro area, there exists a potential for water use conflict and well interference for all appropriators
- Potential for significant decline in aquifer water levels
  - A nearby DNR observation well documents a declining trend in aquifer water levels
  - Regional groundwater modeling indicates significant aquifer decline under pumping rates that meet the projected range of 2040 demand
- Potential for impacts of groundwater pumping on surface water features and ecosystems
  - A state-protected calcareous fen has been mapped nearby
  - A state-designated trout stream has been mapped nearby
  - Surface waters in this area may be directly connected to regional groundwater system
  - A spring has been mapped nearby
- Significant vulnerability to contamination
  - A sinkhole (karst) has been mapped nearby
  - A vulnerable Drinking Water Supply Management Area has been designated in the area
  - A Special Well and Boring Construction Area has been designated in the area
  - Travel time from land surface to bedrock aquifers is estimated to be less than 50 years
- Significant uncertainty about aquifer productivity and extent
  - The area may not be well-represented by a Minnesota Department of Health aquifer test
  - The county geologic atlas is more than twenty years old
  - The area may not be represented by a Minnesota Department of Natural Resources or community observation well
- Regulatory considerations
  - A Groundwater Management Area has been designated within the community

Note: Local studies may be underway or completed to provide more information about these issues.

The Metropolitan Council's *Local Planning Handbook* contains interactive maps of all of these issues, and they are also summarized in Chapter 5 of this *Master Water Supply Plan*.

As appropriate, incorporate the following actions into plans and programs, consistent with your organization's roles and responsibilities:

- Acknowledge the issues above and support partnerships to address them in local water supply plans and water appropriation permit applications.
- Explore and support water demand (water conservation and efficiency) programs such as incentives, ordinances, education and outreach, rates and other approaches. The Metropolitan Council's *Water Conservation Toolbox* can support these efforts.
- Promote the evaluation of water conflict and well interference as part of the water appropriation permit request and review process. Before requesting water appropriations, water users in this areas should evaluate the need to address water conflict and well interference including a) an inventory of all active domestic and public water supply wells near proposed well locations and b) an analysis of existing water level/water withdrawal data to identify where future drawdowns could affect domestic wells.
- Support collaborative efforts to evaluate the likelihood of significant declines in aquifer water levels before water appropriation permits are requested. The analysis may be determined in consultation with DNR and can vary from a graphical comparison of water levels to local groundwater flow modeling. If this analysis suggests future declines are likely to be unacceptable, a management plan should be developed and include additional water level and pumping rate monitoring, triggers and actions to protect aquifer levels, a schedule for periodic analysis of data to identify the need for action to mitigate impacts, and a schedule for periodic and timely reporting to DNR.
- Work with partners to evaluate relationships between aquifer withdrawals and surface water features. If a connection is likely, management plans should include aquifer testing, monitoring water levels and pumping rates and surface water flow, triggers and actions to protect aquifer levels, a schedule for periodic analysis of data to identify the need for action to mitigate impacts, and a schedule for periodic and timely reporting to DNR.
- Collaborate with partners, including MDH, to support local actions that prevent the spread of contamination. This may include implementation of source water protection plan measures to mitigate public health risks Where significant contamination exists, MDH will continue enhanced monitoring, and public water suppliers in the area may need to implement treatment processes to meet Safe Drinking Water Act requirements and manage pumping to better control the extent and magnitude of contaminant plumes.
- Work with partners to identify opportunities for sharing information, reducing duplicate work, and partnering on projects that improve understanding about aquifer productivity and extent.
- Partner with DNR and neighboring water users to use water in accordance with the approved Groundwater Management Area plan.
- Support collaborative efforts to periodically review local water supply risks and potential alternatives to mitigate those risks. Technical advances, regulatory adjustments and sub-regional developments can present new opportunities for local water suppliers to enhance the resiliency, sustainability, and affordability of their water supplies.
- Continue to work with local, state and federal agencies, as required.

Note: The actions listed above may be underway or completed, and information may be available from local public water suppliers, planners, or water resource managers.

Additional information and guidance is provided in the Local Planning Handbook. Metropolitan Council staff can also provide technical and planning assistance.

Local work underway or completed:

Since 2011, the community has increased use of the Tunnel City Wonewoc aquifer above the average 2003-2011 amounts.

Appendix 2: Water Demand Projections

DATE: February 13, 2015

TO: Twin Cities Metropolitan Area Water Suppliers

FROM: Metropolitan Council Water Supply Planning Unit

SUBJECT: Water Demand Projection Methodology and Preliminary Results

This memorandum provides a summary of the methods used to project water demand for the public water supply systems in the Twin Cities Metropolitan Area. This work is being done in support of the regional Master Water Supply Plan update that is currently in progress. Presented are the data sources used, and assumptions made, in projecting water use through 2040 for each water system in the region.

Generally speaking, the method used is a per capita unit use coefficient approach for each of the municipal water utilities in the seven-county metropolitan area. This approach calculates a per capita water use for each community, based on historical water use, population data, and input received from community public water suppliers. Future water demand projections are obtained by multiplying future population projections by the estimated per capita unit use coefficient:

(Projected Water Use) = **(Projected Population)** X **(Per Capita Water Use)**

The discussion that follows describes the method used to calculate initial projections for each community. Input was also received from communities on draft projections that were distributed in October 2014. A second draft was distributed in January 2015, and a second round of comments were incorporated into the version that was used for running the regional groundwater flow model for the draft Master Water Supply Plan. Local forecasts were used in lieu of Metropolitan Council forecasts when they were provided by communities.

Historical Water Use Data

Water use data for annual use was obtained from the Minnesota Department of Natural Resources (DNR) water use database (SWUDS). The annual use data was taken from data published on the DNR website for each year between 2000 and 2010:

http://www.dnr.state.mn.us/waters/watermgmt_section/appropriations/wateruse.html

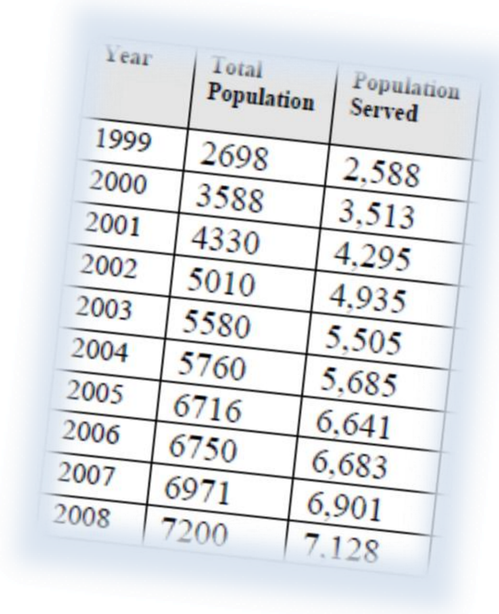
Historical Population Data

Total Population

Total population for each community was obtained from US Census data for 2000 and 2010. Total population was interpolated linearly between 2000 and 2010. Metropolitan Council population estimates were used for 2011 and 2012.

Population Served

In many communities, there is a difference between total population and population served by the public water system. Data on population served by the public water system in each community were obtained from Water Supply Plans submitted to the DNR by each community. Those plans require public water suppliers to report estimates for total population of the community and population served by the water system for each of the ten years prior to plan submittal. For each year with complete data in the Water Supply Plan for each community, the population not served by the water system was calculated as the difference between the reported total population and population served. This unserved population was averaged over the number of years with complete data.



Year	Total Population	Population Served
1999	2698	2,588
2000	3588	3,513
2001	4330	4,295
2002	5010	4,935
2003	5580	5,505
2004	5760	5,685
2005	6716	6,641
2006	6750	6,683
2007	6971	6,901
2008	7200	7,128

Figure 1. Example of Population Reporting from Local Water Supply Plan

Following the calculations of average unserved population, the data were manually reviewed for inconsistencies and outliers. Adjustments were also made based on local input.

The average unserved population was used to calculate an estimated population served for each year between 2003 and 2012. The estimated population served was set equal to the interpolated census total population minus the average unserved population for each community. In this way, the estimated population served is tied to the recorded census population for each community.

(Population Served) = (Interpolated Census Population) – (Average Unserved Population)

Per Capita Water Use Calculation

Total per capita water use for each community was calculated for each year between 2003 and 2012 by dividing the reported water use by the estimated population served. The per capita water use was then averaged over this ten-year period. The average per capita water use based on population served is reported in this way for each community.

(Water Use Per Person) = (Total Water Use) / (Population Served)

This value represents the total water use per capita for each community. This includes all water use in the community, including commercial, industrial, institutional, and other uses. Therefore, it is not necessarily indicative of the amount of water used in each household. This is an important distinction since a community may have a large amount of water-intensive industry that drives up the total water use per capita. Therefore, the total per capita use by itself may not be an accurate indicator of the effectiveness of conservation programs for example.

Population Forecasts

Water demand projections were based in part on population forecasts from Thrive MSP 2040, the Metropolitan Council's updated regional development framework. These forecasts are derived from macroeconomic models, and more details can be found on the Metropolitan Council website:

http://metrocouncil.org/Data-and-Maps/Data/Census,-Forecasts-Estimates.aspx

Unless otherwise specified by a community, forecasted population served by municipal water systems was calculated by subtracting the average population not served, as previously described, from the total population forecast for each community. It is assumed by this method that the population currently not served by the public water system in each community will remain unserved through 2040. It is also assumed that future population growth and development will be served by the public water system.

In some cases, the unserved portions of a community will become served as a water system expands its service area. This would result in a projected population served that is too low by the current method. In other cases, future population growth and development could occur in areas that are not served by a public water system. This would result in a projected population served that is too high. Therefore, these potential inaccuracies for each community should be taken into account by local planners when utilizing these projections for water system planning purposes, and local knowledge should be used to adjust these projections where possible.

Water Demand Projections

Unless otherwise specified by a community, the projected population served was multiplied by the historical average per capita water use to calculate the water demand projection for each community. This method assumes that the historical average per capita water use, as estimated for each year between 2003 and 2012, is representative of future per capita water use.

Actual per capita water use is likely to fluctuate around an average value, depending primarily on weather, but also on economic factors. Therefore, actual water use could be higher or lower than the average values calculated by the method described in this memorandum. In addition to annual fluctuation in per capita water use, there are also long-term trends in per capita water use that are emerging in some locations and within specific water use categories.

For example, the Water Research Foundation and the US Environmental Protection Agency jointly commissioned a study in 2010 to investigate trends in residential water use[1]. This work found that newer homes tend to use less water indoors, and that older homes are reducing indoor water use over time through the retrofitting of older plumbing fixtures with newer water conserving fixtures. In communities with newer development, the reduction in water use indoors may be offset by other factors such as larger lots and automatic lawn irrigation systems.

There appears to be a trend toward lower per capita water use in many communities in the metro area. This is illustrated in Figure 2, which shows the trend in per capita use between 1990 and 2012 for the City of Richfield. Similar trends can be found for many communities in the region.

---

[1] Coomes P, Rockaway T, Rivard J, Kornstein B (Center for Infrastructure Research, University of Louisville, Louisville, KY). North America Residential Water Usage Trends Since 1992. Denver, CO: Water Research Foundation: 2010.

