WATER AVAILABILITY, ACCESS, AND USE

AUTHORED BY:

DANIEL HENELY
GREG JOHNSON
JENNIFER KOSTRZEWSKI
EMILY RESSEGER
LANYA ROSS
JUDY SVENTEK

March 30, 2023

Table of Contents

Table of Figures

Table of Tables

Acronyms and abbreviations

BWSR – Minnesota Board of Water and Soil Resources

CAP – Metropolitan Council's Climate Action Plan

DNR – Minnesota Department of Natural Resources

DWSMA – Drinking Water Supply Management Area

EI – Environmental Initiative

EPA – Environmental Protection Agency

LWSP – Local Water Supply Plan

MDA – Minnesota Department of Agriculture

MDH – Minnesota Department of Health

MGD – million gallons per day

MPCA – Minnesota Pollution Control Agency

MWSP – Metropolitan Council's Master Water Supply Plan

NPR – National Public Radio

RDG – Metropolitan Council's Regional Development Guide

SSTS - subsurface sewage treatment systems

SWPA – source water protection area

UMN – University of Minnesota

UMRSWPP – Upper Mississippi River Source Water Protection Project

WHO – World Health Organization

WHPA – wellhead protection area

WHPP – Wellhead Protection Plan

WRPP – Metropolitan Council's Water Resources Policy Plan

Policy research approach

The Metropolitan Council (Met Council) is charged by state statute to develop plans for orderly and economical growth of the seven-county Twin Cities metropolitan region (metro region). Publications like the metropolitan development guide (**Thrive MSP 2040**) and associated system plans, including the **Water Resources Policy Plan**, are the primary vehicle for us to share our vision and goals for the region. They are updated every ten years but have a twenty-five-year planning horizon to allow for long-term development of the region. Each iteration of regional planning builds upon the previous effort while adjusting our actions, policies, and vision to address current issues, mitigate future risks, and optimize regional opportunities.

The 2050 Water Resources Policy Plan, like the 2040 plan before it, will be an integrated plan that supports our core mission to operate and manage the regional wastewater system, provide water supply planning, and provide surface water planning and management throughout the region. It will serve as our guide to address issues affecting our waters and to protect these resources for future generations.

This research paper is part of a series investigating current and future water concerns for the metro region. Together, these papers will inform our 2050 Water Resources Policy Plan. The paper topics are:

- Protecting source water areas
- Rural water concerns
- Water and climate
- Water availability, access, and use
- Water reuse
- Water quality
- Wastewater concerns

The project's intent is to share our current understanding of issues, identify current policy connections or gaps, and propose future policies and strategies to ensure sustainable water resources. Not all the recommendations included in the papers will move forward for inclusion into the Water Resources Policy Plan, and conversely, the Water Resources Policy Plan may include policies not discussed in these papers. The intent is to begin to develop a shared understanding and conversation about topics that are connected to all aspects of our core services.

Research paper topics were investigated using three core principles:

- **One Water, integrated water management:** The metro region is water-rich, and that water holds immense value. Integrated water management, also known as "One Water," addresses water as it moves from water supply, through wastewater systems, and into surface waters. The ultimate goal of integrated water management is sustainable, high-quality water in the region.
- **Use existing systems:** The metro region has a robust water planning and wastewater operations system with many actors – community water and wastewater utilities, watershed management organizations, and regional, county, state, and federal agencies. Coordination and collaboration between these groups is necessary to protect our water for future generations.

- **Metric-based policies:** It is hard to quantify policy success without accountability. We will provide policy options with associated metrics and measurable outcomes, where possible, to demonstrate the effectiveness of our water policies and actions.

Introduction and background

Water resource sustainability is dependent on many facets, the most important of which are water availability, access, and use. All three components must be present to have functioning water systems that accommodate water uses for a variety of purposes.

- **Water availability** is a culmination of water balance (where water demand for current and future human purposes does not significantly harm ecosystems) and water quality (where water chemistry does not preclude it for use).
- **Water access** is the ability of water to be reached or obtained physically– from clean, running water in faucets to recreational opportunities on a river, lake, or stream to water near plant and animal communities in order to sustain life. It is of little consequence if the water is available if no one can access it.
- **Water use** incorporates both direct (bathing, drinking, cooking) and indirect purposes (recreation, industrial processes). Often both water availability and access determine an individual's ability to use the water in an intended manner.

Water must be available, accessible, and usable for our water to truly be sustainable.

Water sustainability is influenced by human and ecosystem demands, equitable apportionment of water among uses, and stress to the water sources. A sustainable water cycle is one where water inputs and outputs are balanced and the needs of the environment and people are met, allowing ecosystems and the built environment to function harmoniously. The issue of water sustainability is one that many communities, public water suppliers, and national and international agencies are tackling. This is due to the many threats that people and ecosystems are currently facing from factors like population growth, land use changes, maintaining and restoring aging infrastructure, public funding, and climate change impacts.

Water is a finite resource that naturally functions as a cohesive and connected cycle. It is constantly moving around the Earth between the atmosphere, oceans, rivers, streams, snowpacks, ice sheets, and underground. However, the societal values and structural systems that have been implemented over the last few centuries have made it challenging for people to recognize the interconnectedness of water and the impact they have on the water system. Furthermore, it is difficult to understand that water is a finite resource when people cannot see what is available in underground aquifers. It is also difficult for us to understand how water dissolves or mobilizes minerals, metals, and other chemicals as it moves across the land. Over time, we have established a relationship with water where it is extracted, used, and then discharged as a waste product.

While the state of Minnesota is considered water-rich, this perception has resulted in many issues in stewardship and conservation. An imbalance in the water cycle from mismanagement has degraded the quality and quantity of the groundwater and surface waters, leading to public health, economic, social, and environmental challenges. As we come to understand the impacts from mismanagement of water, we recognize that to solve these water challenges is to view water in all of its forms as an essential resource. Managing water as a finite resource and ensuring long-term resilience and reliability to meet both community and ecosystem needs requires an understanding of how water is being used throughout the seven-county metro region. Therefore, it is important to characterize the entire water cycle – in both natural and built environments - to understand how we are using and impacting the water while considering how we can be more sustainable in making sure it will be available to future generations.

Today, nearly three million residents and numerous businesses and industries exist within the metro region, all using water in different ways for different purposes. However, water continues to move through and between communities across the surface, in the ground, and through the built environment as it is used. As shown in **Figure 1**, the water cycle has been altered in many ways. Water is drawn from numerous sources, traveling through water distribution systems, into homes, farms, businesses, industrial plants, and other locations before ultimately being treated and discharged back into the cycle for use again.

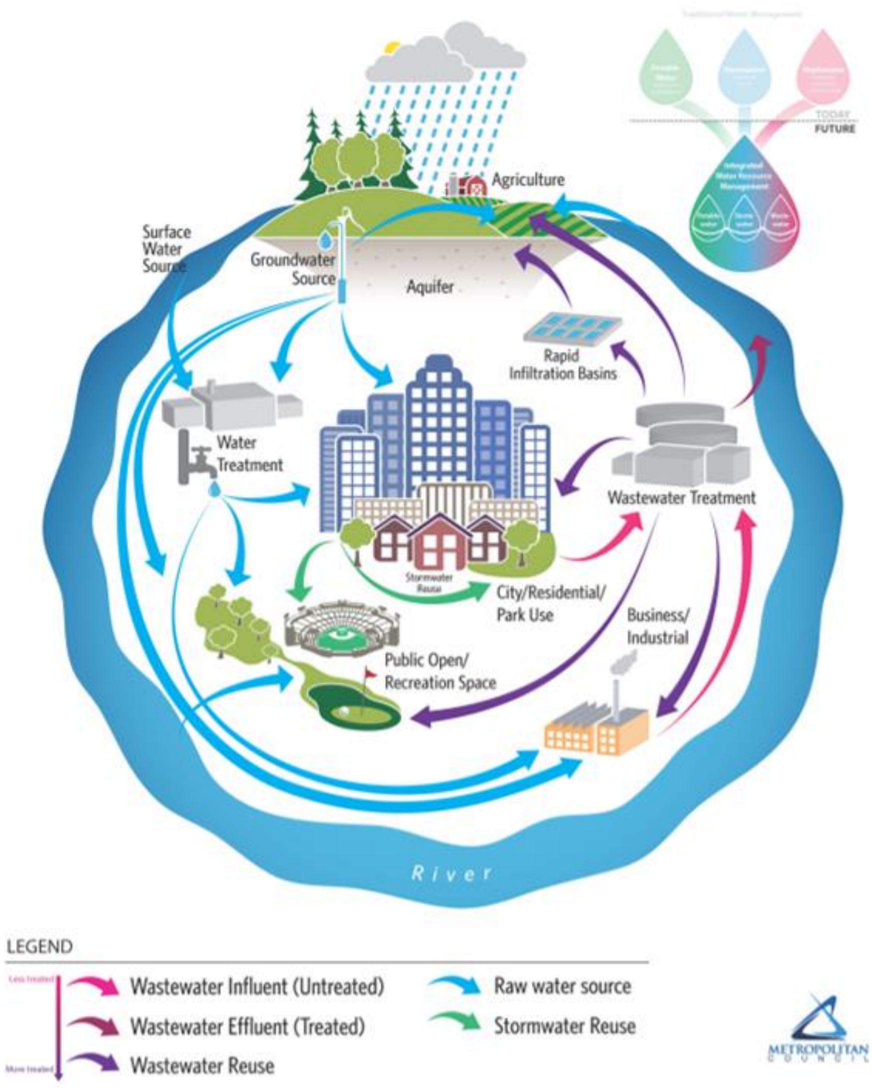


Figure 1: The water cycle (Source: Metropolitan Council)

Figure 2 presents a simplified version of Figure 1 as a feedback cycle. This process is quite easy to follow in a naturally occurring hydrological cycle. However, as our landscape changes and the

number of uses grows, this cycle becomes more and more complex. As alterations are made to the water system, other changes can manifest. These long-term impacts show up in many ways and are often challenging to detect until they have caused significant harm to the water system.

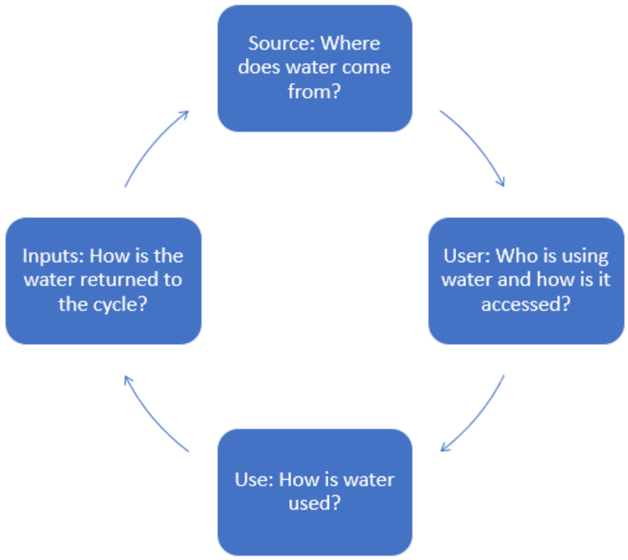
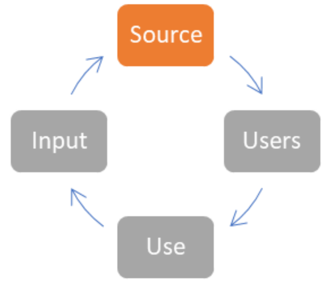


Figure 2: A simple water cycle feedback loop

In the feedback loop above, the inflows are characterized by the quantity of water moving from inputs to the source, and the outflows are characterized by the quantity of water moving from the source to the user. The use of the source drives the quantity and quality of the water necessary to support the user, and public policies and regulations drive the level of treatment and level of water conservation needed to support the water system's long-term health.

In this paper, we attempt to identify how the water cycle of water sources, users, uses, and inputs inform our concept of regional water availability, access, and use. We will be revisiting this water cycle throughout the paper to ground our discussion of crucial concerns and recommendations. It is applicable across various water sectors (water supply, wastewater treatment, water resources management) and can help identify policy opportunities and challenges. We acknowledge that this paper contains many examples from the water utility perspective and not as many from water resources management. This is a framework and policy area that we will continue to strengthen in the coming years to better understand how to ensure sustainable water now and for future generations.

Source – Where does our water come from?



By characterizing the sources of water needed for today's users, we can evaluate if water quality supports the uses or if water management changes are needed to sustain these resources over time. Recognizing that water is a finite resource and that all water has value, it is important to take a holistic view in characterizing the sources of water. To this well as describing how precipitation and stormwater runoff contribute to sustaining the quantity and quality of these resources.

In the metro region, water is currently accessed from three primary sources:

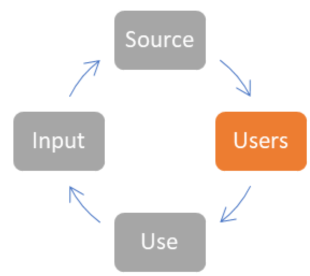
- **Groundwater:** In our region, groundwater is stored in aquifers which lie beneath the land surface. While water is easily withdrawn from these aquifers, it takes a very long time to replenish the aquifers. This source of water is finite in the sense that once the water is withdrawn, the resource will be depleted.
- **Surface water:** Our region has many surface waters, which includes rivers, lakes, streams, and wetlands. These waters range in size and quality and are connected with one another through both natural and man-made conveyance systems. Many of these resources are accessed via the regional parks and trails system. With 56 regional parks and park reserves totaling more than 54,000 acres, nearly 400 miles of interconnected trails, and 8 special recreation features, the system provides a wealth of opportunities for recreation, exercise, gatherings, and solitude.
- **Precipitation and stormwater:** This source of water is the most unpredictable. When it falls as precipitation, it infiltrates into the ground until the ground becomes saturated, at which point it runs off the landscape and flows to storm sewers, drainage ditches, and surface waters. When it snows, it accumulates on the landscape until the outside temperatures rise above freezing, causing snowmelt. The water that runs off the landscape after a rain event or during snowmelt is commonly referred to as stormwater runoff, which collects and transports pollutants from the landscape.

The amount of groundwater that can be sustainably withdrawn from groundwater sources 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 is the ultimate source of water to the groundwater system. Using recharge estimates by the U.S. Geological Survey and Minnesota Pollution Control Agency, the Met Council forecasts 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 (Met 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 the approximate limit (as an estimated range) on how much groundwater can be pumped without causing unacceptable conditions. 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. Results suggest that the region might sustainably withdraw approximately 400 to 500 million gallons of groundwater per day in areas where high-capacity wells currently exist. 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 region's most visible water supply source is its surface water, and the Mississippi River is the region's largest source of surface water. 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.[1] Frequent discussion of these limits resulted from 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 indicates 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).

Users – Who is using our water and how are they accessing it?



Characterizing how water is moving from its source and traveling across the metro region to reach its end user is critical in understanding the water balance. It reveals who depends on the availability of water, which sources of water they depend on, and which infrastructure they depend on to access the water. It also provides insight on how these different users may view the availability of water differently. This section describes the different types of users that exist within the region and the different ways these users are accessing the water.

The metro region is a diverse landscape, full of many different communities across the urban-rural spectrum. Here, a network of people, plants, and wildlife connects through waterways, natural areas, trails, and transportation corridors in the agricultural, suburban, and urban landscapes that comprise the metro region (**Figure 3**).

As human societies have grown in this region, so have the many uses for water. It is now transported across the landscape through a system of humanmade channels, including watermains, ditches, and stormwater infrastructure, and ends up in public facilities, households, businesses, farms, and industrial plants. The different users of water have driven the layout of water distribution systems, as well as how water is managed to support conservation and stewardship.

The users of water in the metro region can be broken down into four primary categories (Error! Reference source not found.), many of which are interconnected. The perceived priority of these users influences where water goes, the level of treatment it must have, and the quantity that can be taken by that user.

[1] 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).