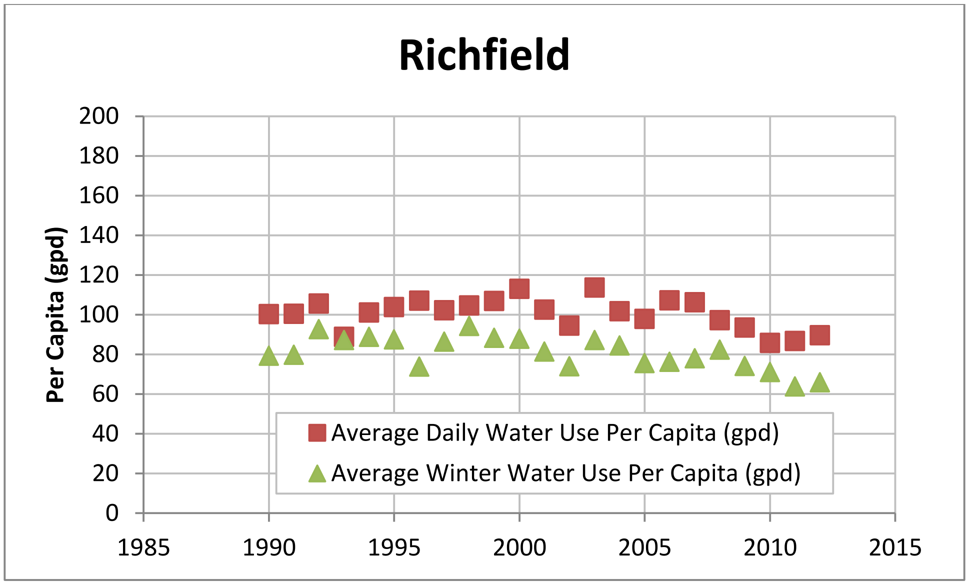


Figure 2. Historical Per Capita Water Use, 1990 – 2012, City of Richfield

While there appears to be a downward trend in this data for many communities in the region, the trend is not obvious for many other communities. Figure 3 shows the same series of data for Maple Grove, where the trend in per capita water use is not as apparent. The causes of the downward trend in some communities are not clear currently, though it could be related to more effective water conservation, economic drivers (especially in commercial water use), and/or climate. The observed trends in water use warrant further study in order to understand the causes and how they could impact future water use.

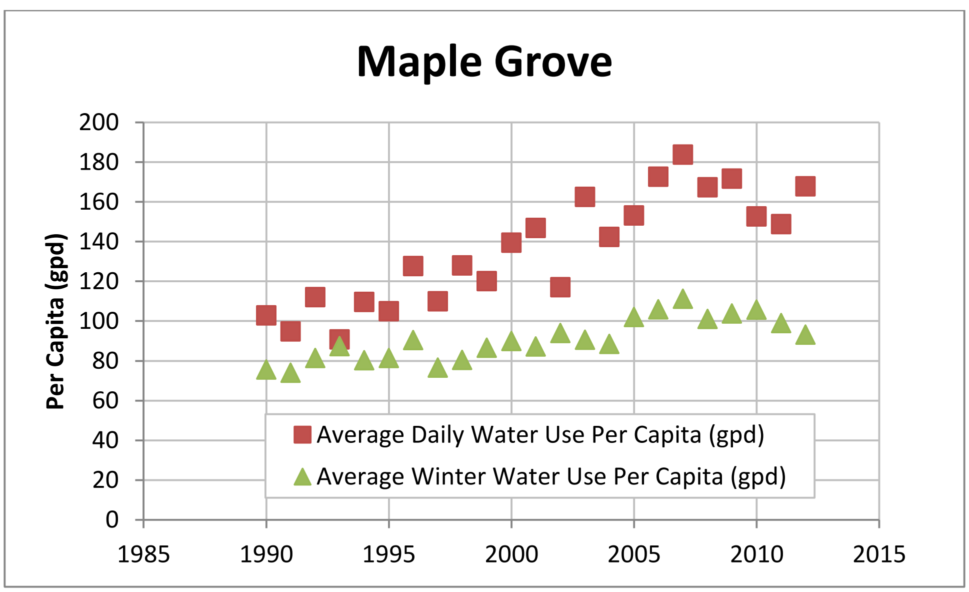


Figure 3. Historical Per Capita Water Use, 1990 – 2012, City of Maple Grove

The regional per capita water use is presented in Figure 4. As a region, there is not a significant trend in per capita water use between 1990 and 2012. However, the winter water use per capita (representing indoor water use) is declining. This has been accompanied by an increase in outdoor water use over the same time period on a per capita basis. Since 2007, there could be a downward trend in per capita water use for the region, though it is not a significant trend in the data at this point. Communities have reported that per capita water use has continued to decline through 2013 and 2014, and that mandatory tiered rate structures that have been implemented over the last couple of years may be the cause.

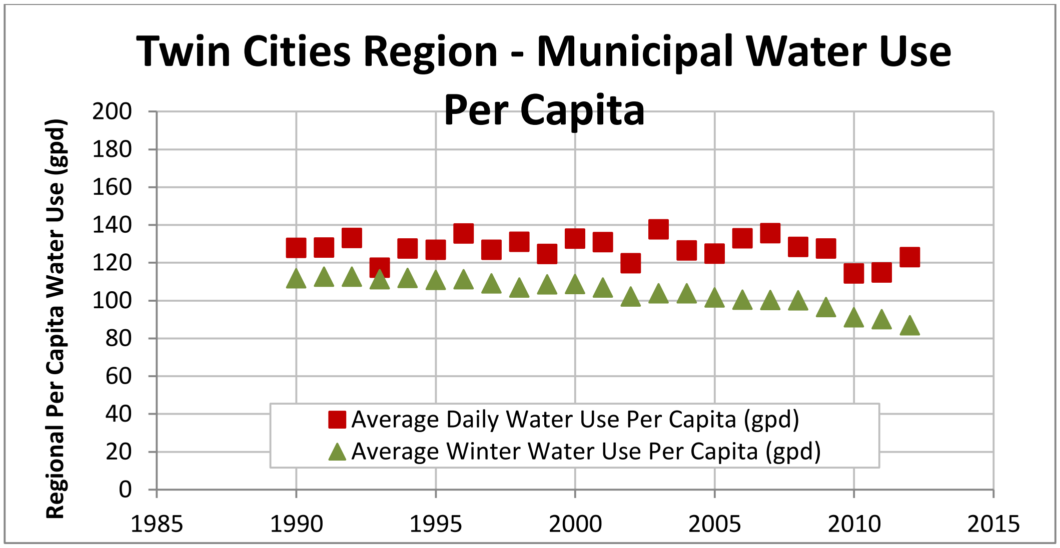


Figure 4. Historical Per Capita Water Use, 1990 – 2012, Twin Cities Metropolitan Area Public Water Systems

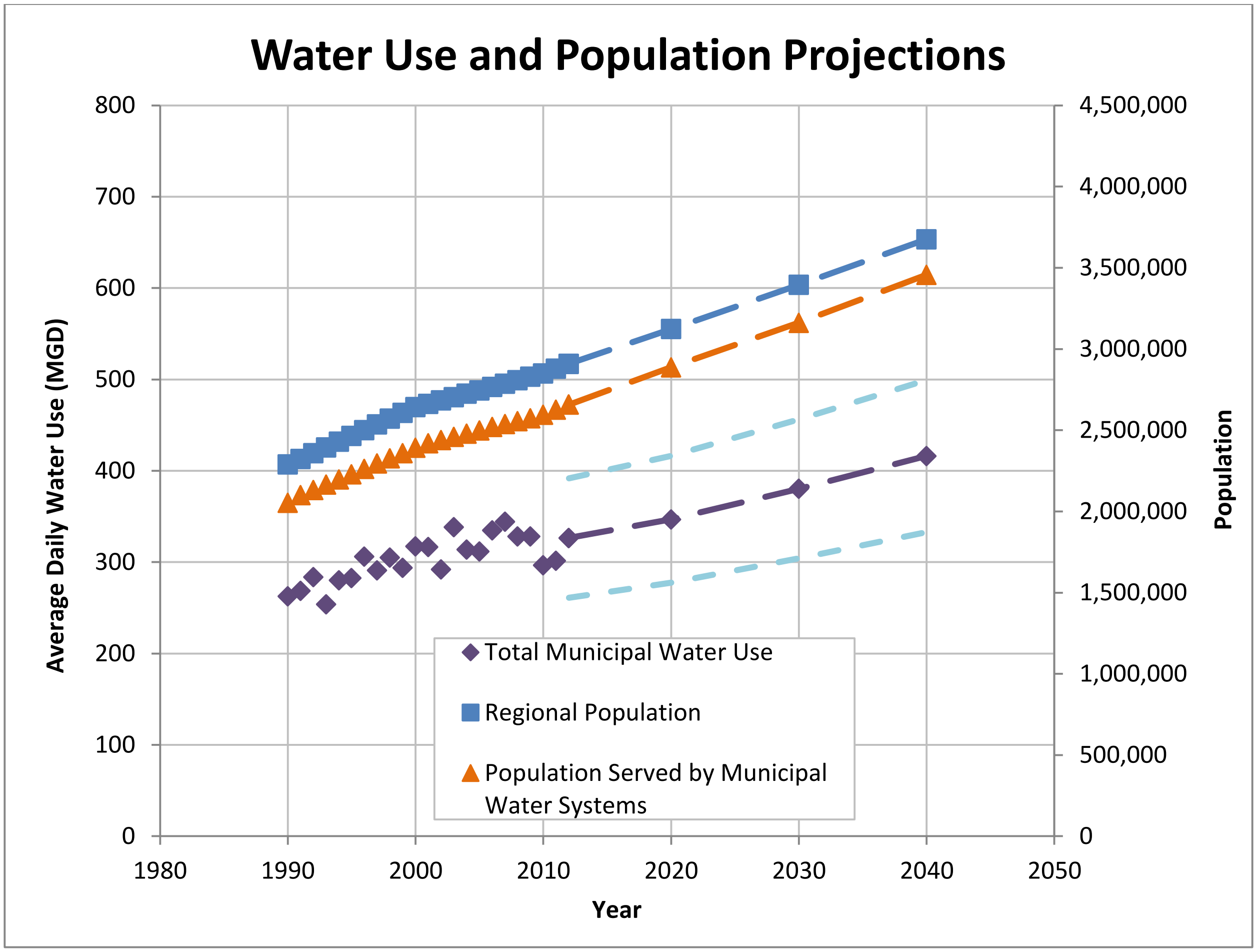
Use of Projections

The Metropolitan Council is developing these water use projections in support of the update to the regional Master Water Supply Plan, currently in progress. This information will help us to understand the magnitude and distribution of future water use in the region. The projections also serve as an input to our modeling efforts to predict resource constraints under future scenarios.

For the purpose of groundwater flow modeling, an average value of water use is appropriate. This is especially true with steady state modeling scenarios, where annual fluctuations in well pumping are not taken into account. For local water system capacity planning, it is important to plan for higher use conditions in order to avoid water shortages. Therefore, the projections presented in the Master Water Supply Plan generally should not be used for local water system capacity planning purposes.

Results

The results of the water demand projections for each public water supplier, as calculated by the methods described in this memorandum are attached. The overall demand projection for the region is presented in Figure 5. The light blue dashed lines above and below the projection indicate a +/- 20% uncertainty in our projections. The regional groundwater model will be run with a range of conditions to understand the sensitivity of model results to demand projection inaccuracy.



Water Use and Population Projections
800
700
600
500
400
300
200
100
0
4,500,000
4,000,000
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
1980
1990
2000
2010
2020
2030
2040
2050
Year
Average Daily Water Use (MGD)
Population
Total Municipal Water Use
Regional Population
Population Served by Municipal Water Systems

Appendix 3: 2040 Groundwater Model Projections

DATE: September 17, 2015

TO: Water Supply Planning Unit, Metropolitan Council

FROM: Anneka Munsell, Environmental Scientist

Lanya Ross, Principal Environmental Scientist

SUBJECT: Metro Model 3 Application: Evaluating 2040 Water Demand

---

Metro Model 3 (MM3) was developed and calibrated for the primary purpose of predicting the effects of current and future groundwater withdrawals and land use on groundwater levels and the base flows of streams at a regional scale. These types of model predictions are useful for interpreting hydrogeologic data, informing future data collection, and for evaluating alternatives to enhance sustainable use of water resources in the metropolitan area.

Metro Model 3 is also available to use as a starting point for more subregional or localized analyses. For example, with refinement, it can be used for well impact evaluations, capture zone analysis, evaluation of surface water impacts, or to explore the impact of land use changes on recharge.

Benefits of this revision of the Metro Model include:

1. Incorporation of new information
2. Implementation of newer and better-supported software
3. Enhanced methods to understand parameter sensitivities and uncertainty in model predictions
4. Improved representation of Quaternary unconsolidated sediments and their influence on the groundwater-flow system
5. The ability to simulate seasonal effects of climatic and pumping stresses
6. An expanded model domain (Metropolitan Council 2014d)

Objectives and Application

Metro Model 3 was designed to help address a broad range of regional planning questions and to be as flexible as practical in order to accommodate new questions or scenarios, while still incorporating the best available data. Some examples of questions the model is intended to help address include:

- Given projected water demands, what impacts may be expected on groundwater levels and groundwater-dependent surface-water features?
- What combinations of source aquifers, well locations, and withdrawal rates can be used to achieve sustainable water consumption?
- How will projected water demand affect groundwater levels in each aquifer across the metropolitan area?

In its current design, Metro Model 3 successfully answers these questions. However, interpretation of the model results must recognize that any model is a simplification of a complex system and accuracy is limited by naturally variable geologic conditions and human error in measurements. For more information on Metro Model 3please see the *Twin Cities Metropolitan Area Groundwater Flow Model Version 3.0* (Metropolitan Council 2014d).

2040 Regional Scenarios

Regional scenarios were run using the model to evaluate the effects of forecasted groundwater withdrawals to the region's aquifer system.

Assumptions

Population and Population Served

The 2040 population for the communities within the seven-county metropolitan area are the population forecast values developed by the Metropolitan Council. Communities that disagree with the Council population forecasts and are actively changing the population forecasts with the Council; the community supplied population forecast is being used. New growth is assumed to be served by the municipal system. For a more detailed explanation of population served please see the technical memorandum, *Water Demand Projection Methodology and Preliminary Results, dated February 13, 2015* (Metropolitan Council, 2015e).

Water Demand

Municipal water demand was projected to 2040 water use using 2002-2012 data and community input. For more information of water demand please see the technical memorandum, *Water Demand Projection Methodology and Preliminary Results, dated February 13, 2015* (Metropolitan Council, 2015e). Between 1988 and 2012 water use for industrial, agricultural, and commercial use has been fairly consistent when compared to municipal demand. Therefore, these uses are assumed to remain constant through 2040.

Water Sources and Well Locations

Sources for municipal use were assumed to remain the same as current sources. Communities were contacted and asked to comment on well locations and sources. Communities fell into four categories:

- Communities served by surface water or by another community
- Communities who do not plan to drill any more wells
- Communities who plan to drill more wells and provided the locations and aquifers
- Communities where locations and sources were the same as in Metro Model 2. For more information please see *Metro Model 2 Technical Report, 2010 Master Water Supply Plan, Appendix E*

See the Table 1 for a list of communities and the category where they fell. Projected water use in excess of 2003-2011 average water use was evenly distributed among future wells. When a community did not plan to drill future wells the excess water use was evenly distributed among the existing wells.

Table 1. Summary of how Twin Cities metropolitan area community public water supply wells were included in Metro Model 3 including: whether or not the community is supplied by another community, if new wells are planned for installation between 2015 and 2040, if community staff provided corrections to the draft well locations and sources shared with communities in December 2014, and if the well locations and sources remain the same as those used by Metro Model 2 to support the 2010 Master Water Supply Plan.

Community	Supplied by Another Community	No Wells Planned	Locations and Sources Updated	Locations and Sources Same as Metro Model 2
Andover			X	
Anoka				X
Apple Valley			X	
Arden Hills	X			
Bayport				X
Belle Plaine		X		
Birchwood	X			
Blaine				X
Bloomington				X
Brooklyn Center		X		
Brooklyn Park			X	
Burnsville		X		
Carver			X	
Centerville		X		
Champlin		X		
Chanhassen			X	
Chaska			X	
Circle Pines			X	
Cologne				X
Columbia Heights	X			
Columbus		X		
Coon Rapids				X
Corcoran	X			
Cottage Grove			X	
Crystal	X			
Dayton			X	
Deephaven	X			
Eagan			X	
East Bethel				X
Eden Prairie			X	
Edina		X		
Elko New Market			X	
Empire Township			X	

Community	Supplied by Another Community	No Wells Planned	Locations and Sources Updated	Locations and Sources Same as Metro Model 2
Excelsior		X		
Farmington				X
Falcon Heights	X			
Forest Lake			X	
Fridley				X
Golden Valley	X			
Greenfield				X
Hamburg				X
Hampton				X
Hastings			X	
Hilltop	X			
Hopkins		X		
Hugo			X	
Inver Grove Heights			X	
Jordan				X
Lake Elmo			X	
Lakeland				X
Lakeland Shores	X			
Lake St. Croix Beach	X			
Lakeville			X	
Lauderdale	X			
Lexington				X
Lilydale	X			
Lino Lakes			X	
Little Canada	X			
Long Lake		X		
Loretto		X		
Mahtomedi		X		
Maple Grove			X	
Maple Plain			X	
Maplewood	X			
Marine On St Croix				X
Mayer				X
Medina				X
Mendota	X			
Mendota Heights	X			
Minneapolis				
Minnetonka		X		

Community	Supplied by Another Community	No Wells Planned	Locations and Sources Updated	Locations and Sources Same as Metro Model 2
Minnetonka Beach				X
Minnetrista			X	
Mound		X		
New Brighton		X		
New Germany		X		
New Hope	X			
New Prague				X
New Trier				X
Newport			X	
Northfield				X
North Oaks	X			
North St. Paul				X
Norwood Young America				X
Oak Grove			X	
Oak Park Heights				X
Oakdale				X
Orono				X
Osseo	X			
Plymouth			X	
Prior Lake		X		
Ramsey		X		
Randolph				X
Richfield		X		
Robbinsdale			X	
Rockford				X
Rogers		X		
Rosemount				X
Roseville	X			
Savage		X		
Shakopee			X	
Shoreview				X
Shorewood				X
South St. Paul			X	
Spring Lake Park		X		
Spring Park				X
St. Anthony				X
St. Bonifaceous				X
St. Francis				X

Community	Supplied by Another Community	No Wells Planned	Locations and Sources Updated	Locations and Sources Same as Metro Model 2
St. Louis Park				X
St. Paul				X
St. Paul Park		X		
Stillwater		X		
Sunfish Lake	X			
Tonka Bay		X		
Vadnais Heights				X
Vermillion				X
Victoria				X
Waconia			X	
Watertown			X	
Wayzata			X	
West St. Paul	X			
White Bear Lake				X
White Bear Twp.		X		
Willernie	X			X
Woodbury			X	
Woodland	X			

"Business as Usual"

This scenario was designed to test the hypothesis that, given projected demands, metropolitan area communities can continue to use water and develop supplies using the traditional assumption of aquifer availability. Due to uncertainty regarding future population, the effectiveness of conservation practices and climate, a 20% increase of municipal water use and a 20% decrease of municipal water use was included in the "Business as Usual" scenario. The 20% increase and decrease was applied to all existing and future municipal wells in the seven-county metropolitan area.

Model Uncertainty

Groundwater models are used to make decisions, to analyze risk, and to manage water systems. While no model can be 100% correct, when properly constructed and evaluated, a model can be a useful and informative tool. Evaluating the uncertainty that exists within a model reinforces the output from the model and makes it more useable to the end user.

Sources of Uncertainty

Model uncertainty comes from four main factors:

1. *Conceptual framework*
2. *Model parameter*
3. *Calibration*
4. *Predictive*

In the Metro Model 3, key contributors to *conceptual framework and model parameter uncertainty* include old geologic atlases. While the geology hasn't changed in the past 20 years, we are now able to better map the geology of the area. Our evolving understanding about fault systems is one example of uncertainty in our conceptual framework. The following county geologic atlases are over 20 years old:

- Dakota
- Hennepin
- Ramsey
- Washington

Key contributors to *calibration uncertainty* include the quality of data in the County Well Index (CWI). CWI was weighted less than other more certain datasets, such as observation wells, but where observation wells are sparse CWI drives head during calibration. While broad spatially, CWI data are uncertain due to the following:

- Inaccurate water-level measurements
- Inaccurate well location
- Inaccurate elevation
- Unstable water level at the time of measurement
- Misidentification or incorrect assignment of hydrostratigraphic units in databases
- Seasonal pumping affects of water levels
- Long-term changes in water levels due to climate or growing water demand

The single biggest contributor to *predictive uncertainty* is uncertainty in future water demand. We do not know for sure how many people will live in the metro, where they will live, how much water they will use, or if sources of water will remain the same. This is where input from City Administrators and Engineers comes in. We recognize that no one knows the city and its water supply better than the city or utility staff. Therefore, we have been asking for input on population, population served, per capita water use, water sources, and well locations.

It is hard to predict water use given all the variables, but historically water use has been in about a +/- 20% range, which is why we are presenting results with this range.

Calibrated MM3

The steady-state Metro Model 3 model estimates average water levels between 2003 and 2011, within a range (plus or minus) about 17 feet.

Because it is a steady-state model, it does not represent water levels for a specific day and time. Instead, it is intended to illustrate where aquifer water levels will come to equilibrium under a given water budget (recharge, pumping, baseflow). In other words, it illustrates where things will ultimately end up.

In general, the model uncertainty is spread fairly evenly throughout the model. Areas where model uncertainty appears to be concentrated, and associated reasons for uncertainty, are:

- Northwest Hennepin County

- Areas of faulting
- Geologic atlas updated in 1989
- Few observation wells

- Eastern Scott County
  - Areas of faulting
- Rice County (note: not in 7 county metro; directly to south of the Twin Cities metropolitan area)
  - Geologic atlas updated 1995
  - Few observation wells
- Le Sueur County (note: not in 7 county metro; directly south of Scott County)
  - Geologic atlas updated in 1991
  - Few observation wells

Model Application

We know that MM3 has an average error of approximately +/- 17 feet and we know the sources of the error. What does this mean for the way the model is applied?

The Metropolitan Council recognizes the error in the model compared to the real world. This error can be minimized when comparing model output to model output. Drawdown shows you the change between two conditions, the starting and ending place doesn't matter as much as the difference between the two conditions.

Table 2: Uses for "out of the box" Metro Model 3

Acceptable	Marginally Acceptable*	Not Acceptable
Compare regional scenarios	General well field placement	Localized well field optimization
Compare sub-regional scenarios	Estimate groundwater/surface water connections	Site specific evaluations
Identify areas where more information is needed	Wellhead protection plans	Predicting time dependant water table elevations
Identify possible problem areas		

*The model can be used as a "back of the envelop calculation" giving the user an idea of a starting place for further analysis.

Calculations using Metro Model 3

Metro Model 3 is currently used by the Metropolitan Council for two specific calculations:

1. Drawdown
2. Available Head

These two calculations are visible in the drawdown figures provided in the Master Water Supply Plan.

Drawdown Calculations

The drawdown is the difference in head (water level) between two points in time. The drawdown $(\mathrm{D_d})$ is calculated as the difference between the model head at 2010 pumping rates $(\mathrm{H_{2010}})$ and the model head at 2040 pumping rates $(\mathrm{H_{2040}})$. The model resulting from the 2010 pumping as reported in SWUDS was designated as the initial condition. This means areas with drawdown are showing an increase in pumping from 2010 pumping conditions.

$$D_d = H_{2010} - H_{2040}$$

The 2040 projected drawdowns are relative to the modeled 2010 pumping as reported in the Minnesota Department of Natural Resources State Water Use Data System (SWUDS). This has been a point of discussion with communities and agency technical staff, and the idea that the most people felt comfortable with is modeling the 2010 pumping as reported in SWUDS to use as a baseline condition. This links the model to a particular year and allows updates of the model to always use the same year so that there is not a moving baseline for calculating drawdown.