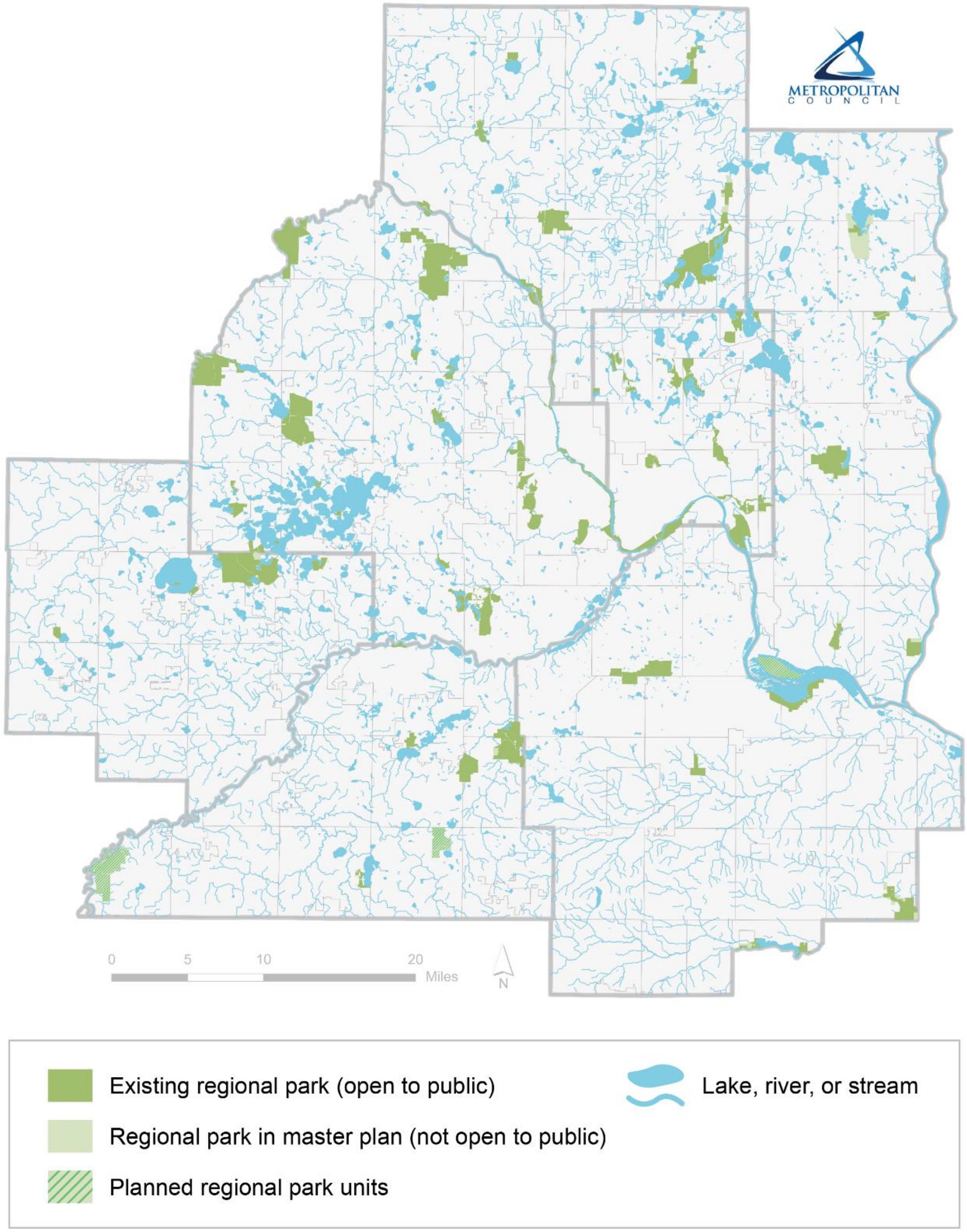


Figure 3: Regional parks system

Table 1: Descriptions of water users and uses

User type	Examples of who is using the water	How are they accessing it?	How are they using it? (primary uses)
Plants, animals, and ecosystems	Plants, animals, and ecosystems	• Absorbing/drinking precipitation directly • Absorbing/drinking surface water directly (including surface waters that receive groundwater) • Burrowing into or absorbing shallow groundwater	• Habitat • Food • Movement/migration
	Pets and livestock	Groundwater or surface water through private wells/intakes or public water infrastructure to households	
Residents*	People living in households situated near or adjacent to a water source – for aesthetics, etc.	Surface water at the source	• Food • Recreation • Transportation • Spiritual, physical, and mental well-being
	People who travel to a water source – for recreation, subsistence, etc.		
	People who collect or use water as precipitation – for watering vegetable gardens, etc.	Precipitation at the source	• Food • Irrigation
	People living in households supplied by municipal water treatment plants	Groundwater or surface water through public water infrastructure to households	• Irrigation • Food • Sanitation • Spiritual, physical, and mental well-being
	Unhoused people who depend on public water facilities for their source of water	Groundwater or surface water through public water infrastructure to public facilities	
	People living in households supplied by private wells	Groundwater via wells	
Governmental, business, institutional, or industrial users*	Entities who collect or use precipitation for stormwater reuse, irrigation, etc.	Precipitation at the source / stormwater infrastructure	• Other purposes (e.g., irrigating landscapes) • Treatment and distribution (e.g., stormwater management)
	Public entities who own and operate public facilities, such as buildings, toilets, and water stations.	Groundwater or surface water through wells or public water infrastructure to public facilities from the municipal water plant or well	• Treatment and distribution • Living • Sanitation • Irrigation
	Regional businesses, industries, agricultural operations	Groundwater or surface water through wells, private water treatment plants, or public water infrastructure to private facilities from a municipal water plant	• Food • Sanitation • Irrigation • Industrial and commercial processes (both consumptive and pass through • Other purposes (e.g., energy crops)
Plants, animals, ecosystems, and human residents, and public and private entities outside of the region	Plants, animals, and ecosystem in downstream drainage areas of the metro region.	Surface waters at the source	• Living • Food • Transportation
	Households and public and private entities in downstream drainage areas of the metro region	Groundwater or surface water through wells and public water infrastructure to households, public entities, and private facilities from a municipal water treatment plant or wells	• Living • Food • Sanitation • Irrigation • Spiritual, physical, and mental well-being

** Note: DNR appropriation permits cover wells that pump greater than 10,000 gallons per day or greater than 1,000,000 gallons per year. Residential users generally fall below that level. Municipal water supplies, golf courses, and other irrigators are generally above that. Industries and restaurants are a mix.*

Plants, animals, ecosystems

All plants and animals need water to survive. Plants require water to grow, metabolize nutrients, and photosynthesize carbon dioxide into oxygen. Animals use water for habitat, hydration, and the digestion of food. Some plant and animal species and ecosystems across the metro region are more vulnerable than others due to their dependency on certain environmental conditions. For example, groundwater dependent natural resources rely on the source of cold, mineral rich water from the ground. If these connections are cut off, these fragile ecosystems and their dependents are likely to lose their source of life.

Residents

According to the 2020 Census, the seven-county metro region is currently home to over three million residents spread across urban, suburban, and rural landscapes. The majority of water used by residents comes from public water systems that treat water so that it meets drinking water standards before it is distributed to its end users. Water supply in the metropolitan region is not a unified system, but comprised of 105 municipal utilities working independently and sometimes together to provide water to the region (Metropolitan Council 2020a). These utilities include infrastructure that withdraws water from aquifers or the Mississippi River, treats it at water treatment facilities, and then distributes it via watermains and pump stations to residents and businesses. This infrastructure represents thousands of assets at varying stages of their lifespan.

Furthermore, there are approximately 60,000 private domestic wells, with less than 10% of the region's population drawing their drinking water from these wells (Metropolitan Council, 2015a). We estimate that residential wells use an average of 75 gallons per person per day, which is approximately 16 million gallons per day (Metropolitan Council 2015b).

The number of households that have private wells and the number of households that are connected to a municipal water plant distribution system are well documented. However, populations using public water supplies as a means for their water (e.g., unhoused residents) are not well understood. This is something that needs to be investigated in more detail. Additionally, residents throughout the region sometimes collect water in rain barrels, lowering their water usage rates for irrigating lawns and gardens. The amount of precipitation that is being collected and used by residents could be better understood to determine their dependency on this source of water.

Business, institutional, and industrial users

The private entities in the metro region include non-residential entities/users that draw water from the municipal water supply system or have private wells. On average, businesses, institutions, and industries in the metro region use about 25-30% of municipal water supplies. However, 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 is consumed by commercial, industrial, and institutional customers. Others, such as Birchwood Village and Centerville, reported very little commercial or other nonresidential water use. Similarly, industrial water demand varies greatly. In some communities such as South St. Paul, almost a third of the municipal water supply is used by industrial customers. In others, none. (Metropolitan Council 2015b).

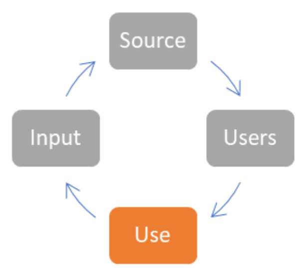
In addition to public water supply, many private entities use water supplied by private wells. Approximately 5,000 private wells serve businesses and organizations. Private industrial water use is distributed among approximately 190 permittees (Metropolitan Council, 2015a). Additionally, over 400 permittees across the region use water for major crop production. While agricultural water use is not as high as municipal water use, summer seasonal use is very high, particularly in rural areas with sandy soils such as in Dakota County (Metropolitan Council 2015b).

Users downstream of the Twin Cities metro region

The availability, access, and use of water in the region impacts the availability of water for residents outside of the metro region. First and foremost, this is the result of topography and drainage patterns (e.g., watershed boundaries). As water is removed, used, and returned to the hydrologic system, the quality and quantity of water available for plants, animals, ecosystems, humans, and businesses in downstream communities is impacted. For example, as water is taken from the Mississippi River for drinking water supplies and water is returned to the river via outfalls where treated wastewater effluent is returned to the river, the quality and quantity of water available is significantly different from when it entered the metro region. This impacts who can use the water and the level of treatment that is needed to meet its intended use. Watershed districts and other watershed-wide stormwater management efforts throughout Minnesota (e.g., BWSR's One Watershed One Plan program) are intended to address these concerns. However, there is still significant room for improvement, especially with respect to the availability of financial resources and the levels of collaboration and cooperation that are needed.

Use – How is our water used?

There are many ways that water is used in the metro region. It is important to understand how water is currently and projected to be used so that everyone can have safe and reliable access to water today and into the future. This section describes the ways that water is used in the region, the different ways that water use is defined, and how those definitions impact the accessibility of water for different users and their uses.



The Met Council recently identified a list of priority waters in the region that provide significant use and benefit to the region. As part of this effort, we defined 9 key uses and benefits of surface waters in the metro: drinking water protection, recreation and tourism, healthy habitat, tranquil connection, equity, science and education, industry and utility, culture and history, and food provisioning (Metropolitan Council 2022c). This information will help guide our policy and decision-making processes to best protect and manage our regional waters for all uses in the metro region.

Other public agencies and departments across Minnesota oversee regulations around water use, treatment, and conservation. Some of these entities include the Minnesota Department of Natural Resources (e.g., water appropriation permits), the Minnesota Pollution Control Agency (e.g., total maximum daily loads and sanitary sewer extension permits), and the Minnesota

Department of Health (e.g., public and private well testing). These entities have different definitions for how water is being used, which are often tied to their legal responsibilities.

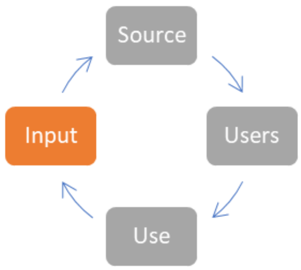
At the federal level, the Environmental Protection Agency's (EPA) Clean Water Act regulates surface waters throughout the United States. These waters have been given different "designations" based on how people typically use the water. This determines how clean the water needs to be to support that use. For example, the standards for a body of water used for domestic consumption are higher than a body of water that is used for swimming.

Based on a review of how federal government, the Met Council, and state agencies define and prioritize use, below is a list of some of the most common uses of water, which are also included in Error! Reference source not found.:

- The most basic use of water is simply for **living**. Fish and other aquatic life cannot breathe without water. Humans, wildlife, and other beings drink water to survive. It is essential for life.
- Water is also used for **food**. This includes food for all beings. It can be accessed at the source by fishing or gathering. Additionally, humans use water to cook food and to support food production in food plots, farms, fish hatcheries, livestock, and other dedicated food production centers.
- Water is used for **transportation**. Goods, people, and other living things are constantly traveling across the water for many different reasons and using a variety of transport mechanisms.
- Water is used for **sanitation**. This includes individual cleanliness, household cleanliness, community cleanliness, and industrial processes, such as meat packing. Water used for this purpose is then carried away through sanitary sewers (hence the name "sanitary") and sent elsewhere for treatment.
- Water is used for **spiritual, physical, and mental well-being**. This includes uses for ritual washing, immersions, and other spiritual activities in sacred places. Additionally, humans participate in water-based recreation activities, such as boating, swimming, or fishing for sport. They also partake in snow-based recreation, such as skiing, snowmobiling, skating, or ice-fishing for sport. Others may prefer an aesthetic experience, such as living on a water-front property or sightseeing at a water-front park. All of these activities support the health and well-being of humans in a variety of ways.
- Water is used for **other purposes**, such as energy, manufacturing, making snow, and irrigating landscapes**.** Nationwide, landscape irrigation is estimated to account for nearly one-third of all residential water use (US EPA, 2016 Jul 12). Mining activities, irrigation of energy crops and ornamental landscapes, and the dilution of chemicals all require significant amounts of water.

These different definitions highlight how competing public priorities can influence the ways in which water is used, accessed, and managed. Due to the many different users and uses of water across the region and the many different policies and public entities that oversee these uses, managing this system is a complex task. It requires education, collaboration, and an understanding of how planning and policy impacts different users in different ways.

Inputs – How is our water returned to the cycle?



By identifying and understanding how water enters, is extracted from, is used, and is returned to the system, we characterize the water balance and can begin to take steps towards ensuring a more sustainable and resilient water cycle. This section describes how water is returned.

Once water has been used, it goes back to one of the three water sources (groundwater, surface water, and atmospheric water). Under natural conditions, much of the water is cycled through the local watershed and groundwatershed and a balance is maintained. Under existing conditions, there are numerous losses as more water is withdrawn from the system than is returned to the local watershed and groundwatershed, creating an imbalance in the availability of water. The following bullets summarize the potential routes of return in maintaining a balanced water system:

- As precipitation or stormwater runoff travels across the landscape, some of it is intercepted by vegetative cover and infiltrated back into the groundwater system. Today, green infrastructure is often used to support groundwater infiltration and recharge, as it can be used as a natural "filter" to achieve water quality goals. Additionally, some communities reclaim water for irrigation using water reclamation plants or stormwater reuse systems, and some are looking at injection into the groundwater to replenish aquifers (Shandilya et al., 2022).
- Storm sewer outfalls, sanitary sewer outfalls, wastewater treatment systems, and other outfalls from human-made pipes carry treated and untreated water, which is discharged to downstream surface waters.
- The sun and wind promote evaporation and transpiration (evapotranspiration), converting water from liquid to a gas and releasing it into the atmosphere. From there, it is carried elsewhere with the wind until it accumulates and returns as precipitation. Certain factors such as heat and dry weather may accelerate the process of evapotranspiration.
- Designed recharge comes from areas that have been constructed or altered to promote infiltration and/or increase aquifer recharge. On a regional scale, designed recharge represents a negligible amount of water compared to natural recharge. On a local scale, design recharge is typically green infrastructure installations that can be important for storm water quality and volume control.

Issue statement

The availability of consistent clean water is crucial to the future of the metro region. Water availability, access, and use are affected by changing and variable sources of water; varying types and quantity of users; shifting user needs; and the methods by which water is returned to the source. Our goal is to improve, support, protect, and enhance access and availability of water for our ecosystems, residents, and business and industrial needs within the region.