Available Head Calculations

Available head is not measured; it is calculated using the model. The available head is the difference between the head (water level) and the upper bedrock surface of the aquifer.

$$H_{available} = Elevation_{Model\ 2010\ pumping} - Elevation_{top\ of\ geologic\ formation}$$

If the calculated available head ($H_{available}$) is greater than 10 feet, then the aquifer is considered confined and the 50% head analysis takes place.

$$If\ H_{available} > 10\ feet\ then:$$

The elevation of the top of the geologic formation ($Elevation_{top\ of\ geologic\ formation}$) is added to 50% of the calculated available head ($H_{available}$) to calculate the 50% head elevation ($H_{available\ elevation}$).

$$H_{available\ elevation} = Elevation_{top\ of\ geologic\ formation} + \frac{1}{2} * H_{available}$$

If the modeled head ($Elevation_{Model\ 2040\ pumping}$)is less than the 50% head elevation ($H_{available\ elevation}$) then that cell is flagged.

$$If\ H_{available\ elevation} < Elevation_{Model\ 2040\ pumping}$$

The 2010 pumping data from SWUDS is input into Metro Model 3 and the output is used to define the water level. The cumulative reported 2010 pumping is divided by 365 days to get average daily pumping, which is then input into the model. Note: If an area has 10 feet of head or less it is considered unconfined and removed from the analysis. Also note that Metro Model 3 is a steady-state model and does not account for seasonal or operational variation.

Appendix 4: Groundwater Optimization Modeling

resourceful. naturally.
engineering and environmental consultants

BARR

Technical Memorandum

To: Lanya Ross, Anneka LaBelle, Ali Elhassan
From: Evan Christianson, Ray Wuolo
Subject: Metro Pumping Optimization 3
Date: April 2, 2015
Project: 23/62-1087.01

1.0 Introduction

This technical memorandum describes the optimization of pumping in the seven-county metropolitan area. The goal of the optimization was to maximize total pumping from existing permitted wells while meeting constraints on baseflow, hydraulic head, flow direction, and flux to/from surface water features as specified by the Metropolitan Council. The optimization uses the steady-state version of the Twin Cities Metropolitan Area Groundwater Flow Model, Version 3.0 (Metro Model 3; Metropolitan Council, 2014)

Optimizations described in technical memorandums dated August 15, 2014 and October 13, 2014 (Barr, 2014a and Barr, 2014b), herein referred to as Optimization 1 and Optimization 2, are similar and complimentary to the optimization described in this technical memorandum, herein referred to as Optimization 3.

2.0 Optimization Software, GWM-VI

The Groundwater Management (GWM) Process for MODFLOW, developed by the USGS (Ahlfeld et al., 2000), was used for the optimization. The version used was GWM-VI (Banta and Ahlfeld, 2013) which allows for parallel processing. No changes were made to the source code of GWM-VI for implementation of this project. All optimization algorithms described in Banta and Ahlfeld (2013) and Ahlfeld et al. (2005) are implemented with no change. However, several pre- and post-processing steps were used to overcome hardwired limitations on the type of constraints available with the standard GWM-VI implementation and are discussed in Section 2.3. Optimizations utilizing GWM-VI require two main inputs: decision variables and constraints; each is discussed below.

2.1 Decision variables

Decision variables are quantifiable controls that are to be determined by the GWM-VI optimization algorithms (Ahlfeld et al., 2000). Decision variables for both Optimizations 1, 2, and 3 were identical and were provided to us by Metropolitan Council. They include existing permitted wells in the seven-county metropolitan area open to any aquifer, except the Mt. Simon Hinckley aquifer, and with use codes from the SWUDS database shown in Table 1. A total of 2,074 wells were included in the optimization. The goal of the optimization was to maximize the objective function, which is essentially the sum of the pumping from all decision variable wells.

Table 1. SWUDS use codes for decision variable wells included in the optimization

Use Code	Description	Use Code	Description
211	Municipal	248	Non-metallic processing
212	Private waterworks	249	Industrial processing
213	Commercial and Institutional	263	Quarry dewatering
215	Fire protection	264	Sand/gravel pit dewatering
229	Power generation	266	Dewatering
232	Institutions	271	Pollution containment
241	Agricultural processing	277	Sewage treatment
242	Pulp and paper processing	289	Non-crop irrigation
246	Petroleum-chemical processing, ethanol	290	Major crop irrigation
247	Metal processing		

2.2 Constraints

Constraints impose restrictions on the values that can be taken by the decision variables (Ahlfeld et al., 2000). Three types of constraints were used: hydraulic head, flux between groundwater and surface-water features (baseflow and basin leakage and/or gain), and groundwater flow-direction. In general, Optimization 3 and Optimization 2 are constrained significantly less than Optimization 1. A summary of constraints imposed for each optimization is shown in Table 2 and details describing each constraint type are presented below.

Table 2. Comparison of constraints between Optimization 1, 2, and 3

Constraint Type	Optimization 1	Optimization 2	Optimization 3
Drawdown from available head for confined bedrock aquifers above the Mt. Simon-Hinckley	75%	75%	50%
Drawdown in the Mt. Simon-Hinckley aquifer	1 foot	1 foot	1 foot
Drawdown at groundwater dependent surface-water features (cancerous fens)	1 foot	1 foot	1 foot
Change in net baseflow to trout streams	-10%	-10%	-10%
Change in net baseflow to other river reaches	Not included	-15%	-15%
Change in net baseflow to the Mississippi River	Not included	-15%	-25%
Change in net groundwater flux for high and outstanding biodiversity	Not included	-15%	-15%
Change in net groundwater flux to potentially vulnerable lakes with wide littoral zone	Not included	-10%	-10%
Change in net groundwater flux for remaining lakes at grouped by Township	Not Included	-15%	-15%
Change in flow directions at site of groundwater contamination	10 degrees	10 degrees	10 degrees

Optimization 1 constrained the flux between groundwater and surface water for trout streams only. As described in more detail below, Optimizations 2 and 3 constrained the flux between groundwater and surface water for all lakes, streams, and wetlands simulated by Metro Model 3 within the seven-county metropolitan area.

2.2.1 Hydraulic Head Constraints

Hydraulic head constraints were used to impose three conditions on the optimization: 1) hydraulic head in confined bedrock aquifers can't drop below a "safe yield" threshold, 2) hydraulic head in the Mt. Simon–Hinckley aquifer can't drop more than 1 foot from the baseline condition, and 3) hydraulic head at groundwater dependent surface-water features (e.g. calcareous fens) can't drop more than 1 foot from the baseline condition. Hydraulic head, representing "safe yield" thresholds, were defined as:

$$Safe\ Yield\ Head = (H_b - Z) * 0.50 + Z$$

Where:

H_b is the base head condition for the aquifer, defined using pumping from the Metro Model 2;
Z is the elevation of the top of the aquifer

The base condition from which drawdown for the Mt. Simon-Hinckley aquifer and groundwater dependent surface-water features were determined was the hydraulic head from the steady-state version of the Metro Model 3.

Hydraulic head constraints representing "safe yield" and limits on drawdown of the Mt. Simon-Hinckley aquifer were implemented at the cell location (row and column) of all pumping wells in the seven-county metro area. Including these head constraints in every model cell is not practicable as it would dramatically increase the total run time for the optimization. These head constraints are more likely to be violated at the location of high pumping stress, compared to distances far from the wells. Vertically, at each cell location, constraints were included only for model layers representing bedrock aquifers being pumped and layers above these aquifers. For example, if the Prairie du Chien is being pumped and lower aquifers are not being pumped, "safe yield" constraints were only included for the Prairie du Chien and St. Peter aquifer, not the deeper aquifers.

2.2.2 Flux between groundwater and surface-water features

All surface-water features in the Metro Model 3 are simulated using the River Package for MODFLOW. The River Package simulates the exchange of water between groundwater and surface water. River Package boundary cells were compiled into groups and the water fluxes into or out of the boundary cells were tracked and summarized for each group. Constraints were imposed to limit the change in flux from the baseline condition resulting from increased pumping. The baseline condition used was the flux simulated with the steady-state version of Metro Model 3.

Groundwater flux to all streams (baseflow) in the seven-county metropolitan area was constrained for the optimization (Figure 1). Each stream was divided into reaches approximately 5 miles in length. Baseflows for trout stream reaches are not allowed to be reduced by more than 10 percent from the baseline conditions. Baseflows for all other reaches, with the exception of the Mississippi River, are not allowed to be reduced more than 15 percent from baseline conditions. Baseflows for the Mississippi River were allowed to be reduced up to 25 percent. A total of 13 trout stream baseflow constraints and 79 non-trout stream baseflow constraints were imposed for the optimization.

River boundary cells that intersect sites of high and outstanding biodiversity identified by the Minnesota County Biological Survey (2013) were grouped together (Figure 1). The groundwater flux into these features was not allowed to decrease more than 15 percent and/or flux out of these features was not allowed to increase more than 15 percent from the baseline simulation. A total of 108 biodiversity area constraints were imposed.

River Package boundary cells that represent lakes identified as being potentially vulnerable to groundwater pumping and having a wide littoral zone (Barr, 2010) were grouped together (Figure 1).

Lakes are considered to have a wide littoral zone if they are less than five feet deep over more than 20 percent of the total surface area. These lakes have a greater potential of being negatively impacted by reductions in stage. For these lakes (68 in the seven county metropolitan area), the water flux out was not allowed to increase more than 10 percent and/or the groundwater flux into these lakes was not allowed to decrease more than 10 percent.

All remaining River Package boundary cells that were not included in groups described above were grouped based on the public land survey township they are located in (Figure 1). This resulted in an additional 103 constraints. For these grouped boundary cells, the total groundwater flux in was not allowed to be reduced by more than 15 percent and/or total water flux out was not allowed to increase more than 15 percent. Grouping these River Package cells, rather than imposing constraints on individual cells or surface water features, was necessary to help keep the total number of constraints to a manageable level to maintain reasonable solution times for the optimization algorithm.

2.2.3 Flow Direction Constraints

Flow direction constraints for Optimizations 1, 2, and 3 are identical and were included for areas of existing groundwater contamination provided by the Metropolitan Council. The flow direction in the vicinity of these contamination areas was not allowed to deviate from the baseline condition by more than 10 degrees. The baseline condition used was the flow direction simulated with the steady-state version of Metro Model 3.

2.3 Substitution of MMProc

GWM-VI uses a stand-alone executable, *MMProc.exe*, to write MODFLOW input files, execute MODFLOW, and extract head and cell-by-cell flow values from MODFLOW output files. *MMProc.exe* is hardwired to only read output from a small number of MODFLOW packages. Two major limitations of *MMProc.exe* necessitated the development of a separate and much more flexible pre- and post-processor: inability to read/write data for the River Package, and implementation of groundwater flow-direction constraints. Pre- and post-processing for Optimization 2 and Optimization 3 are identical. Pre- and post-processing Optimization 1 involved less constraints associated with River Package boundary cells. Description of the pre- and post-processing steps described in the technical memo from August 14, 2014 and is repeated below for completeness.

A python script, *pyMMProc.py*, was developed to handle the capabilities of *MMProc.exe* while being more flexible and allowing use of the River Package and flow-direction constraints. A comparison of how *MMProc.exe* and *pyMMProc.py* interact with GWM-VI and MODFLOW is shown on Figure 2a and Figure 2b.

The source code for this script is provided with the project deliverables and is documented internally. A brief description of how the script works is provided below for those not familiar with the python programing language.

GWM-VI creates a file called *MMProc.in.jtf* at the start of an optimization run that acts as a template file for well pumping rates. Throughout the optimization, GWM-VI (or a runner program called *jrunner* if running in parallel mode) uses *MMProc.in.jtf* to create a file called *MMProc.in* which contains pumping rates for MODFLOW to use. Updated pumping rates are pulled from *MMProc.in* and used by *pyMMProc.py* to generate a new Well (WEL) Package and Revised Multi-Node Well (MNW2) Package files for MODFLOW. *pyMMProc.py* then executes MODFLOW.