The Met Council needs a more comprehensive assessment and water balance of the regional water cycle to better identify water needs and to work with partners to balance those needs to ensure water access and availability.

Our role

As the regional wastewater system operator and the planning agency for wastewater, surface water, and water supply in the seven-county metro region, we strive to ensure sustainable water resources through intentional planning and operations. Our wastewater treatment plants continually meet National Pollutant Discharge Elimination System (NPDES) Permit requirements. Our wastewater, surface water, and water supply planning functions work to promote sustainable water resources while addressing the pollution and other factors that impact those resources. Clean water for drinking and recreation are important parts of the region's livability and prosperity. We work with our partners, utilize our regional influence, and perform our statutory responsibilities to protect and preserve our water.

While we are responsible for essential regional services such as regional water supply and surface water planning and wastewater treatment, local governments focus on planning for their communities, including local water supply and source water protection planning. Together, we work as a team to ensure clean water for future generations.

We have three primary water planning focuses supported by state and federal statute.

- **Wastewater:** We prepare a comprehensive development guide consisting of policy statements, goals, standards, programs, and maps prescribing guides for the orderly and economical development of the region. The regional wastewater collection and treatment system is one of the four regional systems included in this effort (Minn. Stat. § 473.145).

- **Water Resources Management:** State and federal law requires us to adopt a water resources plan and federal requirements for a regional management plan to address pollution from point sources, such as treatment plant discharges, and nonpoint sources, such as stormwater runoff (Minn. Stat. § 473.157; 33 U.S.C. §1288).

- **Water Supply Planning:** We are required to create plans to address regional water supply needs, including creating the regional Master Water Supply Plan, developing and maintaining technical information related to water supply issues and concerns, providing assistance to communities in the development of their local water supply plans, and identifying approaches for emerging water supply issues (Minn. Stat. § 473.1565).

As a part of our statutory authority, we are required to review and comment on Local Comprehensive Sewer, Local Surface Water Management, and Local Water Supply Plans (as described in Minn. Stat. § 103G.291, subd. 3) to ensure that they are in conformance and compliance with the regional plans.

Crucial concerns

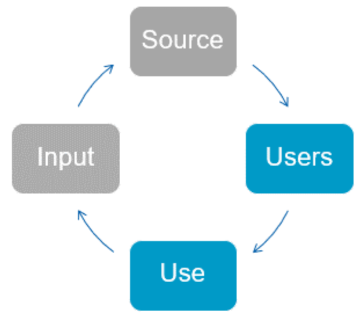
This section identifies the crucial concerns related to water availability, access, and use in the Twin Cities metro region.

We need to highlight the challenges we face as water moves through the sources, users, uses, and inputs phases of the cycle to improve water availability, access, and use across our region. In this section, we explore the primary drivers that influence related hazards and risks. With those drivers in mind, we need to highlight areas to focus policy and planning work (our crucial concerns). These then form the basis of our policy recommendations.

To ensure that water resources and infrastructure are sustainable and resilient in order to meet the needs of present and future generations, it is important to understand what is within our control to manage and what we will need to adapt to moving forward. The information presented in this section identifies a number of the gaps, opportunities, and recommendations that are discussed following the key concern sections.

Primary drivers

Population and employment growth



The metro region's population has grown significantly since the creation of the Met Council. The population has doubled between 1960 and 2020, climbing from 1.5 million residents to 3.2 million residents, and it is forecast to continue to increase to 3.82 million by 2050 (**Figure 4**). Without careful planning and best management practices, this growing population can place significant stress on water availability and quality through changes in water users and potential rebalancing of uses based on shifting demographics (Damania, 2019). This is a crucial concern for us as we support regional growth and ensure sustainable water resources. Policies, planning, and investment will be needed to prevent conflicts between these goals.

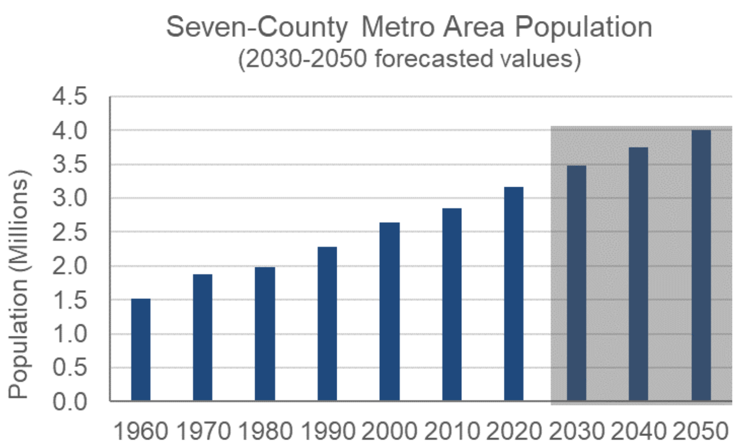


Figure 4: Seven-county metro region population and forecasts, 1960-2050 (US Census Bureau, n.d.; Metropolitan Council, 2021)

Employment has also grown from about 800,000 jobs in 1970 to 1.5 million today (Metropolitan Council, 2023). These jobs reflect growing and changing commercial and industrial practices in the region. Today, the three largest employment categories are Health Care and Social Assistance, Manufacturing, and Retail Trade; employment in these fields has shifted over time – with corresponding changes in how water is used as illustrated in **Figure 5**. Examples of water use by different types of businesses have been documented in dozens of research projects through the Minnesota Technical Assistance Program, and these reports are available online at ***http://www.mntap.umn.edu/resources/publications/solutions/***.

Economic changes, and related impacts on water use, are expected to continue- – though hard to predict. A variety of high-water-demand businesses periodically explore sites in the region and make local news. Recent examples include Niagara Bottling in Elko New Market (Mahron, 2022) and a Google server farm in Becker (Nesterak, 2020).

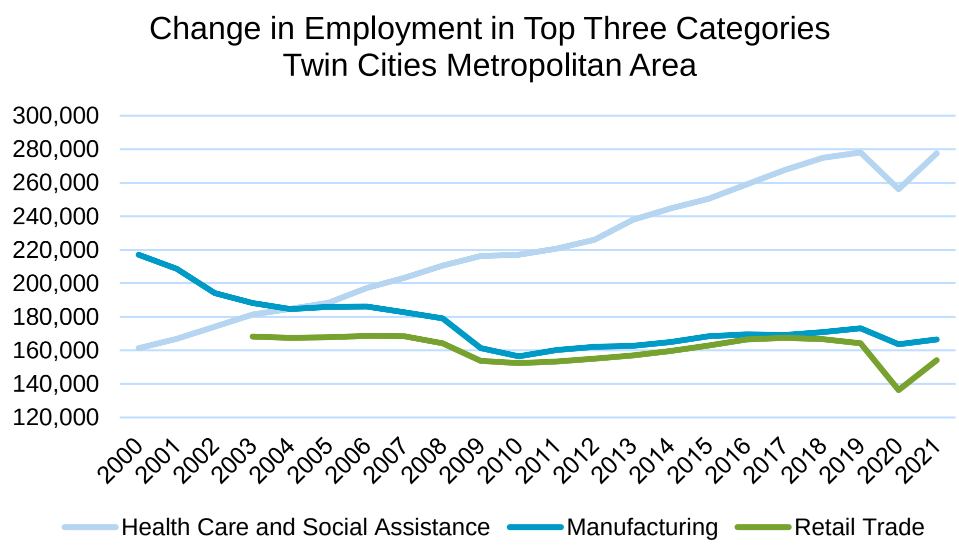
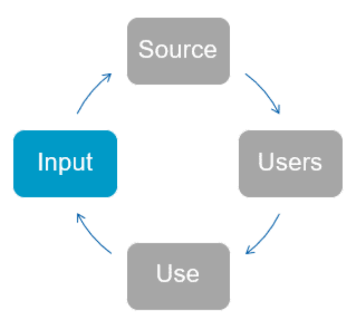


Figure 5: Change over time in employment in health care and social assistance, manufacturing, and retail trade.

Projecting the impacts of population and employment growth on regional water use is a complex challenge, but some simplifying assumptions can be used to make estimates. For example, Met Council projections of future wastewater flow (generally equivalent to indoor water use) are based on assuming 60 gallons per person per day and 15 gallons per employee per day from new development and gradual reduction of wastewater flow from existing development (Metropolitan Council, 2018c). Indoor and outdoor water use varies considerably from community to community and from year to year (Metropolitan Council, 2015a).

Land use change



As more people moved into the metro region, land uses and needs changed and development expanded (**Figure 6**). These changes impacted how water returns to the cycle. In the process, land surfaces changed from farm fields, woodlands, and open spaces to roads, parking lots, and buildings. There was a 56% increase in developed areas between 1968 and 2020. These increases affected the amount of environmental pollution, modified the ways water infiltrated and moved across the landscape, and reduced the potential for groundwater recharge – all factors influencing the quality and quantity of inputs of water back into water sources in the urban areas of the metro.

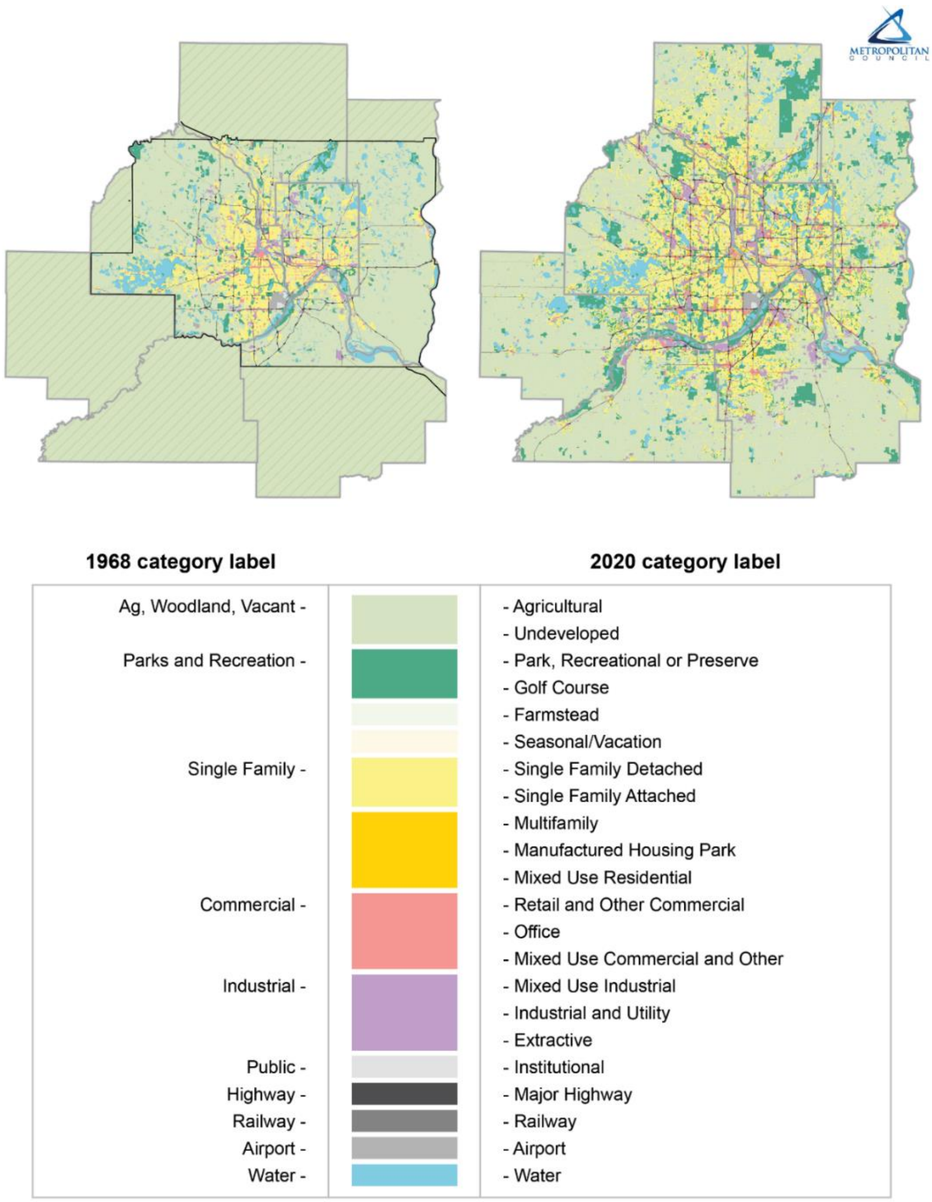


Figure 6: Metro region land use, 1968 and 2020.

Metro region land use in 1968 was identified at the time within the black outline. The 2020 metro region land use was identified across the entire 7-county area. Comparisons were only made between areas with data and were not extrapolated.

Growth, economic development, and land use changes are factors which can be influenced while moving into the future. The metro region is expected to continue growing in size and diversity. With this growth and development will come increasing demand on our finite water resources, as illustrated in Figure 7. The impacts of this growth on water availability in the region are influenced by historic and current limitations within the system and the use of technologies like water reuse and conservation.

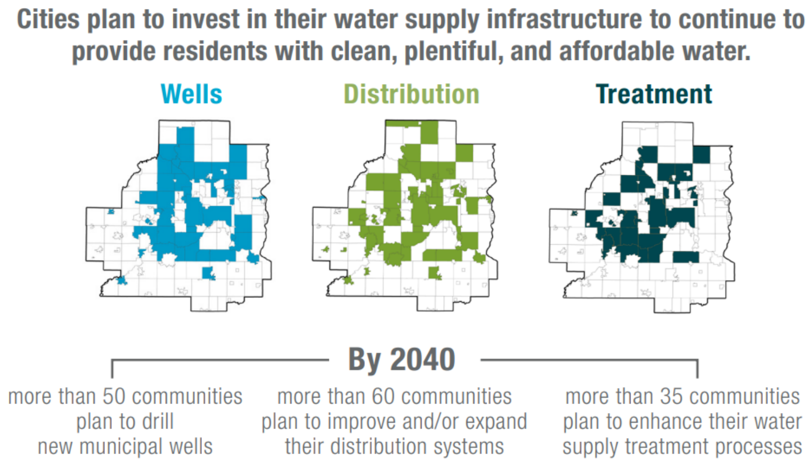
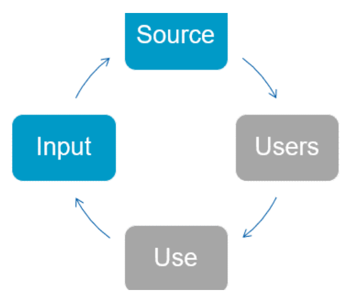


Figure 7: Communities plan for water supply infrastructure through 2040.
For example, based on information submitted to the Council in local comprehensive plan updates as of August 31, 2020, by 2040 more than 50 communities plan to drill new municipal wells (left), more than 60 communities plan to improve and/or expand their distribution systems (middle), and more than 35 communities plan to enhance their water supply treatment processes (right).

Still today, more than any other factor, employment and economic opportunities attract new people to the metro region. By 2050, the metro region is projected to have about 3.82 million people (gain 657,000 residents more than in 2020), with 45% of the population expected to be Black, Indigenous, and populations of color. The aging of baby boomers will lead to nearly doubling of the 65-and-older population by 2050. (Metropolitan Council 2023). With this growing population, new developments, policies, and land use changes will further influence water availability and access across the region.

Current and future climate



The metro region has a northern midcontinental climate pattern – summers are warm and humid; winters are cold and snowfall is common; and rainfall can occur during the spring, summer, and fall (**Figure 8**). This precipitation pattern results in water contamination events primarily in the spring through fall, with large non-point source pollution spikes during snowmelt and large storms.

Figure 8: Minneapolis-Saint Paul Airport monthly precipitation and snow normals, 1991-2020

(National Oceanic and Atmospheric Administration [NOAA], n.d.)

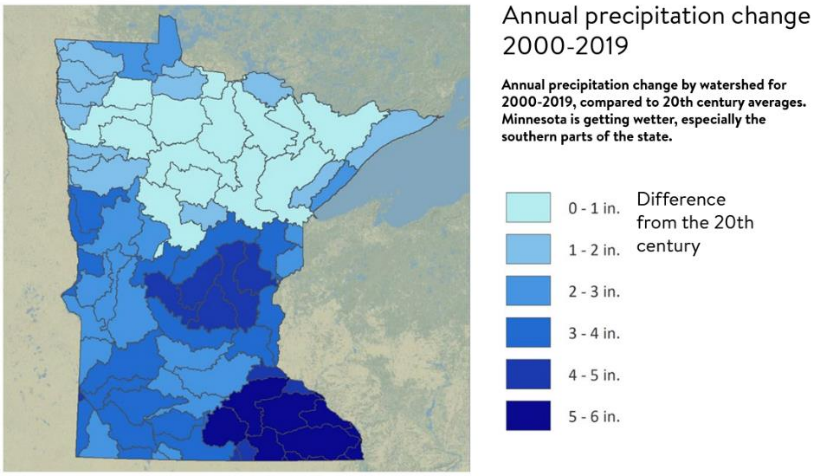


Figure 9: Annual precipitation change, 2000-2019 (Our Minnesota Climate, 2022)

Precipitation amounts have and are expected to continue increasing due to climate change. The timing of the precipitation is not shifting, the storm events have and will still occur spring through fall, but the intensity and amount of precipitation has changed. The metro region is already experiencing 3-4 inches more precipitation annually than the 20th-century average (**Figure 9**). At the same time, the drought of 2021-2022 has demonstrated that we must be prepared for extended periods of drought and heat as well.

Climate change is a natural limitation for water and a significant concern for municipalities, regions, and states as its current and predicated impacts will affect water resources and utilities in a more direct manner than many other sectors. The impacts from climate change have the direct ability to affect water resources by decreasing availability of water in sources and changing the amount and pathways of water inputs back to its sources. This would lead to decreases in available water for drinking and recreation, increases in contamination of source water, and increases in demand for water. **Table 2** contains the most relevant and crucial climate change concerns with regards to water resources and how they are predicated to impact water availability.

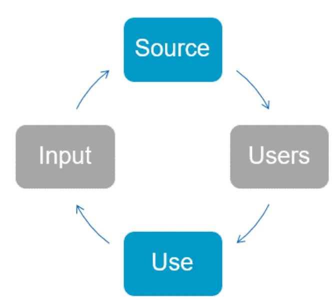
Table 2: Projected climate concerns and water availability impact

Climate Concerns	Confidence in Projected Change	Water Availability Impact
Warmer Winters	Highest	▪ Extended growing season may require more water for irrigation ▪ Freeze thaw cycles can cause more wear on municipal infrastructure ▪ Warmer winters would mean more melting surfaces that freeze before the next snowfall, which can act as a barrier to infiltration
Extreme Rainfall	Highest	▪ Heavier precipitation events would lead to an increase in surface runoff carrying pollutants and sediments to water sources as soils become quickly saturated and don't have time to infiltrate

		▪ Decrease in water infiltration during storm events would lead to decrease in aquifer recharge ▪ Heavier precipitation events with increased overland flow could lead to flooding events which could direct more inflow and infiltration to wastewater treatment plants (Metropolitan Council, 2018a). ▪ Changes in precipitation patterns resulting in wetter conditions (but not extreme rainfall) may raise the water table, resulting in localized flooding.
Heat Waves	High	▪ Increased municipal water use for cooling, swimming pools, and irrigation ▪ Increased evaporation from water bodies making less water available for aquatic life and for recreational uses ▪ Stress/death of urban tree canopy, which would reduce shading in cities and cause further increases in heat and stress for local population through the Urban Heat Island effect.
Drought	Moderately High	▪ Increase in irrigation needed to keep critical natural assets alive ▪ Could lead to more concentrated sewage being delivered to wastewater treatment plants and therefore reduce treatment efficiency ▪ Wastewater effluent being discharged to drought stricken receiving waters will not receive that same level of dilution, and therefore could cause declines in drinking water quality if that water is then picked up downstream for drinking (Benotti et al., 2010).

For more information about our specific climate concerns and recommended policies, please see the Water and Climate research paper.

Current water restrictions



In addition to natural water limitations, we do have areas of the metro region that have political constraints on their water resources affecting the water sources and uses. These restrictions must be considered as we plan to ensure water is available and accessible for regional growth and the prosperity for our residents and businesses.

- **Restrictions due to Court Order** - Cities within five miles of White Bear Lake have already started to experience growth limitations associated with water availability. Both Hugo and Lake Elmo have publicly stated that limits on groundwater appropriations resulting from the White Bear Lake Restoration Association lawsuit have changed their planning and development process.
- **Restrictions due to Court Order / PFAS / Growth Pressure** - Lake Elmo is currently caught between the White Bear Lake lawsuit groundwater appropriations restrictions, southern Washington county PFAS contamination, and an agreement with Met Council

to provide for urban development within the city. A new municipal well constructed in the southwest part of the city was found to have PFAS contamination and cannot be added to the municipal water supply system. The city placed a moratorium on development in that area in part because it could not guarantee that sufficient water supply or infrastructure would be available. Drawing more water from other municipal wells within the city or drilling another new well is not feasible because of the current prohibition on new water appropriations within five miles of White Bear Lake.

- **Areas where state protective restrictions limit commercial, industrial, and residential use** – The Met Council guides regional growth to support our economic and societal needs, which requires adequate water be available to meet long-range seasonal requirements for domestic, agricultural, fish and wildlife, recreational, power, navigation, and quality control purposes. At times, there can be imbalances between protecting and sustaining water resources and water demand. The Met Council, with input from our partners, has a role to predict and plan for these imbalances and inherent tensions to achieve the optimal regional planning objectives.

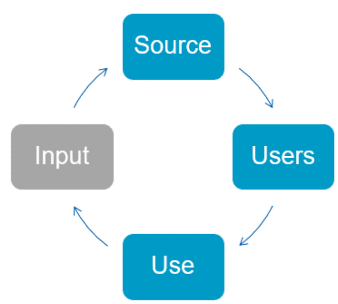
Key concerns

Given the primary drivers influencing water availability, use and access related risks, and our role as a regional planning organization, our key concerns for maintaining water availability and access for needed uses focus on:

- Increasing water demand pressures
- Threats to groundwater-dependent natural resources
- Growing water contamination
- Aging infrastructure challenges

These four crucial concerns form the basis of our policy recommendations.

Increasing water demand pressures



Water quantity is the culmination of natural factors (i.e., geology) and how we have altered the landscape to limit recharge, altered flows, and changed our precipitation patterns (i.e., climate change) that limit the availability of water. By characterizing the amount of available water and comparing it to withdrawal rates and demand projections, a clearer picture of the risks and vulnerabilities can be gained.

Projections of future water demand are related to growth. Estimates of future water demand in the metro region show an increase of about 20% by 2040, as shown in **Figure 10** (Metropolitan Council, 2015a).

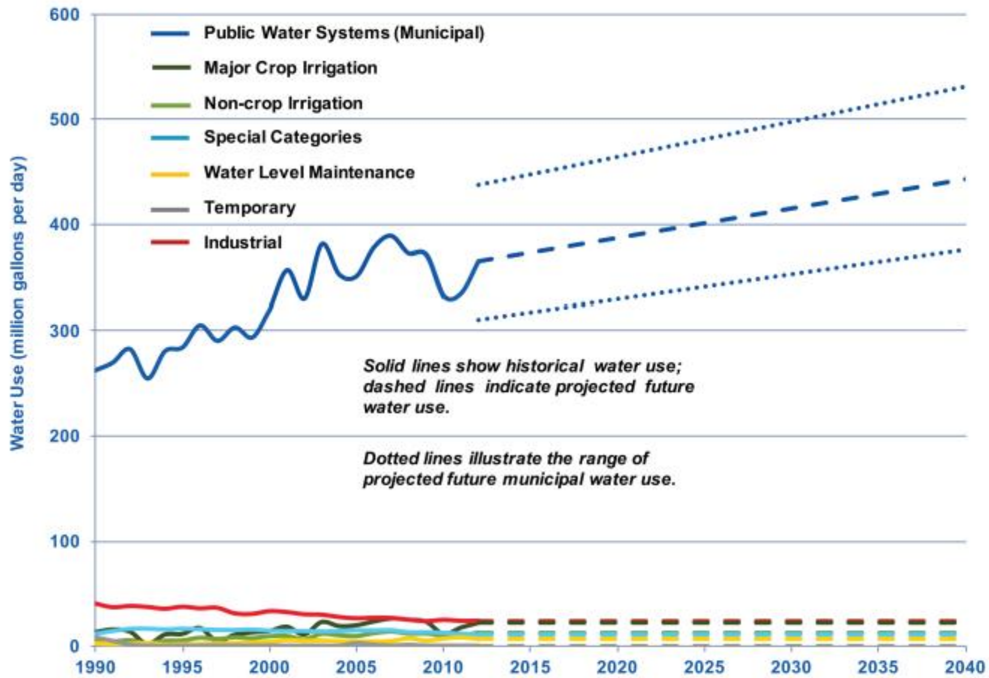


Figure 10: Projected water use in the Twin Cities metro region

If increased water demand draws on the same sources currently being used, this may lead to lower levels in underlying aquifers. Regional groundwater modeling has been done to estimate where future pumping increases might impact aquifers the most. The range of model results below are based on estimated water demand for a population of about 3.70 million people, plus and minus 20%. Areas in southern Washington County and northern Dakota County appear most susceptible to problems related to aquifer depletion. In areas where groundwater pumping is planned to decrease or stop, such as northwestern Dakota County, aquifers are likely to rebound (rise).

While regional groundwater model results are useful for highlighting general areas for concern and provide useful information to consider as part of regional growth planning, it is too coarse a tool to predict more localized issues. For example, Savage Fen, Valley Creek, and White Bear Lake (as discussed Groundwater-surface water interaction section) are areas where surface water has been observed to be affected by aquifer drawdown but are not predicted by the model. Further investigation of projected growth and related water demand and of localized drawdown are opportunities for future groundwater investigations.

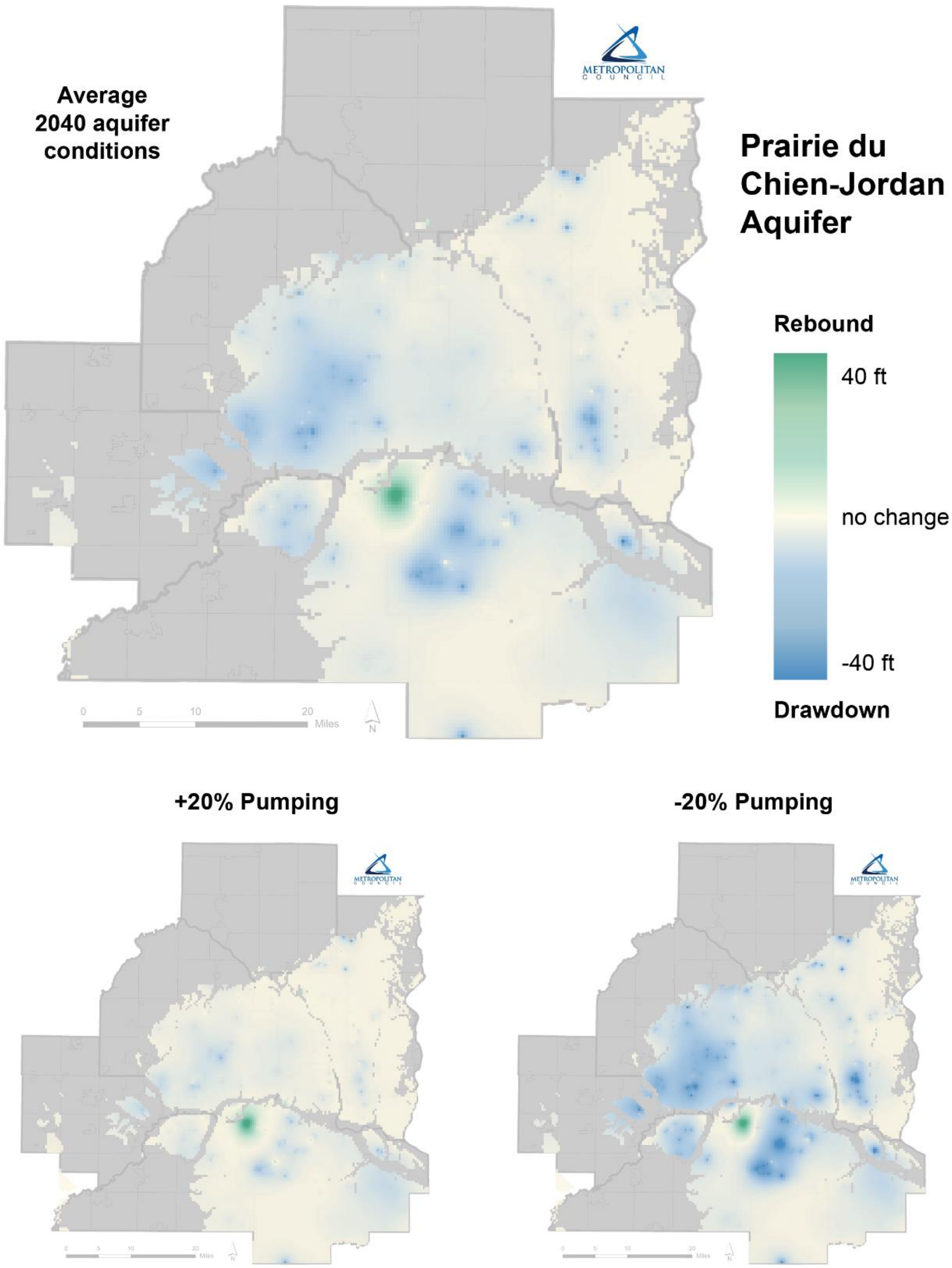


Figure 11: Potential declines in the Prairie du Chien-Jordan Aquifer.