After MODFLOW is completed, *pyMMProc.py* extracts hydraulic head and river flux data from MODFLOW output files associated with the head and river observation packages. Selected hydraulic head data are used to calculate groundwater flow-directions by solving a three-point problem. The deviation in groundwater flow direction from a provided base condition is then determined. The change in river flux from the base condition is also calculated. All hydraulic head, change in flow direction, and change in river flux are written to a file called *Simulated_Values.out* which is read directly by GWM-VI.

pyMMproc.py also checks to make sure that MODFLOW converged and that no pumping rates were reduced by the MNW2 or Upstream Weighting (UPW) Package. Convergence status and pumping rate status are written to a file called *modflow.status* which is read directly by GWM-VI.

The use of pyMMproc.py necessitates slight modifications on how GWM-VI input files are set up that may not be initially intuitive. Input files were set up to treat all constraints, including baseflow and flow-direction constraints as head constraints. All constraint types are included in the head constraints (HEDCON) input file. This was necessary due to GWM-VI only supporting the Stream Package, whereas the Metro Model 3 uses the River Package. If GWM-VI input files were set up using the stream constraints (STRMCON) input file, GWM-VI would expect to find a Steam Package, which does not exist for Metro Model 3.

2.4 Limitations of GWM-VI

During the course of this optimization several hindrances were encountered that relate to the GWM-VI software. We have notified the developers of GWM-VI about these issues; however, there is currently no timeline for fixing them. A discussion of these issues and current workarounds to each are described below.

1.) **Solving of the linear program (LP) is not optimized or parallelized**. The SLP solver used by GWM-VI has two main phases: 1) calculation of the response matrix, which requires MODFLOW to be run once for every decision variable and 2) solving the LP. Previous versions of GMW (prior to GWM-VI) were not able to run is a parallel or distributed fashion. So, calculation of the response matrix was by far the most time consuming phase of solving the optimization problem. With the introduction of parallel processing in GWM-VI, calculation of the response matrix can be completed in a fraction of the time previously required, given that enough processors are available. During this project, we used up to 75 processors for calculating the response matrix. Solving the LP is not parallelized and must be completed on a single processor. The solution time for a single LP problem is roughly proportional to the number of constraints cubed.

2.) **Pumping from multi-node wells being reduced.** Wells simulated with the MNW2 Package can have their pumping rate automatically reduced if the head in the well or surrounding aquifer drops to levels that would not be able to supply the specified pumping rate for a well. This is an unfavorable occurrence for the GWM-VI algorithms because constraints may be met only because the pumping was automatically reduced by MODFLOW. GWM-VI overcomes this issue by checking information in the *modflow.status* file written by MMproc (or pyMMproc). If any wells have their pumping reduced it is indicated in the *modflow.status* file and GWM-VI automatically reduces pumping rates for all wells based on equation 73 in Ahlfeld (2005) and attempts an additional MODFLOW simulation. This continues iteratively until all MNW2 wells pump at the specified rates. The problem with this approach is that all wells have their pumping reduced if just a single MNW2 well is causing a problem. So, if many iterations of reducing pumping from all wells are required to prevent a single MNW2 well from pumping at a rate less than specified there is very little change in the total pumping.

   Overcoming this issue required stopping GWM-VI at each iteration of the SLP solver and adjusting pumping rates wells that were causing problems. Implementing this process dramatically increased progress of the optimization. The process of adjusting pumping rates was automated for Optimization 2 and Optimization 3 but still required manually stopping and restarting GWM-VI at each iteration.

3.0 Results of Optimization

3.1 Pumping Rates

Total optimized pumping from the wells included in the optimization is 374 million gallons per day (MGD). This represents a 43-percent increase in the base pumping of 261 MGD, which is the pumping from the steady-state version of the Metro Model 3 and represents average pumping from 2003 to 2011. A comparison of optimized total pumping rates for Optimizations 1, 2, and 3 is shown in Table 3.

Table 3. Comparison of results from Optimization 1, 2, and 3.

Optimization	Total optimized pumping (MGD)
1	743
2	368
3	374

Further analysis of the optimized pumping is beyond the scope of this project but it is our understanding that it will be completed by the Metropolitan Council. However, we have tried to provide the Metropolitan Council with some insight, based on what we learned during the optimization process and a cursory inspection of the results. A discussion is provided in Section 4.0 below.

3.2 Binding constraints and shadow prices

While 5,237 constraints were imposed for the optimization, only a subset actually controls the formulation of an optimal solution. These constraints are said to “bind” the solution because they prevent decision variables (well pumping) from taking values that would further improve the optimization. Each binding constraint has a “shadow price” which reflects how sensitive the optimization is to the constraint. For additional discussion of binding constraints and shadow prices the reader is referred to Ahlfeld et al. (2005) pg. 51. Binding constraints and associated shadow prices calculated by GWM-VI during the last iteration of the optimization are presented in Attachment A. A total of 184 (out of 5,237 total) constraints were found to be binding. Overall, baseflow constraints (trout and other streams) were the most sensitive, constituting 12 of the top 30 constraints with the largest shadow price. Change in flux on the township and range scale constituted 9 of the top 30 constraints with the largest shadow price. Table A2 summarizes binding constraints by constraint type. Figure 3 shows the spatial distribution of binding constraints.

4.0 Discussion

Analysis of the optimization results are not part of the scope of this project and it is our understanding that such analysis is planned to be completed by Metropolitan Council staff. However, the following observations were noted during this project and may warrant further review, discussion, or follow-up optimization.

1.) Optimization 1 showed large increases in pumping sustained by induced leakage from River Package boundary cells. Significantly increasing the constraints imposed on River Boundary cells for Optimization 2 greatly reduced these issues, and hence reduced the total optimized pumping volumes. Optimization 3 imposed strictor constraints regarding safe yield (50% available head vs.

75% available head) and less restrictive constraints on baseflow to the Mississippi River. Overall Optimization 3 resulted in slightly more pumping than Optimization 2, primarily because the optimization is very sensitive to constraints imposed on baseflow of the Mississippi River. There may still be areas where induced leakage may be occurring beyond sustainable levels but are highly local and smaller than the scale to which we can impose constraints.

2.) Many of the constraints with the largest shadow price (see Section 3.2) are reaches of the Mississippi River. A constraint imposing no more than a 25 percent reduction in baseflow from baseline conditions was used for these reaches. Because these reaches are major groundwater discharge zones for the region, many wells, particularly in the deeper aquifers, affect baseflow to these reaches by capturing flow that would go to the river under lower pumping conditions. It should be noted that the constraint imposed does not represent a 25 percent reduction in total flow; the vast majority of flow comes from upstream. Allowing for a greater reduction in baseflow to these reaches would result in a higher optimized pumping volume, potentially significantly higher given the magnitude of the shadow price for these constraints.
3.) For some communities, the optimized pumping scheme results in municipal pumping being reduced to nearly zero. The reality and feasibility of such a scenario is uncertain.
4.) This type of optimization is very non-linear and typically non-unique. It is very likely that different distributions may result in nearly identical total pumping. We believe the addition of more constraints for Optimizations 2 and 3 has helped move toward the more unique solution. However, the level of uniqueness has not been quantified.

Limitations of the model, optimization, and choice of wells and constraints should be carefully considered when using these results for long-term planning. The optimization was limited to only existing wells and assumes that conditions have reached steady-state. New wells, added in undeveloped areas or aquifers, would certainly increase the total pumping of the region while still meeting imposed constraints. Also, in certain areas local concerns such as well interference or impacts to surface waters not accurately simulated at the scale of the Metro Model 3 may be deemed unacceptable even though all constraints imposed were met.

5.0 References

Ahlfeld, D.P., Barlow, P.M. and Mulligan, A.E., 2005. GWM—A ground-water management process for the U.S. Geological Survey modular ground-water model (MODFLOW-2000): U.S. Geological Survey Open-File Report 2005-1072, 124p.

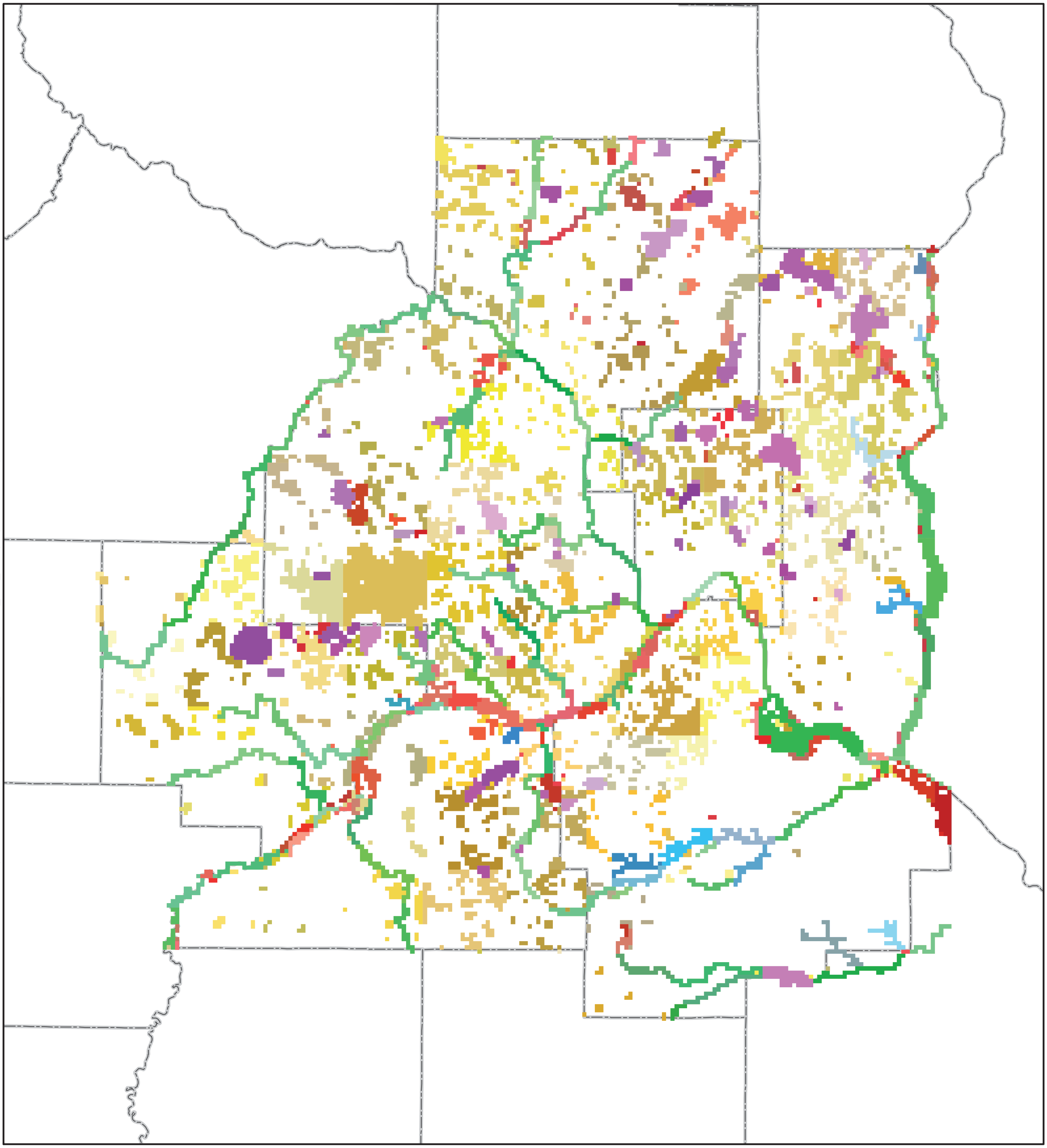
Banta, E.R. and Ahlfeld, D.P., 2013. GWM-VI—Groundwater Management with parallel processing for multiple MODFLOW versions: U.S. Geological Survey Techniques and Methods, book 6, chap. A48, 33p.

Barr Engineering. 2014a. Metro Pumping Optimization, Technical Memorandum from Evan Christianson and Ray Wuolo to Lanya Ross, Anneka LaBelle, and Ali Elhassan, August 15, 2014.

Barr Engineering. 2014b. Metro Pumping Optimization 2, Technical Memorandum from Evan Christianson and Ray Wuolo to Lanya Ross, Anneka LaBelle, and Eli Elhassan, October 13, 2014.

Metropolitan Council, 2014. Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3.0. Prepared by Barr Engineering. Metropolitan Council: Saint Paul, MN.

Minnesota County Biological Survey. 2013. MBS Sites of Biodiversity Significance, Minnesota Department of Natural Resources, Division of Ecological Resources, shapefile geospatial data.



River Packge Boundary Cell Constraints

- Biodiversity Area
- Stream/River
- Trout Stream
- Township Range Group
- Vulnerable Basin

N

Miles

10 0

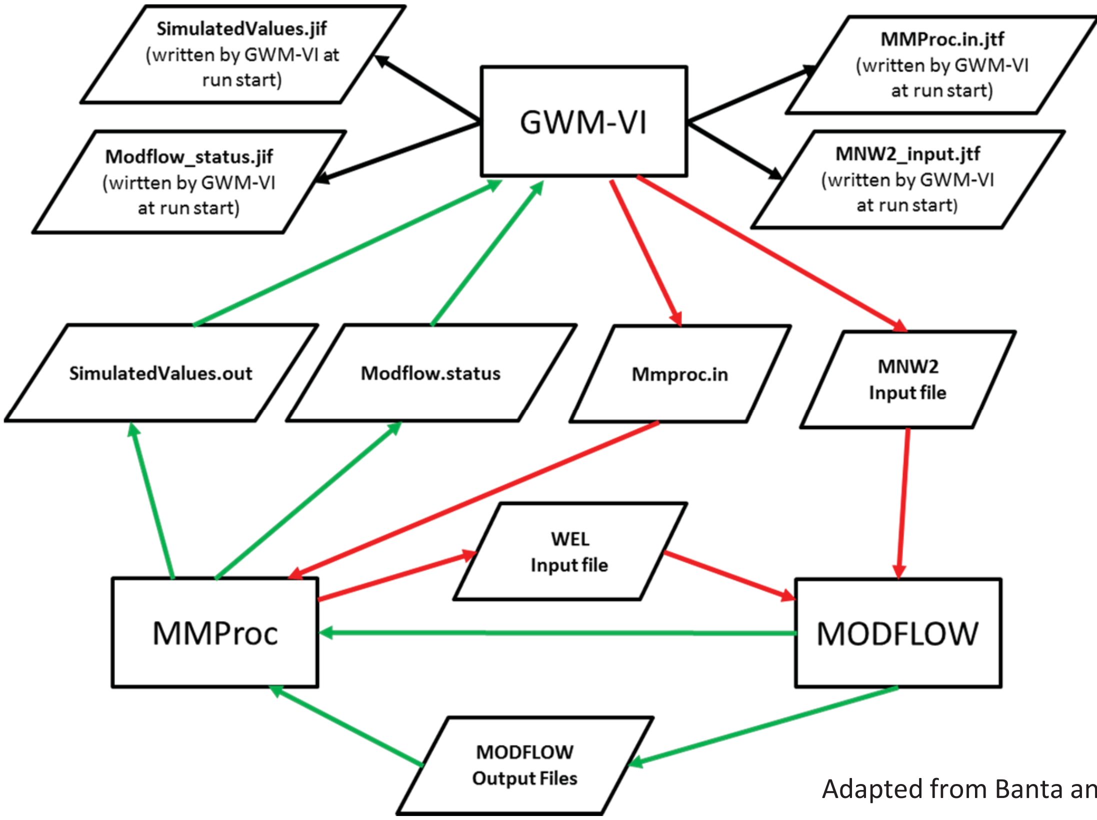
BARR

Figure 1

RIVER PACKAGE BOUNDRY
CELL CONSTRAINTS
Pumping Optimization 3
Metropolitan Council

Barr Footer: ArcGIS 10.2.1, 2014-10-13 12:20 File: I:\Projects\23\62\1087\Maps\Pumping_Optimization\River_Cell_Grouping.mxd User: egc

1a. Interaction of MMProc with GWM-VI and MODFLOW



Adapted from Banta and Ahlfeld, 2013

1b. Interaction of pyMMProc with GWM-VI and MODFLOW

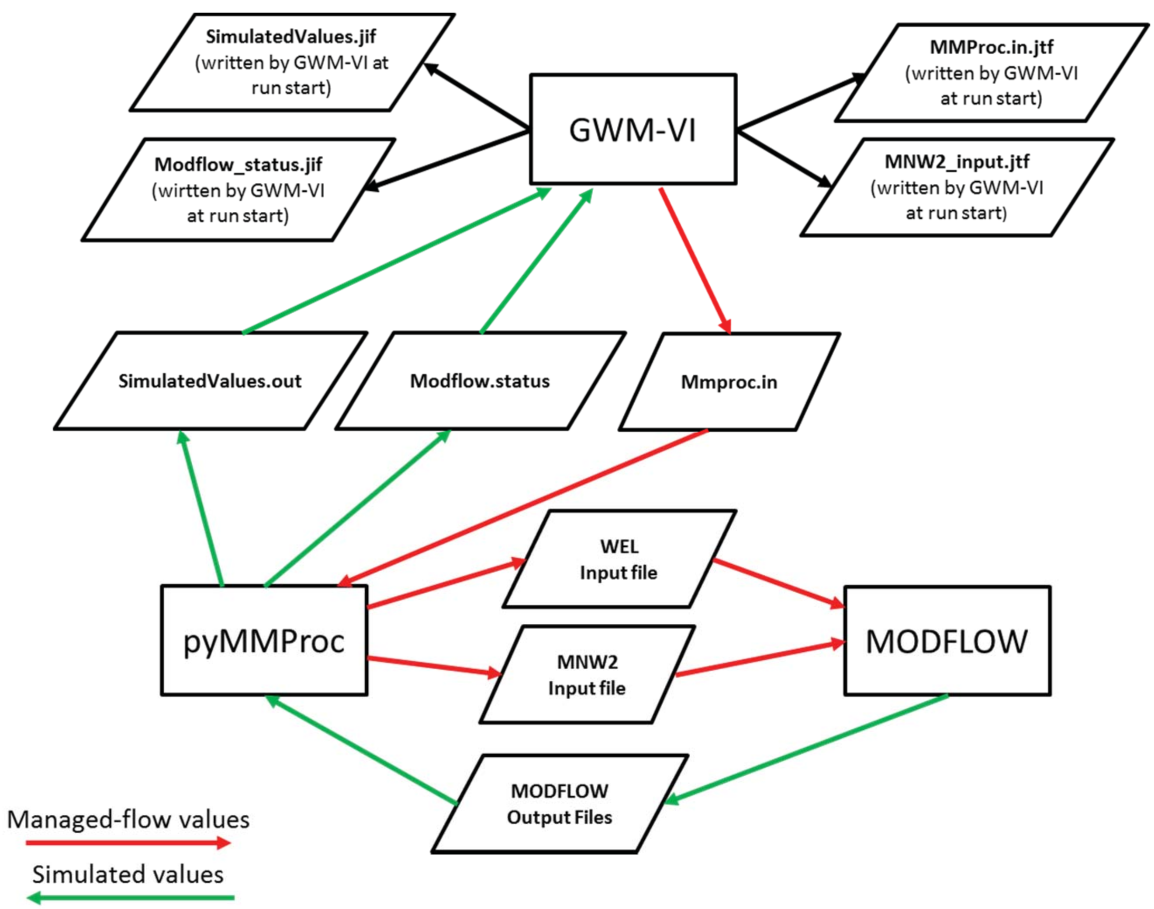
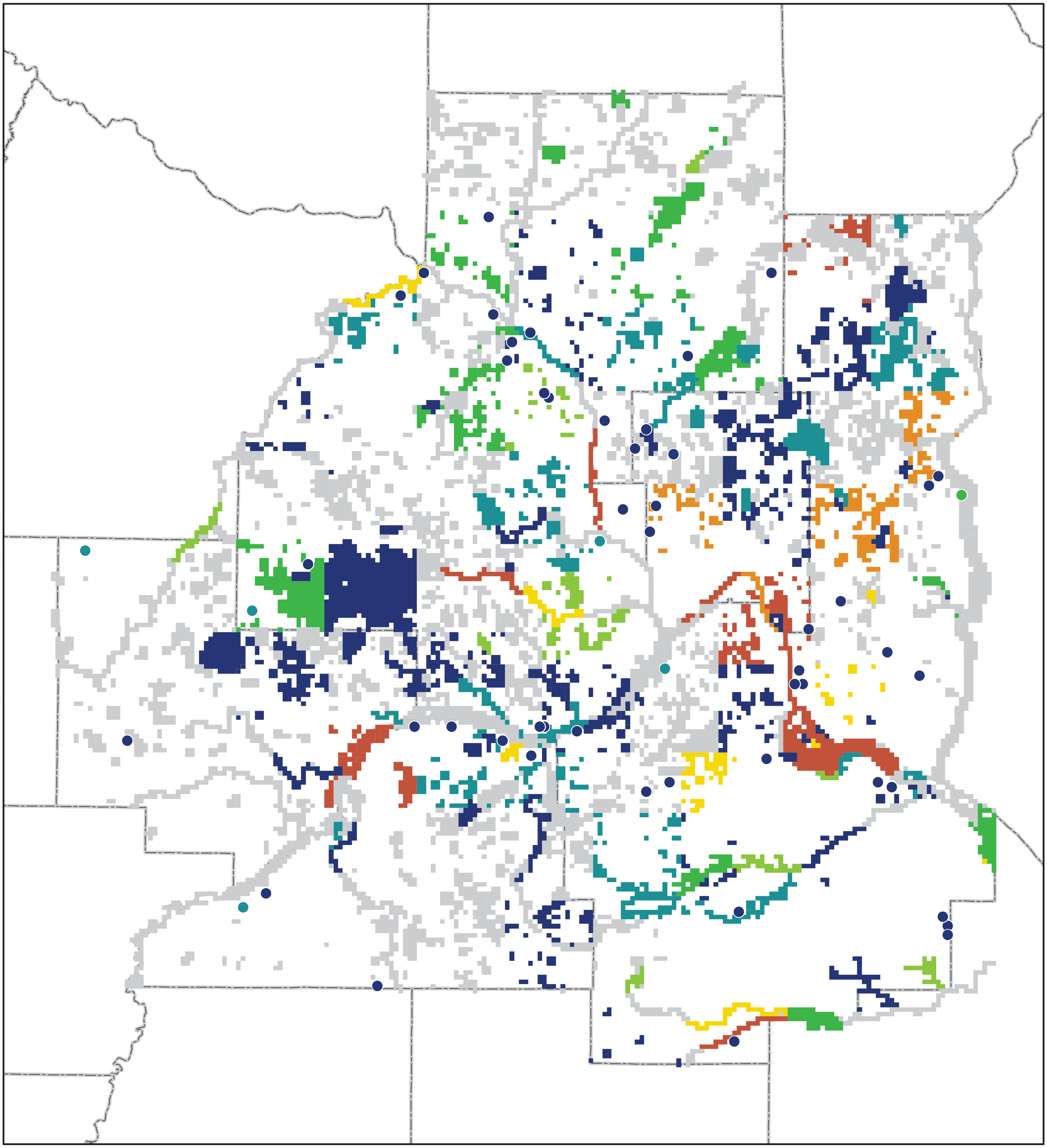