These maps show aquifer declines under pumping conditions projected to serve a population of 3.7 million people, if historical per person water use trends continue and if future demand is met using current water supply sources (Metropolitan Council, 2015a)

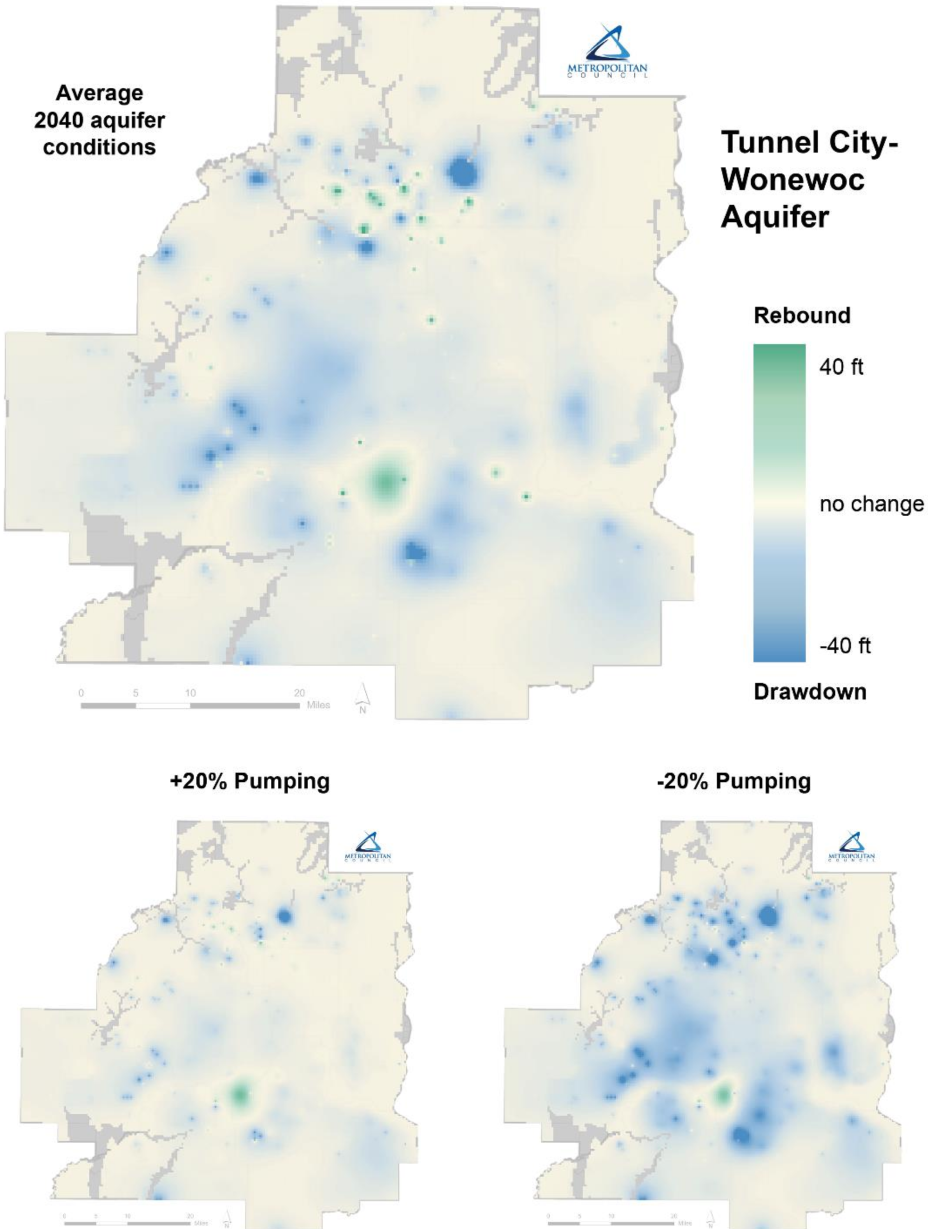


Figure 12: Potential declines in the Tunnel City-Wonewoc Aquifer.

These maps show aquifer declines under pumping conditions projected to serve a population of 3.7 million people, if historical per person water use trends continue and if future demand is met using current water supply sources (Metropolitan Council, 2015a).

Aquifer drawdown has the potential to impact surface waters. Increased groundwater withdrawals, in concert with decreased infiltration linked to increased impervious surfaces from urbanization, leads to a decrease in available water. Climate change contributes to the loss of infiltration by increasing drought duration and delivering precipitation in more extreme events. Soils become saturated during extreme precipitation events, and more water runs off as stormwater.

Recharge rates limit the amount of water that can be sustainably extracted from aquifers. If withdrawals of groundwater exceed recharge rates, the withdrawals are unsustainable (without intervention). This system imbalance causes vulnerabilities to water supplies and ecosystems.

While the Met Council has projected future water demand through 2040 in Figure 8 and modeled the impacts of that increased demand in Figure 9 and 10, these approaches assume current water trends will continue with flat projections shown in Figure 8 for all water use except municipal water supplies. However, history and the political reality elsewhere in the country and world show that significant changes to our industrial or technological landscape have the potential to alter these water demands.

Recently, Elko New Market experienced a water demand decision. Their changing water use landscape include the proposed Niagara bottling plant that would use 310 million gallons of groundwater water through the city's municipal system a year (Stanley 2023), likely shipping much of the bottled water produced around the country. The city has stated their current system has capacity to serve the Niagara facility; however, if a number of high-capacity water users like this were permitted to pump and consume water from our region, it could change the regional landscape of future water demand.

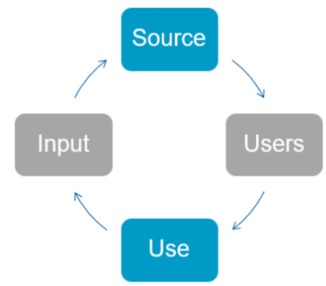
On a larger scale, in the recent past there have also been proposals to take water from the water-rich Midwest and ship it to the arid southwest, such as the proposal to do so by train from Dakota County in 2019 (Ferarro 2021). This proposal was rejected at the time as withdrawals were proposed for the Mount Simon aquifer, which already had significant restrictions on it by the DNR, but given the continued multi-decadal, severe drought in the western part of the country, there will likely be more such proposals. Additionally, there are potentially emerging industrial needs for large volumes of consumptive or non-consumptive water, such as cooling of cryptocurrency mining (Morgenson 2021) or data centers, that could impact our region's water demand in the future.

Water demand recommendations

- Convene a regional discussion to redefine the concept of "sustainable water" in order to direct and align efforts to support sustainable water resources.
- Update estimates of available water supplies, future water demands, and impacts of shocks on metro region water.
- Determine and plan regional growth to mitigate potential aquifer level decline through forecasting groundwater modeling, scenario planning, and targeted water conservation and efficiency efforts.
- Evaluate the uncertainty of aquifer productivity and extent, particularly in the parts of the metro region where the Prairie du Chien-Jordan aquifer is not present or currently being overused.
- Evaluate the impact of climate change on water quantity and availability to inform water demand decisions.

- Determine if there are any major users of water that could be identified and targeted for quantity reductions, conservation, and water reuse where applicable.
- Support the recommendations of the Interagency workgroup on water reuse to further stormwater and wastewater reuse and decrease demands on clean potable water.
- Direct residents and developers toward alternatives to using drinking water supplies for lawn watering, the installation of low maintenance turf (e.g., no-mow grass), or avoiding turf-grass landscaping altogether to reduce impacts on summer water demand.

Threats to groundwater-dependent natural resources



Groundwater flows from areas of higher water levels to areas of lower levels, influencing the direction of flows within and between aquifers. Groundwater flow directions do not necessarily follow the surface topography, especially in deeper aquifers.

In the metro region, groundwater flow in the upper aquifer units is towards the major rivers (Sanocki et al., 2008), (Delin, G.H. and Woodward, D.G., 1984). Groundwater flows toward the major discharge zones of the Mississippi, Minnesota, and St. Croix Rivers. Within these major watersheds, discharge to the gaining portions of smaller streams and tributaries can also take place from the surficial aquifers.

Groundwater-inflow rates into smaller streams can be estimated from streamflow gauging records. Baseflow conditions (i.e., the groundwater component of stream flow) typically account for most of the flow during the winter months, when stormwater runoff is low. On an annual average, approximately 15 to 25 percent of total flow in streams results from groundwater discharge into the streams.

Groundwater discharges to surface water features in areas where the water table intersects the ground surface (**Figure 13**). In areas where clean groundwater feeds surface water features, the quality of the water is generally enhanced. Groundwater lowers the temperature of surface water, which provides habitat for groundwater-dependent biological communities. When water is allowed to infiltrate and flow through the subsurface, it is filtered through the pore spaces in the soil, which can remove certain contaminants before discharge to ground and surface waters.

Surface water features that require groundwater to maintain their ecological function and value are called groundwater-dependent natural resources. Groundwater-dependent natural resources in the metro area these include:

- Groundwater seeps and springs
- Trout streams
- Wetlands, including bogs and fens.

Groundwater-dependent natural resources are important because they greatly enrich the biodiversity of an area. They support plant and animal species that depend on optimum groundwater temperatures and/or chemistry to survive. Groundwater-dependent natural resources are relatively rare, so the associated plant and animal species are also rare. They are vulnerable to development and an increase in impervious surfaces. If recharge is limited or restricted upgradient of a groundwater dependent natural resource, its source of groundwater may be cut off. Additionally, water supply is often limited by the effects it will have on surface water features. High-capacity wells have the potential to draw down water levels in their vicinity and can draw water away from groundwater-dependent natural resources.

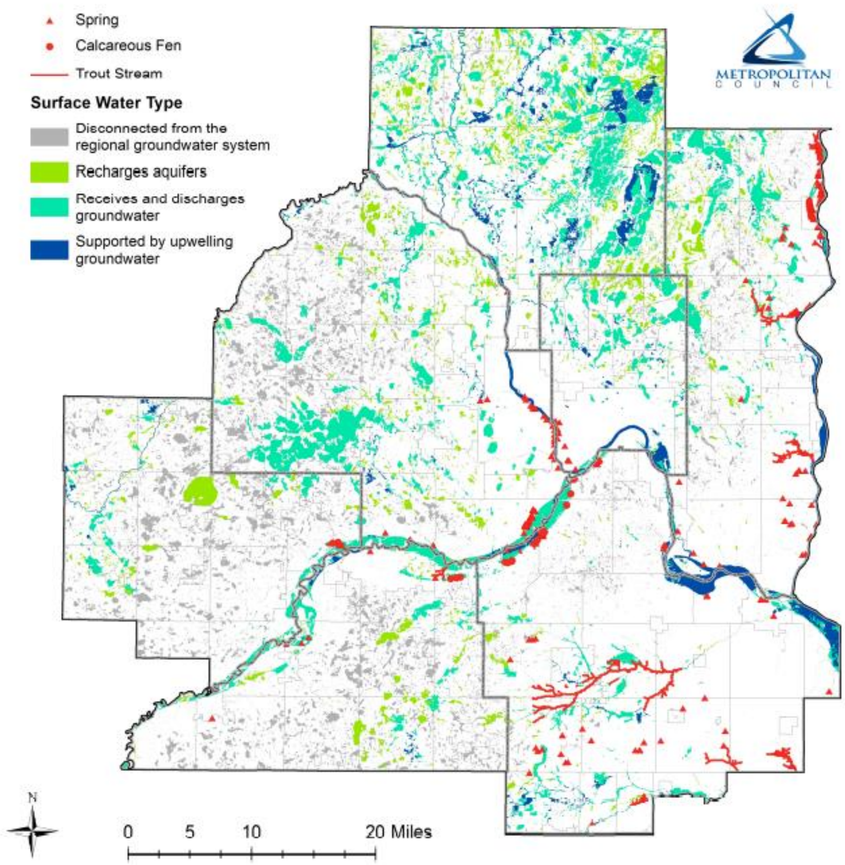


Figure 13: Surface water types and their connection to groundwater

Notable examples of regional groundwater-dependent natural resources

Savage Fen

Savage Fen is located in Scott County along the Minnesota River Valley. It is a calcareous fen, meaning that it receives groundwater with a high mineral content and high pH upwelling from the limestone bedrock. Calcareous Fens are protected from degradation by state law.

The nearby cities of Savage and Burnsville get their water supply from groundwater. Growth and development in both cities increased the need for additional municipal water supply wells. The increase in pumping began to have adverse effects on Savage Fen and other nearby groundwater dependent natural resources.

In the late 1990s, Savage and Burnsville officials worked with the DNR to create a plan for managing groundwater resources in order to restore and protect the natural hydrology of Savage Fen. Savage officials agreed to spend roughly $50,000 more per well to drill wells deeper to avoid the upper supporting aquifers. At the same time, they backed off use of old wells close to the fen and reduced water withdrawals.

Kraemer Mining & Materials Inc. operates a large quarry near Savage Fen. Large volumes of water are pumped to dewater the quarry. The drawdown of the groundwater at the quarry also lowers the groundwater level at the fen. In 2009, Savage made a joint agreement with Burnsville to use some of the water that Kraemer had previously been dumping into the Minnesota River from dewatering the quarry. Conserving this water allowed the City of Burnsville to reduce pumping from municipal wells, which helped to raise groundwater levels near Savage Fen.

Valley Creek

Valley Creek runs through the City of Afton to the Saint Croix River. The creek is one of a few designated trout streams remaining in the metro region.

The City of Woodbury draws its water supply primarily from the Prairie du Chien-Jordan aquifer. Rapid growth in the 1980s through 2000s necessitated the need for several new municipal wells. Some wells were planned to be drilled within three miles of Valley Creek. Groundwater modeling showed that the wells could potentially draw enough groundwater away from the Creek to decrease the total flow by 25% or more. Furthermore, the trout population would likely be stressed because relatively cool groundwater keeps the temperature of the Creek low enough for trout to survive the hot summer months.

Extensive aquifer tests were conducted along with more detailed groundwater modeling to estimate the impacts to Valley Creek from future proposed wells. The proposed wells were relocated to other areas where the groundwater models indicated they would have less impact on Valley Creek.

White Bear Lake

White Bear Lake is one of the premier recreational lakes in the Twin Cities region. In 2016, water levels had reached historic lows that interfered with recreational docks and boating and necessitated the closing of public beaches. A group of local business owners and homeowners sued the DNR claiming that pumping of the underlying Prairie du Chien aquifer was the cause of the low lake levels. The court ruled that the DNR was responsible for the negative impacts to lake levels because the agency issued water appropriations permits beyond the safe yield capacity of the aquifer.

The United States Geological Survey conducted an extensive study of the geology and hydrogeology of White Bear Lake. They demonstrated that the lake is a flow-through lake, and that a significant part of its hydrology is dependent on groundwater. They conducted studies that showed a hydrologic connection between the lake and the underlying aquifers and that changes in precipitation could not account for lake level declines alone. They also developed a groundwater model that estimated lake level was approximately 2.5 feet lower than the natural water level because of groundwater pumping.

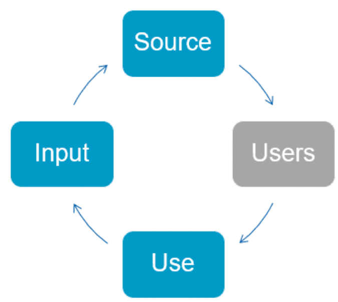
The lawsuit was appealed to the Minnesota Supreme Court, which decided in favor of the business owners and homeowners' group. The settlement required local municipalities to develop a plan to limit residential groundwater use to 75 gallons per day per person and 90 gallons per day overall. No new wells or increases in water appropriation permits are allowed for cities within five miles of White Bear Lake until the plans are implemented. A lawn watering ban is to be enforced when water levels in White Bear Lake reach a trigger elevation of 923.5 feet and continue until it has reached a level of 924 feet.

The DNR established the North and East Metro Groundwater Management Area partly in response to the lawsuit. City representatives, regulators, and other interested parties meet regularly to discuss water management issues and develop a regional plan for meeting the requirements of the lawsuit settlement. The DNR also developed a more detailed groundwater model to assist with reviewing future water appropriation permits.

Groundwater-surface water interactions recommendations

- Assess where connections between surface waters and groundwater occur and where use patterns, behaviors and other factors may increase resource stress
- Identify, map, and evaluate groundwater recharge areas that are vulnerable to development so that their recharge value can be protected (e.g., wellhead protection areas).
- Model groundwater flow in the water table (Quaternary) aquifer to better assess groundwater and surface water interactions.
- Develop injection capacity maps of regional aquifers to determine where intentional aquifer recharge could be viable to help mitigate withdrawal impacts on groundwater sources.

Growing water contamination



Water contamination affects our ability to use water and our commitment to protect and restore our regional water resources. In this section, we will touch on how water contamination is connected to water availability. For a deeper investigation about how water quality impacts our region, please see our Water Quality research paper.

The quality of the source water is a risk to water availability and is related to the level of contamination that exists. Contamination can occur from natural and human-made sources and can impact water availability in the following ways:

- Make drinking water unavailable – when contamination exceeds state approved standards
- Make drinking water more costly – when higher levels of treatment are needed to remove contamination
- Make water unavailable for all plant and animal life – when it is too contaminated to support life
- Make water unavailable for some plant and animal life – when only certain species can survive
- Make water unavailable for recreational activities – when loss of fish species, closure of beaches to swimming, etc., occur

Water contamination can affect ecosystem health and water availability for drinking water from both surface water and groundwater sources. With the abundance of lakes, rivers, and streams in the region, surface water contamination has the potential to have a significant impact on water availability. Contamination can reach the surface water system through a variety of pathways including:

- Direct stormwater runoff from rainfall and snowmelt
- Municipal stormwater conveyance infrastructure
- Infiltration into the ground and groundwater interflow into streams and waterbodies
- Direct deposition through the air or rain

For groundwater sources, contamination often occurs through infiltration of contaminants through the ground or directly via the well system in cases of flooding and overtopping. The vulnerability of aquifers to contamination is dependent on the geologic characteristics of the overlying material and the aquifer itself. A map of groundwater travel time through bedrock and vulnerable drinking water supplies is shown on **Figure 14**.