Figure 2

Comparison of
MMProc and pyMMProc
interaction with
GWM-VI and MODFLOW
Pumping Optimization 3
Metropolitan Council



Barr Footer: ArcGIS 10.2.1, 2014-10-13 12:19 File: I:\Projects\23\62\1087\Maps\Pumping_Optimization\Optimization2_Binding_Constraints.mxd User: egc

Binding Hydraulic Head and Safe Yield Constraints

Shadow Price

- > 1.50e+008
- 1.26e+008 - 1.50e+008
- 1.01e+008 - 1.25e+008
- 7.51e+007 - 1.00e+008
- 5.01e+007 - 7.50e+007
- 2.51e+007 - 5.00e+007
- < 2.50e+007

Binding River Boundary Constraints

Shadow Price

- > 1.50e+008
- 1.26e+008 - 1.50e+008
- 1.01e+008 - 1.25e+008
- 7.51e+007 - 1.00e+008
- 5.01e+007 - 7.50e+007
- 2.51e+007 - 5.00e+007
- < 2.50e+007
- Non-Binding River Cells

Miles

0 2.5 5

BARR

Figure 3

BINDING CONSTRAINTS
Pumping Optimization 3
Metropolitan Council

Attachment A

Binding Constraints and Shadow Prices

Table A-1

Binding Constraints and Shadow Price

Constraint Name	Description	Row	Col	Absolute Shadow Price
Riv_016	Mississippi River (Downtown St. Paul)	--	--	3.14E+08
Riv_013	Mississippi River (N. Minneapolis, Fridley, Brooklyn Center)	--	--	2.96E+08
T28_R22	Township 28, Range 22	--	--	2.56E+08
T32_R21	Township 32 Range 21	--	--	2.04E+08
Riv_165	Mississippi River / Sping Lake	--	--	2.00E+08
T115_R23	Township 115, Range 23	--	--	1.84E+08
Riv_018	Mississippi River (S. St. Paul, Invergrove Heights, Newport, St. Paul Park)	--	--	1.81E+08
Riv_136	Cannon River (Northfield, Randolph)	--	--	1.73E+08
Vul_083	Crosby Lake	--	--	1.62E+08
Riv_120	Minnehaha Creek (Minnetonka, Hopkins, St. Louis Park)	--	--	1.57E+08
Riv_055	Minnesota River (Chaska, Carver)	--	--	1.54E+08
T29_R21	Township 29 Range 21	--	--	1.50E+08
Riv_017	Mississippi River (St. Paul)	--	--	1.48E+08
T30_R20	Township 30 Range 20	--	--	1.33E+08
T29_R23	Township 29 Range 23	--	--	1.32E+08
Riv_135	Chub Creek	--	--	1.20E+08
Vul_023	Powers Lake	--	--	1.14E+08
Trout_03	Eagle Creek	--	--	1.13E+08
T27_R21	Township 27 Range 21	--	--	1.12E+08
T115_R19	Township 115 Range 19	--	--	1.12E+08
Bio_083	Ravenna 17	--	--	1.11E+08
Riv_121	Minnehaha Creek (St. Louis Park, Edina)	--	--	1.05E+08
Riv_033	Crow River (Rogers, St. Michael)	--	--	1.04E+08
Trout_07	Trout Brook	--	--	9.39E+07
Trout_12	Vermillion River (Empire)	--	--	9.00E+07
Riv_041	Crow River (Watertown, Delano)	--	--	8.60E+07
Bio_026	Rice Lake Natural Area	--	--	8.50E+07
T119_R21	Township 119 Range 21	--	--	8.19E+07
Bio_038	Chub Lake South	--	--	8.06E+07
Vul_066	Bryant Lake	--	--	7.91E+07
T28_R24	Township 28 Range 24	--	--	7.70E+07
Bio_031	Sedil East	--	--	7.61E+07
Bio_009	Mud Hen Lake Area	--	--	7.44E+07
Riv_113	Elm Creek (Maple Grove, Champlin, Dayton)	--	--	7.42E+07
T119_R22	Township 119 Range 22	--	--	7.40E+07
T32_R23	Township 32 Range 23	--	--	7.29E+07
T114_R16	Township 114 Range 16	--	--	6.85E+07
T31_R22	Township 31 Range 22	--	--	6.78E+07
Trout_11	Vermillion River (Farmington, Empire Twp)	--	--	6.76E+07
T32_R25	Township 32 Range 25	--	--	6.69E+07
Vul_005	Coon Lake	--	--	6.65E+07
T117_R24	Township 117 Range 24	--	--	6.53E+07
Bio_068	Linwood 5 Natural Area	--	--	5.99E+07
Vul_004	Byllesby Lake	--	--	5.63E+07
T28_R20	Township 28 Range 20	--	--	5.57E+07
Vul_016	George Lake	--	--	5.33E+07
T34_R23	Township 34 Range 23	--	--	5.29E+07
CM207_296	Mt. Simon Hinckley	207	296	5.07E+07
T29_R24	Township 29 Range 24	--	--	4.71E+07
Vul_064	Centerville Lake	--	--	4.62E+07
Vul_035	Medicine Lake	--	--	4.48E+07
Bio_002	Ninninger West	--	--	4.35E+07
Vul_065	Ham Lake	--	--	4.31E+07
Riv_011	Mississippi River (Champlin, Coon Rapids, Brooklyn Park)	--	--	4.22E+07
T115_R21	Township 115 Range 21	--	--	4.11E+07
Riv_148	S. Branch Vermillion River (Castle Rock Twp.)	--	--	4.10E+07
T113_R19	Township 113 Range 19	--	--	3.88E+07
Trout_13	S. Branch Vermillion R. (Castle Rock Twp, Empire Twp., Vermillion Twp.)	--	--	3.88E+07
T120_R23	Township 120 Range 23	--	--	3.82E+07
T31_R20	Township 31 Range 20	--	--	3.74E+07
CM296_141	Mt. Simon Hinckley	296	141	3.48E+07
Vul_058	Gervais Lake	--	--	3.42E+07
Bio_007	St. Lawrence 13	--	--	3.32E+07
Trout_09	Vermillion River (Eureka Twp.)	--	--	3.29E+07
Riv_115	Rice Creek (Mounds View, Arden Hills, Shoreview)	--	--	3.26E+07
CM219_107	Mt. Simon Hinckley	219	107	3.19E+07
Bio_074	Conley Lake Backwaters	--	--	3.17E+07
Vul_003	Turtle Lake	--	--	3.13E+07
Bio_078	North Ninninger 34	--	--	3.12E+07
Trout_10	Vermillion River (Lakeville, Farmington)	--	--	3.07E+07

Table A-1
Binding Constraints and Shadow Price

Constraint Name	Description	Row	Col	Absolute Shadow Price
Vul_089	Bone Lake	--	--	3.06E+07
T31_R23	Township 31 Range 23	--	--	3.02E+07
Vul_047	White Bear Lake	--	--	2.94E+07
Vul_001	DeMontreville Lake	--	--	2.92E+07
Bio_015	Nine Mile Creek	--	--	2.85E+07
T114_R20	Township 114 Range 20	--	--	2.83E+07
CM232_143	Mt. Simon Hinckley	232	143	2.73E+07
T115_R22	Township 115 Range 22	--	--	2.72E+07
GWSW1	Gun Club Lake South	--	--	2.67E+07
Riv_126	Purgatory Creek	--	--	2.62E+07
Trout_01	Assumption Creek	--	--	2.60E+07
CM217_218	Mt. Simon Hinckley	127	218	2.60E+07
T118_R21	Township 118 Range 21	--	--	2.56E+07
Riv_132	Unnamed (Burnsville)	--	--	2.48E+07
T117_R23	Township 117 Range 23	--	--	2.40E+07
Riv_097	Carver Creek	--	--	2.30E+07
Bio_099	Empire 15	--	--	2.25E+07
Riv_150	Vermillion River (Vermillion)	--	--	2.23E+07
Vul_062	Hannan Lake	--	--	2.12E+07
T29_R22	Township 9 Range 22	--	--	2.12E+07
Bio_066	East Rosemount 18	--	--	2.11E+07
Trout_06	Pine Creek	--	--	2.03E+07
T27_R22	Township 27 Range 22	--	--	1.88E+07
Riv_118	Basset Creek (Plymouth, Golden Valley)	--	--	1.85E+07
CM260_116	Mt. Simon Hinckley	260	116	1.80E+07
T119_R24	Township 119 Range 24	--	--	1.77E+07
Vul_050	Upper Prior Lake	--	--	1.72E+07
Vul_049	Unnamed (Cottage Grove)	--	--	1.69E+07
Vul_009	Long Lake	--	--	1.68E+07
Bio_019	Dean's Lake	--	--	1.64E+07
T32_R24	Township 32 Range 24	--	--	1.61E+07
Vul_021	Big Marine Lake	--	--	1.57E+07
T114_R18	Township 114 Range 18	--	--	1.53E+07
T115_R17	Township 115 Range 17	--	--	1.51E+07
CM264_254	Mt. Simon Hinckley	264	254	1.34E+07
T116_R22	Township 116 Range 22	--	--	1.19E+07
Riv_124	Nine Mile Creek	--	--	1.19E+07
Riv_100	Sand Creek (Jordan)	--	--	1.09E+07
T114_R19	Township 114 Range 19	--	--	1.09E+07
CM159_255	Mt. Simon Hinckley	159	255	1.07E+07
Bio_097	Camp Hduhapi	--	--	1.05E+07
Riv_146	Unnamed (Empire Twp.)	--	--	9.37E+06
CM257_178	Mt. Simon Hinckley	257	178	8.48E+06
Bio_060	Pigs Eye SNA	--	--	8.25E+06
GWSW4	Savage Fen	--	--	7.92E+06
T120_R21	Township 120 Range 21	--	--	7.80E+06
T112_R17	Township 112 Range 17	--	--	7.23E+06
Bio_091	Belwin Gravel Pit	--	--	6.81E+06
Riv_102	Credit River (Credit River Twp, Savage)	--	--	6.14E+06
Vul_039	Minnewashta Lake	--	--	6.03E+06
T30_R22	Township 30 Range 22	--	--	5.85E+06
T31_R21	Township 31 Range 21	--	--	5.53E+06
Vul_014	Lake Waconia	--	--	5.33E+06
T113_R21	Township 113 Range 21	--	--	5.08E+06
OP325_247	Praire du Chein Group	--	--	4.82E+06
CM177_237	Mt. Simon Hinckley	177	237	4.59E+06
CM168_195	Mt. Simon Hinckley	168	195	4.55E+06
T112_R20	Township 112 Range 20	--	--	4.42E+06
OP257_186	Praire du Chein Group	--	--	4.21E+06
Bio_058	Black Dog Lake area	--	--	4.16E+06
CM313_170	Mt. Simon Hinckley	313	170	4.05E+06
Vul_029	Olsen Lake	--	--	3.92E+06
T27_R24	Township 27 Range 24	--	--	2.98E+06
CM222_155	Mt. Simon Hinckley	222	155	2.96E+06
Bio_107	Grey Cloud Dunes East	--	--	2.78E+06
T31_R24	Township 31 Range 24	--	--	2.78E+06
Riv_127	Riley Creek (Chanhassen, Eden Prairie)	--	--	2.60E+06
Vul_025	Lotus Lake	--	--	2.56E+06
Bio_087	Wilder Forest	--	--	2.46E+06
CM178_198	Mt. Simon Hinckley	178	198	2.35E+06

Table A-1
Binding Constraints and Shadow Price

Constraint Name	Description	Row	Col	Absolute Shadow Price
Riv_131	Unnamed (Eagan)	--	--	2.23E+06
Vul_028	Dutch Lake	--	--	1.92E+06
Vul_008	Lake Elmo	--	--	1.81E+06
Bio_076	Savage Fen, Credit River	--	--	1.75E+06
CM191_219	Mt. Simon Hinckley	191	219	1.44E+06
CJ269_278	Jordan Sandstone	269	278	1.16E+06
Vul_088	Weaver Lake	--	--	8.04E+05
CJ203_291	Jordan Sandstone	203	291	7.44E+05
Vul_011	Smetana Lake	--	--	7.12E+05
Vul_078	Pleasant Lake	--	--	6.14E+05
Vul_027	Murphy Lake	--	--	5.92E+05
CT293_146	Tunnel City	293	146	4.41E+05
Bio_072	Grey Cloud Dunes West	--	--	4.35E+05
CT159_180	Tunnel City	159	180	3.57E+05
OP236_263	Praire du Chein Group	236	263	2.94E+05
CJ205_289	Jordan Sandstone	205	289	2.87E+05
CJ246_287	Jordan Sandstone	246	287	2.82E+05
CT147_194	Tunnel City	147	194	2.74E+05
CJ270_281	Jordan Sandstone	270	281	2.70E+05
T116_R24	Township 116 Range 24	--	--	2.52E+05
CT164_175	Tunnel City	164	175	2.05E+05
FlowDir3	TCAAP Plume (St Anthony, Minneapolis)	--	--	165000.00
FlowDir2	TCAAP Plume (New Brighton)	--	--	145000.00
CJ300_293	Jordan Sandstone	300	293	1.26E+05
CJ302_293	Jordan Sandstone	302	293	9.49E+04
OP258_213	Praire du Chein Group	258	213	9.02E+04
CJ264_254	Jordan Sandstone	264	254	7.80E+04
CT172_203	Tunnel City	172	203	7.27E+04
OP257_205	Praire du Chein Group	257	205	6.08E+04
OP241_280	Praire du Chein Group	241	280	6.04E+04
OP257_206	Praire du Chein Group	257	206	5.96E+04
OP297_248	Praire du Chein Group	297	245	4.33E+04
OP269_233	Praire du Chein Group	269	233	3.57E+04
CT185_206	Tunnel City	185	206	3.13E+04
CJ298_292	Jordan Sandstone	298	292	2.09E+04
CT186_207	Tunnel City	186	207	1.88E+04
Riv_114	Rice Creek (Fridley)	--	--	1.41E+04
CJ230_270	Jordan Sandstone	230	270	1.20E+04
CT260_197	Tunnel City	260	197	9.75E+03
CT174_199	Tunnel City	174	199	7.56E+03
OP271_228	Praire du Chein Group	271	228	6.83E+03
FlowDir7	St. Paul Park Refinery	--	--	6450.00
CT279_287	Tunnel City	279	287	3.31E+03
CT186_206	Tunnel City	186	206	2.53E+03

Color Key

Trout streams baseflow constraint
Non-trout streams baselfow constraint
Groundwater dependent features hydraulic head constraint (calcerous fens)
Flow direction constraint
Mt. Simon-Hinckley aquifer change in hydraulic head constraint
Safe yield for confined bedrock aquifers constraint
Surface water flux constraint (Township and Range groups)
Vulnerable surface water features with wide litoral zone constraint
Sites of high biodiversity constraint

Table A-2

Summary of Binding Constraints by Constraint Type

Group	Sum Total Shadow Price	Percent Total Shadow Price	Number of Constraints with Shadow Price	Average Shadow Price	Rank of Average Shadow Price
Township Range	2.47E+09	33.66%	45	5.49E+07	3
Stream/River	2.39E+09	32.48%	28	8.52E+07	1
Vulnerable Surface Water Basin	9.32E+08	12.69%	29	3.21E+07	5
Biodiversity Area	7.52E+08	10.24%	22	3.42E+07	4
Trout Stream	5.13E+08	6.99%	9	5.70E+07	2
Mt. Simon Hinckley Hydraulic Head	2.41E+08	3.28%	15	1.61E+07	7
Groundwater Dependent Feature (Fen)	3.46E+07	0.47%	2	1.73E+07	6
Safe Yield for Confined Bedrock Aquifer	1.42E+07	0.19%	31	4.57E+05	8
Flow Direction	3.16E+05	0.00%	3	1.05E+05	9

Appendix 5: Community Highlights

Saint Paul

Rainwater Harvesting at CHS Field

CHS Field is a regional ballpark in the heart of the Lowertown neighborhood of Saint Paul, Minnesota just a few hundred feet from America's greatest river. CHS Field is home to the Saint Paul Saints minor league baseball team. The ballpark has a capacity of 7,000 spectators, will host approximately 400,000 visitors annually and will be used for a both sporting and non-sporting events.

With population on the rise, Minnesota's groundwater supplies continue to decline and stormwater runoff pollutes local lakes and the Mississippi River. Ballparks require large amounts of water for irrigation, drinking and other operational activities. To reduce consumption of potable water as well as the amount of polluted runoff flowing to the Mississippi River, the City of Saint Paul, Saint Paul Saints, Metropolitan Council and Capitol Region Watershed District collaborated to collect and store rainwater and use it for irrigation and other uses at CHS Field. Why do this? Because even in the Land of 10,000 Lakes, water is a resource we can't afford to take for granted.

Project implementation

Partnerships

This reuse project was part of the original plan and budget for the ball park, but several partners worked together to provide funding and technical support for the project: City of St. Paul, Capital Region Watershed District, Metropolitan Council, and the St. Paul Saints.

Finding a potential water source

Rooftops provide a great opportunity to collect rainwater because the water flowing off roofs is relatively clean compared to streets or parking lots. CHS Field doesn't have a lot of roof cover, but the Metropolitan Council offered the roof area of the Green Line light rail Operations and Maintenance Facility (OMF) located next door. A pipe installed between the properties allows rainwater to flow from roughly ¾-acre portion of the OMF roof to a 27,000- gallon steel cistern tank below the ballpark concourse near center field.

Treating water to ensure it is safe to use

Harvested rainwater at CHS Field is used to irrigate the ball field and flush toilets. Before it can be used for those purposes, water is treated to ensure it is safe. A vortex filter removes large particles such as leaves and sediment (or baseballs!) from the water before it goes to the cistern. From there, a pump pulls water from the cistern and sends it through two filters that remove smaller particles. Finally, UV light is used to disinfect the water before it is sent to the irrigation system or toilets.

Using the water

Irrigation

The harvested rainwater is used to irrigate the main playing field, which includes two acres of sod. The area is watered by 115 irrigation heads and 7,000 feet of irrigation pipe.

Toilet flushing

The public toilets located behind center field include nine water closets and four urinals which are serviced by water from the cistern. The remaining 127 public toilets are located too far away to be served by the cistern, but all toilets in the park include water-saving fixtures.

Challenges

Plumbing Code

The success of the project required obtaining approval from the plumbing inspector for rainwater reuse inside the building (toilets).

The rainwater harvesting design was reviewed and approved locally under Minnesota Plumbing Code Rule 4715.0330 *"Alternative Fixtures, Appurtenances, Materials, and Methods."* Criteria within Uniform Plumbing Code Chapter 17 (*"Non-Potable Rainwater Catchment Systems"*) were used to support the review and approval. Water quality treatment standards were derived from NSF/ANSI 350 for onsite residential and commercial water reuse treatment systems.

Property owner cooperation during construction

The success of the project required construction of rainwater conveyance piping inside an active rail facility (the Metro Transit Green Line Operations and Maintenance Facility), followed by construction of a cistern and conveyance piping at the ball park. Close coordination between property owners and partners ensured the success of the project.

Maximizing the amount of water storage in a minimum amount of space

Project Benefits

- Annual potable water reduction estimated at 450,000 gallons
- Annual cost savings of more than $1,600

What may help other communities?

Partnerships and incentives

- The Metropolitan Council granted $100,000 to the City for the rainwater harvesting system Capitol Region Watershed District granted $246,500 to the City for the rainwater harvesting system
- The Metropolitan Council funded the OMF rainwater conveyance retrofit ($82,800)
- Metropolitan Council funds are from the Clean Water Land and Legacy Amendment

Lessons learned

- Take officials on tours of similar projects to help them feel comfortable about supporting innovative stormwater reuse projects
- Pay close attention to the roof; are there HVAC units that have condensate that should be piped away from the rainwater harvesting area?
- Work closely with MDH to determine the appropriate level of water treatment

Awards and Recognition

- 2015 Clean Water Champion Award from the Freshwater Society

Contact the Project Partners

- Brian Davis, Senior Engineer, Metropolitan Council, (651) 602-1519

Savage & Burnsville

Water Supply Partnership

For the past 6 years the Cities of Savage and Burnsville have worked together to utilize quarry water that was previously discarded to the Minnesota River as part of mining operations at the Kraemer Quarry in Burnsville. Annually, via a water use agreement, Burnsville provides more than 600 million gallons of potable water to Savage, which accounts for about 79% of their annual demand. The partnership has reduced groundwater pumping between the Cities of Savage and Burnsville by 1.1 to 1.2 billion gallons per year. This reduction in pumping has resulted in rebounding water levels in the Jordan Aquifer since the project came on-line in 2009. The $14 million project included construction of a quarry surface water intake, supply watermains and water treatment plant addition and upgrades.

Project implementation

Prior to construction agreements and funding between Burnsville and the City of Savage, State of Minnesota and Kraemer Mining and Materials were required. As lead agency, Burnsville constructed the surface water intake which consists of two pumping stations along with connecting water system infrastructure to convey water to the existing water treatment plant. An addition was made to the plant to allow for treatment of this water. Additional improvements to enhance water aesthetics made by Burnsville after completion of the initial project included a Granular Activated Carbon building, surface water drainage improvements and baffling improvements to the finished water reservoir.

The project has been operating for 6 years and annually provides 1.1 to 1.2 billion gallons of potable water. This water supplements the 2 billion gallons of ground water pumped by the City.

Challenges

The primary challenges once operations began were related to the aesthetics of the new water supply. The new mixed supply was harder and had a different taste and odor. Savage and Burnsville staffs worked together on several collaborative solutions to solve these issues. Communication, patience and cooperation were key in solving these issues. The water quality complaints related to the initial issues have virtually been eliminated in both communities.

Project Benefits

- Reuse of 1.1 billion gallons of water annually
- Reduction of 1.1 billion gallons of groundwater pumping and rebounding water levels in the Jordan Aquifer
- Viable/sustainable long term source of water for the communities

What may help other communities?

It can be done if communities are willing to work together, trust each other and collaborate. However, this type of partnership and success can’t occur without state and agency help.

Partnerships and incentives

This project would not have been possible without collaboration of Kraemer Mining and Materials, State of Minnesota, MDH, DNR and Cities of Savage and Burnsville. Below is the cost participation in the project:

- State of Minnesota: $5.5 Million
- Kraemer Mining and Materials: $3.0 Million
- City of Savage: $2.0 Million
- City of Burnsville: $3.5 Million
- Total SWTP Capital Cost: $14.0 million

Community commitment to sustainability, water supply security, and collaboration

The potable use of 1.1 billion gallons of previously discarded quarry water has resulted in rebounding water levels in the Jordan Aquifer locally, and will help ensure sustainability of the water supply for Savage and Burnsville.

Lessons Learned

- Mixing of surface and groundwater is complicated and upfront investment in pilot results will reduce issues
- Understand potential operational issues of connected system, such as impacts to chlorine levels
- Proactive education of Public, Council and City Staff on issues such as:
  - Potential changes in water aesthetics (taste, odor and hardness etc.)
  - Water is “safe” exceeds all standards

Awards and Recognitions

- 2009 City Engineers of Minnesota Project of the Year – Honorable Mention
- 2009 Environmental Initiative Award
- 2009 National League of Cities Silver Award for Municipal Excellence
- 2010 Finance and Commerce Top Project Award
- 2010 Minnesota Society of Professional Engineers Merit Award
- 2010 American Council of Engineering Companies Grand Award
- 2010 American Council of Engineering Companies National Recognition Award

Contact the Community

Steve Albrecht
City of Burnsville
952-895-4544
steve.albrecht@burnsvillemn.gov