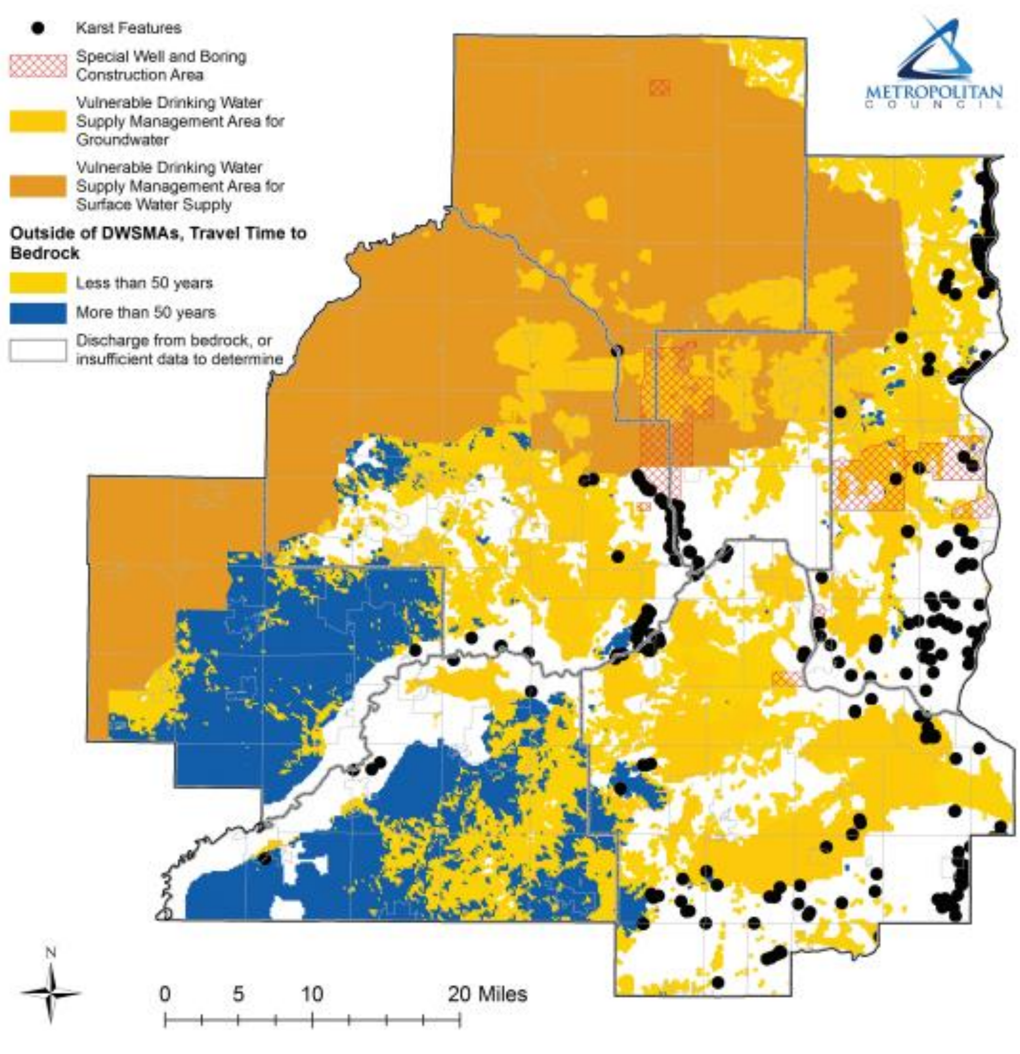


Figure 14: Vulnerable drinking water supplies and travel time to bedrock (Metropolitan Council, 2015a)

There are numerous contaminants that affect surface water and groundwater resources. The tables below (**Table 3**, **Table 4**, **Table 5**) are a snapshot of example contaminants of concern for the metro region. Though it should be noted that while contamination issues are the responsibility of the MPCA and the MDH, the Met Council plays a role in identifying and supporting communities most impacted by these contaminants.

Table 3: Natural contamination examples

Contamination Type	Description
Minerals	The groundwater in the metro region is generally hard, with elevated concentrations of sodium, potassium, and chloride. Chloride is contained in geologic materials; however, increasing chloride concentrations in regional aquifers are attributed to the use of road salt (Andrews et al., 1997).
Metals	Trace metals generally do not have EPA Maximum Contaminant Levels (MCLs) (Andrews et al., 1997). Iron and manganese have been observed to occur in metro region groundwater. Both iron and manganese can present aesthetic/taste problems, stain plumbing fixtures, and clog watermains and plumbing. Arsenic can occur naturally in groundwater within the Lower St. Croix River Watershed. 20% of tested wells in the watershed have elevated levels arsenic and ~4% exceed water standards.
Radionuclides	Radium occurs naturally in geologic materials. Radium is a known carcinogen, and prolonged exposure to groundwater containing radionuclides can cause cancer (Minnesota Department of Health 2022d). 2.5% of sampled wells that are open to the Mt. Simon-Hinckley aquifer in the metro region exceeded radium MCLs. 100% of sampled wells exceeding the limit were within the footprint of the Des Moines lobe, which is known to contain shale that supplies arsenic to groundwater (Kanivetsky, 2000). Elsewhere, combined radium measurements are generally low.

Table 4: Human-made contamination examples

Contamination Type	Description
Chloride	Chloride contamination is a significant concern for drinking water availability and ecosystem health due to its useful but deleterious properties and widespread use. The main sources of chloride in Minnesota are de-icing salt, fertilizer, and discharge of brine solution from

	residential ion exchange water softeners (Overbo et al., n.d.), though this varies by region.
Per- and polyfluoroalkyl substances (PFAS)	Per- and polyfluoroalkyl substances (PFAS) are a group of persistent synthetic chemicals significantly impacting the region. Because of past manufacturing in the metro region and extensive use as water- and grease-resistant applications on consumer products and packaging, PFAS enter the environment in many ways (e.g., chemical spills, landfill leachate, residential and industrial wastewater, and biosolids). Once released, the chemicals can contaminate surface waters, drinking water supplies, and build up in the tissues of fish, wildlife, and humans.
Nutrients – nitrogen and phosphorus	Nutrients are essential to turf management and agricultural production. They are a byproduct from animal wastes, septic and wastewater treatment plant (WWTP) discharge, and urban runoff. In the metro region, we track various chemical compounds of nitrogen and phosphorus, both of which can lead to contamination of groundwater and surface water when excess nutrients run off the landscape or are infiltrated into the groundwater system. These excess nutrients can create algal blooms, anoxic water conditions, and may result in large fish kills.

Table 5: Examples of contaminants of emerging concern

Contamination Type	**Description**
Pharmaceuticals	Antibiotics, followed by analgesics (ibuprofen, paracetamol, diclofenac), are the most prolific worldwide but can vary by geographic location and consumption levels (Patel et al., 2019). While some compounds break down quickly, they are considered 'pseudo-persistent' due to their continuous addition to the environment in small but significant quantities.
Microplastics and nanoplastics	Microplastics and nanoplastics are an emerging concern for surface water sources due to the number of products containing these materials and the pervasive usage of plastic materials. (Minnesota Department of Health, 2019). Microfibers from textiles are the most common microplastics.

CASE STUDY – Elevated nitrate concentrations in drinking water supplies

Nitrate, a chemical species of nitrogen, contaminates source water in southern Washington County and the Hastings area. These areas share a similar geology and land use. Soils are sandy, originating from glacial outwash. Both areas have a history of row crop agriculture with a high reliance on nitrogen fertilizers. The susceptibility to groundwater contamination is high because of the short travel times for water infiltrating from the surface to reach groundwater. Other geologic characteristics, including faulting and karst create preferential pathways that allow contaminants to more easily reach and spread through the groundwater system.

The Maximum Contaminant Level (MCL) for nitrate in drinking water is 10 mg/L (ppm). Infants below the age of six months who drink water containing nitrate in excess of the maximum contaminant level could become seriously ill and, if untreated, may die. **Figure 15** shows that 26% of the wells in the Hastings area were found to have nitrate concentrations above the MCL (Dakota County, 2003).

There are several effective treatment technologies available for nitrate removal in drinking water including ion exchange, reverse osmosis, and electrodialysis. However, these treatment technologies are costly and their installation can have lasting water affordability effects. In 2008, Hastings Public works spent $3.5 million on a water treatment plant upgrade to lower nitrate levels, an estimated cost of $410 per household. Other municipal water suppliers such as the City of Rosemount monitor nitrates carefully, but so far have not needed to take corrective actions.

Individual well owners can purchase and operate private systems, but the operational costs alone can be several hundreds of dollars per year.

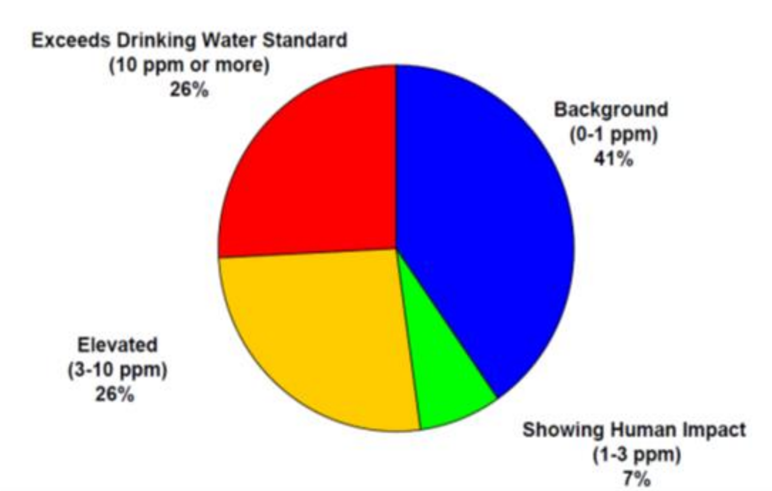


Figure 15:Nitrate concentrations in Hastings area groundwater (Dakota County, 2003)

Dakota County, the Minnesota Department of Agriculture, and other groups are working with farmers to minimize nitrate contamination through best management practices, including:

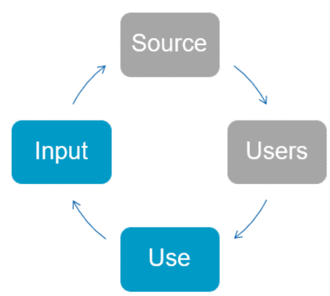
- Avoiding overapplication of fertilizer
- Using no-till agriculture and other practices that reduce run off
- Timing fertilizer applications to improve retention and reduce infiltration
- Maintaining buffer strips of vegetation that reduce runoff and take up nitrogen

Water contamination recommendations

- Follow recent EPA and MDH data, guidance, and regulations with respect to drinking water contaminants, including radionuclides and emerging contaminants, and work with state health officials as needed to keep track of current trends, data, and recommended best management practices.

- Evaluate and consider alternative water sources (i.e., surface water supplies and water reuse) for public water systems with drinking water standards exceedances.
- Encourage our partners and public water utilities to consider elevated levels of manganese in their municipal water treatment of drinking water in public water systems.
- Promote private wells owners to sample and test their well water for arsenic, PFAS, and other contaminants and install point-of-use treatment devices (i.e., reverse osmosis and granular activated carbon filtration systems) as needed.
- Evaluate and consider community water softening treatment for public water systems that discharge chloride to sanitary sewer collection systems and ultimately to the Met Council wastewater treatment plants with our partners and public water utilities.
- Promote and encourage partners to participate in the MPCA's Smart Salting training that helps organizations that apply road salt to improve operator effectiveness and reduce chloride pollution while keeping roads, parking lots, and sidewalks safe.
- Monitor PFAS data in public and private wells sampled by the State of Minnesota to determine areas of detections in the metro region (see MDH Interactive Dashboard at ***Interactive Dashboard for PFAS Testing in Drinking Water – MN Dept. of Health (state.mn.us)***.
- In agricultural areas, promote agriculture best management practices including the timing, rate, placement, and source of fertilizer application and vegetated filter strips to provide vegetated land areas between pollutant sources and surface water bodies for non-agricultural areas.

Aging infrastructure challenges



For residents, businesses, and industries to use water, it must be extracted from the source, treated, and transported to the use location. After its use, the used water must be treated and returned to a source. All movement and conveyance of water in the built environment requires water infrastructure. Water supply and wastewater treatment systems were installed as the region developed, creating a range of infrastructure age of newly installed to over a hundred years old.

The age of water mains is a major issue for utilities across the state of Minnesota, with the majority of pipes being older than 50 years and some older than 100 years. Older pipes are prone to rusting, cracking, and occasionally bursting.

Source water is treated prior to use distribution through a variety of methods and technologies, though surface water requires more treatment than groundwater prior to distribution due to the higher potential for contamination. Like water mains, treatment plants and supply wells are aging out, and smaller utilities are in greater need of support to maintain and upgrade these assets. The Minnesota Public Facilities Authority (PFA) and Department of Health administer the Drinking Water Revolving Fund Project Priority List (PPL) to which public water suppliers can submit projects to receive low interest loans and grants. This list is ranked based on different categories, including health protection, adequate water supply, and financial need. The

2023 list includes 673 projects within the state of Minnesota and within the top ten, nine of the projects are for upgrades to water treatment systems (Minnesota Department of Health, n.d.).

Wastewater treatment systems have the potential to impact water availability through their connections to surface water sources when treated wastewater is returned to the environment. Contaminants that are not removed through the treatment process can impact the ecosystem or become introduced into the drinking water supply.

MCES invests almost $130 million a year to preserve infrastructure, with $100 million of that amount spent on interceptor pipe rehabilitation and lift station renovation (Metropolitan Council, 2019).

Inflow and infiltration (I&I) of groundwater and runoff into the sanitary system through cracks and breaks in the pipes can reduce the capacity of pipes to receive wastewater, which reduces their capacity to convey wastewater to the WWTP. This causes the WWTP to treat more wastewater than should be required (Metropolitan Council, 2022f). The majority of I&I that enters the wastewater system comes from private infrastructure and includes uncapped sewer cleanouts, improperly connected sump pumps, and improperly connected storm gutters (Metropolitan Council, 2018b).

Stormwater infrastructure includes catch basins, storm sewer pipes, outfalls, stormwater ponds, and stormwater management practices (BMPs) which are mostly the responsibility of each municipality. There are some stormwater BMPs that are operated and maintained by homeowners associations, public and private entities, and residents.

Similar to sanitary sewers and water distribution mains, storm sewer pipes are also prone to cracking and other age-related issues, require operation and maintenance, suffer from capacity issues, and need to be rehabilitated on similar timelines. Many of these issues are addressed through the MS4 permit requirements.

CASE STUDY – St. Louis Park water main break

On May 21, 2022, the cast iron water main on Minnetonka Boulevard burst, sending water into the street and into the adjacent sanitary system. This water overloaded the sanitary system, causing it to back up and send sewage into the basements of multiple homes. Two weeks later on June 3rd, 2022, the same 20-ft section of pipe failed again, sending sewage into homes that had just begun repairs from the initial flooding. The City of St. Louis Park offered compensation for the damage – up to $60,00 affected by the first break and up to $80,000 for those affected by both. The city hired a firm to conduct a water main evaluation to determine the exact cause of the break (St. Louis Park, MN, 2022).

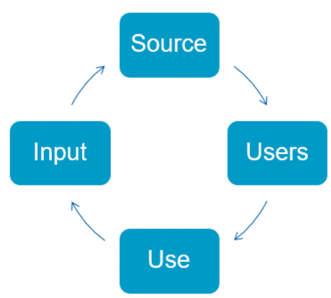
Continuous leaks from water mains are not immediately apparent the way that a full break is, but they can still cause huge water losses from a system over time. A nationwide survey of water main pipes found that the majority were cast iron (CI) pipes, 82% of which are 50+ years old and 46% of which are experiencing an increase in break rates since 2012 (Folkman, 2018). Water main break rates are considered the indicator of pipe conditions since the majority of infrastructure is underground. This survey also found that smaller utilities had break rates that occurred almost twice as often as those of large utilities, indicating that they are being replaced or maintained at slower rates. This is often due to the fact that smaller utilities are often rural and have more pipes per customer compared with larger and more urban utilities, resulting in a greater financial burden for maintenance and replacement for that utility (Folkman, 2018).

Older water mains can be cleaned and re-lined to prevent future rusting and improve the flow of water through the pipes. In Minneapolis, water main lining is an ongoing project, as the majority of mains in the city were installed before the 1960s and made of unlined cast iron. As the unlined pipes corrode and age, mineral deposits collect inside the pipes. These deposits decrease pipe capacity, hindering water availability, but do not pose a health risk. Minneapolis rehabilitates approximately 7 miles of mains every year for their approximately 1,000 miles of water mains (Minneapolis, n.d.).

Aging infrastructure recommendations

- The Met Council commits to regional long-term investments in our wastewater treatment and collection system to safeguard sustainable water for all residents and areas of the region.
- Public water utilities should study and implement water utility rates that provide adequate funding to replace and rehabilitate aging infrastructure in addition to covering operational costs and depreciation.
- Public water systems should aggressively pursue federal and state infrastructure funding programs, as well as adopt public policies that promote innovation in the water sector.
- Public water utilities should implement asset management programs to identify aging and deficient areas of their water supply, treatment, storage, and distribution systems; estimate the costs to replace or rehabilitate these systems; prioritize the recommended improvements; and implement the improvements over a scheduled timeframe of 1 to 30 years.
- Public water utilities should evaluate and consider using newer technologies such as predictive analytics to identify potential asset failures and accelerate repairs (both above- and in situ below-ground) to optimize use of funds when replacing and rehabilitating water distribution systems.
- Promote customer engagement efforts to increase water conservation to extend the life expectancies for critical water infrastructure components.

Equity considerations



Public policy and industry practice have produced an unequal landscape across American neighborhoods. This has caused a disproportionate burden on people and communities of color, including negative impacts on wealth building, health, and environmental justice issues. Discriminatory housing practices from both federal and private programs have contributed to the segregation of neighborhoods, making it possible to geographically target and withhold public investment. In 2016, the median net worth among white families was 10 times that of black families, and more than 8 times that of Hispanic families (Loh et al., 2020). Impacts from these programs and practices can be seen and felt within the metro region.

Achieving water equity means everyone has reliable access to clean, safe water. It means there is a source with enough clean water for all users for all their uses, and returned to the source. It requires investment in communities that are vulnerable, traditionally underserved, and disproportionately affected by water availability issues. For these investments to be equitable, they must be community-led and aim to undo a historic or existing disparities. Therefore, it is important to understand who is vulnerable across the metro region and the historic or existing inequities they face that reinforce barriers or conflicts with regard to water availability, access, and use.

Community vulnerability is a multidimensional issue with many different definitions. We have adopted the US Water Alliance's definition (US Water Alliance, 2021):

> Vulnerable communities face historic or contemporary barriers to economic and social opportunities and a healthy environment. The principal factors in community vulnerability are income, race or ethnicity, age, language ability, and geographic location. This may include low-income people, communities of color, immigrants, seniors, children, people with disabilities, people with limited English-speaking ability, rural communities, tribal communities, people living in unincorporated areas, people living in public housing, and people currently or formerly incarcerated.

In the context of this research paper, vulnerability is associated with a community's ability to sustain water availability, access, and use in the event of a disaster or stressor on the system. Sustaining those basic needs depends on having a secure source of water. Water security cannot be achieved without having water physically available, accessible, usable, and most importantly, having these three things consistently reliable across time (Rosinger and Young, 2020). This is illustrated in **Figure 16** below.

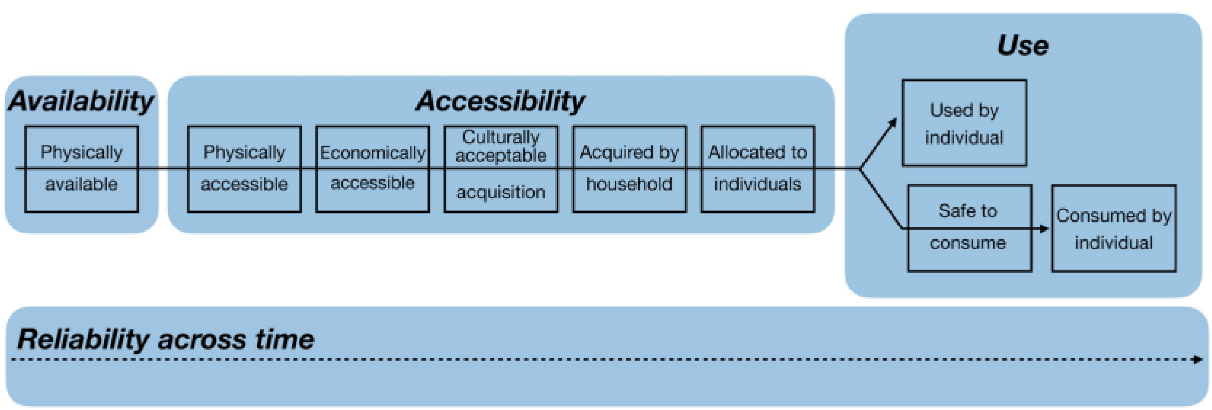


Figure 16: The four domains of water insecurity: availability, accessibility, use, and reliability.

The four domains of water can be measured at the macro and micro levels. While many indicators of water insecurity focus on physical availability, household water insecurity captures experiences of accessibility, use and reliability. Household water insecurity occurs when any of these domains are not present (Rosinger and Young, 2020).

There are many historic and current practices that cause barriers and conflicts for vulnerable communities. These practices are interrelated, complex, and are connected to affordability, respect, and inclusion of differing perspectives.

Water affordability and accessibility are different for everyone. One of the reasons people have difficulty accessing water is that it is not affordable for everyone. According to a 2021 Twin Cities metro region water values survey, the affordability of water, wastewater, and stormwater service charges are perceived to be expensive for approximately one-third of respondents (31%, 28%, 24% respectively), (Roth et al., 2022). Water affordability is not only about how much things cost monetarily but also about health, time, and social costs. These additional costs tend to impact women, children, and Black, Indigenous, and residents of color disproportionately.

Sometimes, rising water costs are the result of infrastructure investments. In Michigan, higher water rates fall disproportionately on people of color, usually in older, depopulated cities because the higher costs are spread across fewer people (Homsy and Warner, 2020). This may also be the case in the Twin Cities region. A study from 2016 on water bills across the region identified that many municipal water suppliers with treatment facilities that were 10 years old or less had high water bills, and utilities with treatment facilities more than 10 years old had water bills less than $40 per month, (Metropolitan Council, 2016 Dec).

For various reasons, many people do not trust their water infrastructure to support their needs. This lack of trust can result in significant costs to the individual in an attempt to supplement or treat their water, which includes monetary costs and costs to health, time, and social ability. In the 2021 Regional Water Values survey, 10% of respondents in the Twin Cities reported using purchased bottled water as their primary drinking water source. Furthermore, “nearly half of respondents (49%) agreed that they are concerned about contaminants in their drinking water” and “reported using a refrigerator filtration system (36%). Other filtration systems used included pitcher filters (16%), sink filter system (11%), and a whole house filter system (9%). Twenty-four percent reported that they do not use any additional treatments,” (Roth et al., 2022).

According to a study by Rosinger et al. (2018), communities of color are far more likely to have a distrust in tap water safety. They also found that Hispanic and non-US-born adults were the most likely to consume a majority of their water from bottled water, which can be 240 to 10,000 times more expensive than tap water. A failure in the water system can reinforce this distrust and create an increased dependency on this unsustainable and unaffordable source of water. Over the long term, this lack of trust in water infrastructure can have detrimental impacts on a community’s financial capacity to sustain a safe, reliable, and affordable water source.

Many factors can reduce trust in the water sector and limit awareness of water problems, including physical and visual inaccessibility of water, language barriers, and cultural constraints (Pradhananga et al., 2019). This impacts the level of knowledge, capacity, and interest people have in the availability, access, and use of the region’s water resources. According to the 2021 Regional Water Values survey, “when respondents were asked about the original source of their household drinking water, 45% percent reported they ‘do not know’ the original source.” Additionally, respondents indicated that “the most trusted information sources when it comes to water included universities/academic institutions (71%), local water and soil agencies (66%), family (65%), and Minnesota state agencies (62%). The most distrusted information source when it comes to water was media, including newspapers, Internet, TV, and social media (41% distrust),” (Roth et al. 2022). Numerous organizations across Minnesota and the region are working to make educational resources more accessible, including Friends of the Mississippi River, Water Bar, and Lower Phalen Creek Project, among many others.

Despite these harmful issues, customer assistance programs are often not reaching those in need. According to a recent report (US Water Alliance, 2022), “most of the cities that track enrollment data in assistance programs found that less than 2.2 percent of income qualified customers are enrolled in assistance programs (including amnesty and payment plans)—leaving about 98 percent of qualified customers without assistance.” In the Met Council’s Water Billing Analysis (2016 Dec), it was reported that 26 municipalities, four energy companies, and one non-profit organization across the region had sponsored conservation programs to reduce costs to water bills. These programs include offering rebates, audits, financial assistance, and targeted education for water conservation.

Representation is not equal. An additional root cause is a lack of respect and representation of other cultural values in decision-making institutions. This results in a dissonance regarding what people need versus what they are receiving. Dissonance shows up in the form of disregarding legal agreements, harmful policies, exclusive meeting venues, exclusive procurement practices, that lead to exclusive communities where water benefits are concentrated.

In 2019, Governor Walz signed an Executive Order 19-24 to affirm the government-to-government relationship between Minnesota and the eleven federally recognized tribal governments in the state. It was issued to ensure that the relationships were built on respect, understanding, and sovereignty. This order was eventually codified into law through Minnesota Statutes 2021, section 10.65 (Executive Order 21-35). However, this desire for mutual appreciation has not always been the standard practice in Minnesota. During the 1990s, Ojibwe tribes in Minnesota and Wisconsin asserted their treaty-defined usufructuary rights by fishing for walleye at times and in ways that violated the two states’ regulations. “When cited for violations, Ojibwe anglers mounted legal challenges based on the treaties, and the Supreme Court ultimately affirmed those rights. White anglers and others expressed outrage that the Ojibwe were being ‘given special rights,’ but the Supreme Court decisions confirmed the Indigenous claim that through the treaties, they had simply retained rights they had always had in and on their own lands,” (McKay, 2020). This is one example of many situations where certain dominant cultural values and institutional priorities were placed above individual rights and needs, and the decisions driving those values disproportionately impacted a distinct group of people.

Representation is further complicated by the way decision-making institutions operate, both structurally and culturally. According to the 2021 metro region water values survey, respondents who identified as Black, Indigenous, or persons of color were concerned to a greater degree than White respondents about several water issues, including lead pipes or lead exposure in water, proper disposal of pharmaceuticals, and water bodies that are not safe for swimming. Additionally, Black, Indigenous, or people of color rated several water values as more important to protect than White respondents did, including having a consistent water supply for lawns and landscaping, avoiding costly water treatment expenses, and for cultural and religious practices (Roth et al., 2022). These differences in values speak to the importance of having these perspectives represented at a decision-making level. However, Black, Indigenous, or residents of color remain largely underrepresented in the survey. The intent of the next phase of this work will be to better characterize those perspectives, but many challenges still exist in doing so.

The underappreciation and exclusion of non-dominant voices and cultural values creates cascading systemic obstructions for vulnerable communities:

- **Accessing public lands:** Public entities across the state of Minnesota work to maintain access and use of parks, trails, water access points, and many other outdoor facilities. Many disparities exist regarding who is able to access these outdoor spaces, how they access them, the quality of the access, and who feels welcome in them. According to the Minnesota Department of Natural Resources (DNR), people of color make up 20 percent of Minnesota's population but only 5 percent of state park visitors (Davis and Matsumoto 2021 May 28). In response to this gap, the state created a new Outdoor Recreation Office to increase access and participation for BIPOC people in Minnesota (Aponte et al., 2021 Mar 24; Timmons, 2021 Feb 19). Additionally, the DNR introduced all-terrain track chairs and adaptive beach chairs for visitors with mobility disabilities, which became available on June 2, 2022, at six state parks throughout the state (Minnesota Department of Natural Resources, 2022 Jun 1).
- **Zoning decisions:** Zoning practices are directly tied to where people live and their ability to access and benefit from water. Zoning influences access to water infrastructure, proximity to pollution sources and contaminated water, proximity to flood prone areas, and proximity to surface water bodies or water ways, among many other things. Additionally, exclusionary zoning practices have limited specific communities from accessing readily available clean and safe water and associated individual and community benefits. For example, historic racial restrictions on property deeds ensured that land near freshwater bodies in Minneapolis, St. Paul, and other communities in the metro would remain mostly white. Similarly, zoning and development practices have inhibited indigenous peoples' access to sacred sites along the Minnesota and Mississippi Rivers (Keeler et al,. 2020). These practices influence the demographics of communities that have established themselves around these water sources, which ultimately inhibits certain people from using and interacting with these waters for their own personal needs, and perpetuates wealth and health gaps.
- **Environmental gentrification:** In Minneapolis, green infrastructure installations have been found to be connected with publicly funded urban redevelopment projects that promote gentrification – physical and cultural displacement resulting from public investment. Therefore, the benefits of these projects were mostly enjoyed by new residents who could afford the associated higher rents, instead of the people that lived there previously (Walker, 2021). Additionally, a lack of planning processes and policies that protect against gentrification allowsthese investments to deepen rather than ameliorate environmental injustice in Minneapolis (Goetz et al., 2019; Walker, 2021; Anguelovski et al., 2022).

Water equity recommendations

- Investigate and understand how unhoused residents use public water supplies and sources as a means for their water across the region.
- Create a database of narratives around water to understand how different people experience water and are impacted by policy and planning for city and township, watershed, and regional planners and water utility providers.
- Explore and identify data sources to support the history, culture, and food provisioning to inform the Priority Waters List.

- Investigate cross-disciplinary water equity issues across Met Council planning systems – to “recognize how environment, housing, and infrastructure are linked across time and space.” (Keeler et al., 2020)
- Support organizations promoting water equity and educational efforts improving the connection and relationship with residents and water.

Connections to current policy

The 2040 Water Resources Policy Plan contains 11 separate policies. None have any specific language regarding water availability, which could be an area to explore in our policy update. However, several of the current policies relate to water availability, access, and use, as denoted below.

Water Resources Policy Plan water sustainability goal

To protect, conserve, and utilize the region’s groundwater and surface water in ways that protect public health, support economic growth and development, maintain habitat and ecosystem health, and provide for recreation.

Policy on watershed approach
The Met Council will work with our partners to develop and implement a regional watershed-based approach that addresses both watershed restoration (improving impaired waters) and protection (maintaining water quality in unimpaired waters).

Supporting actions related to supporting water availability, access, and use:

- Work with the watershed management structure in the metro area on issues that transcend watershed organization boundaries. This supports the preparation of water management plans and promotes the protection and restoration of local and regional water resources (lakes, rivers, streams, wetlands, and groundwater).
- Facilitate discussions on regional water issues that transcend community or watershed organization boundaries.

Policy on sustainable water supplies

While recognizing local control and responsibility for owning, operating, and maintaining water supply systems, we will work with our partners 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.

Supporting actions related to supporting water availability, access, and use:

- Support community efforts to improve water supply resiliency by cooperatively identifying economically and technically feasible water supply alternatives.
- Facilitate discussions on water supply issues that transcend community boundaries through subregional work groups and on an ad hoc basis as needed.
- Collaborate with partners to perform special studies as needed.

Policy on assessing and protecting regional water resources

The Met 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.

Supporting actions related to supporting water availability, access, and use:

- With our many partners, monitor the quality of regional lakes and rivers and the quality and flow of regional streams.
- Work with our partners to fill gaps in assessments of lake, stream, river, and groundwater data.
- Assess and evaluate long-term water quality trends for the region's lakes, streams, and rivers and identify key issues to be addressed.
- Maintain a regional database that contains easily accessible water quality, quantity, and other water-related information collected as part of the Met Council's monitoring programs.
- In partnership with others, complete technical studies to understand regional and subregional long-term water supply availability and demand.
- 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.
- Convene stakeholders and collaborate with partners to identify implementation paths for water quality improvement.

Policy on water conservation and reuse

The Met Council will work with our partners to identify emerging issues and challenges for the region and identify solutions that include the use of water conservation, wastewater and stormwater reuse, and low-impact development practices to promote a more sustainable region.

Supporting actions related to supporting water availability, access, and use:

- Identify and pursue options to reuse treated wastewater to supplement groundwater and surface water as sources of water to support regional growth, when economically feasible.
- Encourage low-impact development, land uses, and cooperative water use practices that minimize impacts on aquifers.
- Investigate reusing treated wastewater, and when cost-effective, implement reuse.
- Provide research and guidance on best management practices to use for effective surface water management.
- In partnership with others, research and promote the development of innovative best management practices, including low-impact development technologies and agricultural practices.
- Install and monitor innovative practices to reduce nonpoint-source pollution at Council facilities and support economically feasible projects that demonstrate new technologies and their effectiveness.

Investment policy

The Met Council will strive to maximize regional benefits from regional investments.

Supporting actions related to supporting water availability, access, and use:

- Invest in nonpoint source pollution control when the cost and long-term benefits are favorable compared to further upgrading wastewater treatment.
- Consider pollutant trading or off-set opportunities with nonpoint sources of pollution when cost-effective and environmentally beneficial.
- Invest in wastewater reuse when justified by the benefits of supplementing groundwater and surface water as sources of non-potable water to support regional growth and by the benefits of maintaining water quality.
- Potentially invest strategically to further the effectiveness of the region's nonpoint source pollution prevention and control program and to ensure efficient investment to achieve regional water quality objectives.
- Support cost-effective investments in water supply infrastructure to promote sustainable use and protect the region's water supplies.

Policy on wastewater sustainability

The Met Council will provide efficient, high-quality, and environmentally sustainable regional wastewater infrastructure and services. The Met Council shall conduct its regional wastewater system operations in a sustainable manner as is economically feasible. Sustainable operations relate not only to water resources but also to increasing energy efficiency and using renewable energy sources; reducing air pollutant emissions; and reducing, reusing, and recycling solid wastes.

Supporting actions related to supporting water availability, access, and use:

- Implement and enforce Waste Discharge Rules for the regional wastewater system. Preserve regional wastewater system assets of the Met Council through effective maintenance, assessment of condition and capacity, and capital investment.
- Reuse treated wastewater to meet non-potable water needs within Met Council wastewater treatment facilities where economically feasible.
- Provide industries with incentives to pretreat wastewater to reduce its strength and thus provide the most environmental and economic benefit for the region.
- Improve sustainability of wastewater operations, when economically feasible.

Draft new and revised policy and implementation strategies/actions

The document's intent is to share our current understanding of issues, identify current policy connections or gaps, and to propose future policies and strategies to ensure sustainable water resources. Not all the recommendations included in this paper will move forward for inclusion into the Water Resources Policy Plan, and conversely, the Water Resources Policy Plan may include policies not discussed in this paper. The intent is to begin to develop a shared understanding and conversation about the protection of source water areas, which is foundational to a prosperous and sustainable region.

The scope of the issue presented in this research paper reveals the need for a regional One Water approach, increased strong regional policies, and better, more frequent collaboration to effectively act in ways that protect our source waters. Collaborations with cities and townships, watershed organizations, state and federal agencies, and other water practitioners can work to undo past harms and plan for water availability, access, and use. Addressing our region's complex water challenges requires diversity of thought, multiple perspectives, and innovative solutions.

Each recommendation starts with a general description of the proposed policy, followed by *draft* proposed policy and strategy (specific actions) language.

These recommendations are intended to spark discussion about policy direction for the 2050 Water Resources Policy Plan. They are not to be considered final recommendations.

As staff developed the following language, they considered:

- The feedback loop of the water system: source, users, use, and inputs
- The full range of Met Council functions and how they relate to the simple feedback loop of the water system
- How the Met Council can enhance and leverage partners' programs
- How proposed policies and related actions represent an integrated water and/or watershed approach
- How resilient the proposed policy and related actions might be under different scenarios of future growth and climate
- The equity impacts of proposed policies and related actions
- Feedback from Metro Area Water Supply Advisory Committee, Water Resources Policy Plan Advisory Group, and Met Council staff during an internal workshop on the topic of public health.

Planning for Sustainable Waters

Regional policymakers should consider establishing a clear policy for long-range integrated water planning to better address the root causes of water access, availability, and use issues. This should incorporate the watershed approach and connect it to water management throughout all our water planning efforts (groundwater, surface water, and wastewater). It should include support for long-term source water management.

<u>Proposed policy recommendation:</u>

The Metropolitan Council will work with our partners to develop and support sustainable waters through integrated water resource planning that addresses the region's water uses and needs.

Proposed actions:

- Convene a regional discussion to redefine the concept of "sustainable water" in order to direct and align efforts to support sustainable water resources.
- Update estimates of available water supplies, future water demands, and impacts of systemic shocks on metro region water.

- Through the review process for comprehensive plans, local water plans, and watershed management plans, Met Council staff will make water resources management a critical part of land use decisions, planning protocols and procedures. This will ensure these plans are making progress toward achieving state and regional goals for protection and restoration of water resources.
- The Met Council commits to regional long-term investments in our wastewater treatment and collection system to safeguard sustainable water – from both water supply demand and capacity impacts to wastewater system – for all residents and areas of the region.
- Create a guide to assist public water utilities in implementing asset management programs to identify aging and deficient areas of their water supply, treatment, storage, and distribution systems; estimate the costs to replace or rehabilitate these systems; prioritize the recommended improvements; and implement the improvements over a scheduled timeframe of 1 to 30 years.
- The Council will evaluate a range of water sources available for users in the region to tap for a variety of purposes, matching water quality and quantity to the requirements of the use.
  - Consider alternative water sources (i.e., surface water suppliers) for public water systems with groundwater supply challenges and/or drinking water standard exceedances.
  - Use reclaimed water for cooling systems, irrigation alternatives, etc., where feasible.

Research and data collection

Regional policymakers should consider establishing a more focused and integrated policy to gather and create data to assess regional water resources (groundwater, surface water, and wastewater). The region has additional assessment needs that are discussed in other research papers.

<u>Proposed policy recommendation:</u>

The Metropolitan Council will collaboratively research and gather regional water data and information on the quality and interconnection of the region's rivers, lakes, streams, and aquifers – to quantify impacts on regional water resources and measure success in achieving regional water goals.

Proposed actions:

- Research and understand how water use and access may be affected by gentrification, land use policies, etc., across the region.
- Create a database of narratives around the regional waters to understand how different people experience water and are impacted by policy and planning for city and township, watershed, and regional planners and water utility providers.
- Explore and identify data sources to support the understanding of water value and use, especially to increase the effectiveness of the Priority Water List.
- Research what "water access" means to people and understand all the pieces of water access at play in our region.

- Investigate cross-disciplinary water equity issues across Met Council planning systems – to “recognize how environment, housing, and infrastructure are linked across time and space.” (Keeler et al., 2020)
- Evaluate the impact of climate change on water quantity and availability to inform water demand decisions.
- Monitor PFAS data in public and private wells sampled by the state of Minnesota to determine areas of detections in the metro region (see MDH Interactive Dashboard at ***Interactive Dashboard for PFAS Testing in Drinking Water – MN Dept. of Health (state.mn.us)***).
- Investigate data, research, and regulations with respect to drinking water contaminants, including radionuclides, manganese, selenium, PFAS, and other emerging contaminants, and work with state health officials to track current trends and recommended best management practices.

Modeling and interpretation

Regional policymakers should consider establishing a more focused and integrated policy to develop models, tools, and resources to understand the impact of drivers and pressures on our regional water resources (groundwater, surface water, and wastewater). The region has additional tools and resource needs that are discussed in other research papers.

Proposed policy recommendation:

The Metropolitan Council will collaboratively develop tools and resources to better understand pressures on and interconnection of the region’s rivers, lakes, streams, and aquifers – to help regional, local, and watershed planners and water utility staff make informed water management decisions.

Proposed actions:

- Develop a regional water budget based on different demand and supply scenarios.
- Determine and plan regional growth to mitigate potential aquifer level decline through forecasting groundwater modeling, scenario planning, and targeted water conservation and efficiency efforts.
- Evaluate the uncertainty of aquifer productivity and extent, particularly in the parts of the metro region where the Prairie du Chien-Jordan aquifer is not present or currently being overused is needed.
- Identify, map, and evaluate groundwater recharge areas that are vulnerable to development so that their recharge value can be protected (e.g., wellhead protection areas).
- Model groundwater flow in the water table and interactions between surficial (Quaternary) aquifers and surface flows to better assess groundwater and surface water interactions.
- Develop injection capacity maps of regional aquifers to determine where intentional aquifer recharge could be viable to help mitigate withdrawal impacts on groundwater sources.

Technology, behavior, and training

Data collection and interpretation can provide a greater understanding of the interconnectedness of our regional waters; however, without the implementation of new technologies or changes in our behaviors, we will not achieve our desired outcome of clean waters for future generations. Policymakers should consider establishing a policy to promote and support regional water actions to have positive influences on our water availability, access, and use.

Proposed policy recommendation:

The Metropolitan Council will support and encourage residents, businesses, and water utilities to incorporate new technology and behaviors, where feasible, as a means of achieving water sustainability in the region.

Proposed actions:

- Support research and pilot projects with public water utilities to evaluate and use newer technologies such as predictive analytics to identify potential asset failures, accelerate repairs, and complete in situ underground pipe repair. This may optimize the use of funds when replacing and rehabilitating water distribution systems.
- Evaluate and consider community water softening treatment for public water systems that discharge chloride to sanitary sewer collection systems and ultimately to the Met Council wastewater treatment plants with our partners and public water utilities.
- Encourage private well owners to sample and test their well water for arsenic, PFAS, and other contaminants and install point of use treatment devices (i.e., reverse osmosis and granular activated carbon filtration systems) as needed.
- Promote and encourage partners and residents to participate in the Board of Soil and Water Resources' Lawns to Legumes program or other local turf grass alternative grants and implementation programs.
- In agricultural areas, promote agriculture best management practices including the timing, rate, placement, and source of fertilizer application; best healthy soil practices; and vegetated filter strips to provide vegetated land areas between pollutant sources and surface water bodies for non-agricultural areas.

Conservation and reuse

As investigated in the Water Reuse research paper, regional policymakers should consider improving the clarity and focus of the current reuse policy in addition to our water conservation policy. This would include recommended reuse and conservation approaches to increase water resources for water availability, access, and use more comprehensively.

Proposed policy recommendation:

The Metropolitan Council supports water conservation and stormwater and wastewater reuse in Minnesota, where feasible, as a means of achieving water sustainability in the region.

Proposed actions:

- Continue to support programs targeting water conservation implementation efforts like the Minnesota Technical Assistance Program (MnTAP) to assist local businesses.

- Promote customer engagement efforts to increase water conservation to extend the life expectancies for critical water infrastructure components.
- Determine if there are any major users of water that could be identified and targeted for quantity reductions, conservation, and water reuse where applicable.
- Encourage the Interagency workgroup on water reuse to develop recommendations that further stormwater and wastewater reuse and decrease demands on clean potable water while protecting residents and infrastructure from harm.
- Support ongoing research to direct residents and developers toward alternatives to using drinking water supplies for lawn watering, the installation of low maintenance turf (e.g., no-mow grass), or avoiding turf grass landscaping altogether to reduce impacts on summer water demand.

Funding & Support

A general understanding of how water and water infrastructure works and supports the prosperity of our region is vital. Public support and funding help to maintain and operate water infrastructure and will be needed as our infrastructure ages. This paper highlights the importance of a shared understanding and inclusion of multiple perspectives to sustain affordable and accessible waters.

Proposed policy recommendation:

The Metropolitan Council will support local water suppliers and other water organizations to develop regional water and water utility knowledge and funding mechanisms to operate and maintain water infrastructure to achieve usable, sustainable waters in the region.

Proposed actions:

- Support organizations promoting water equity and educational efforts improving the connection and relationship with residents and regional waters.
- Public water utilities should study and implement water utility rates that provide adequate funding to replace and rehabilitate aging infrastructure in addition to covering operational costs and depreciation.
- Public water systems should aggressively pursue federal and state infrastructure funding programs, as well as adopt public policies that promote innovation in the water sector.

Next steps

This topical research paper is the first step in the process of creating regional water policies to safeguard our waters and to protect the livability and prosperity of the region (Error! Reference source not found.). The ideas in this paper are intended to spark discussion and generate additional water-focused policy recommendations to provide the foundation of the 2050 Water Resources Policy Plan. This paper was created and reviewed by our Met Council staff. Our planned next step is to gather and include the perspectives of our partners on important policy recommendations.

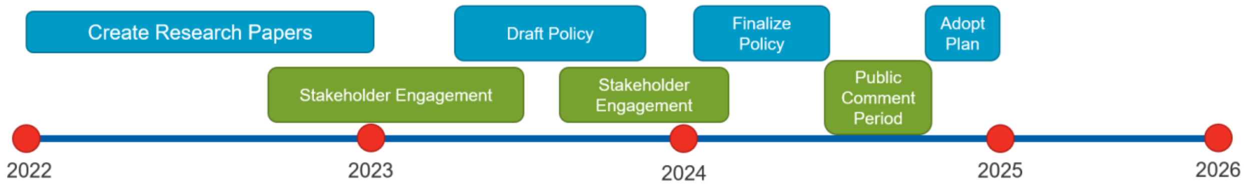


Figure 17: Water Resources Policy Plan timeline

After this additional information is gathered, we will update the draft policy recommendations through an interactive process of drafting policies, listening to stakeholder feedback, and integrating the information collected to assist our Met Council members in developing, evaluating, refining, and adopting these new policies. Alternating between engagement and policy creation will allow stakeholders to participate and shape plan content from the very beginning. This proposed process is an intentional attempt to bring more voices and perspectives to the table and to help us produce polices and implementation strategies that are reflective of the region’s water priorities.

If you have any questions or feedback about the content of this paper, please contact Jen Kostrzewski at ***jennifer.kostrzewski@metc.state.mn.us***.

References

33 U.S. Code § 1288. https://www.govinfo.gov/app/details/USCODE-2011-title33/USCODE-2011-title33-chap26-subchapII-sec1288

Allard A, Cipolla CN. 2018. The View From Watery Places: Rivers and Portages in the Fur Trade Era. Open Rivers J. [accessed 2022 Dec 21]. ***https://openrivers.lib.umn.edu/article/the-view-from-watery-places/***.

Anguelovski I, Connolly JJT, Cole H, Garcia-Lamarca M, Triguero-Mas M, Baró F, Martin N, Conesa D, Shokry G, del Pulgar CP, et al. 2022. Green gentrification in European and North American cities. Nat Commun. 13(1):3816. Doi:10.1038/s41467-022-31572-1.

Aponte R, Atlas-Ingebretson L, Bauer M, Burke J, Christensen E, Christianson M, Friesz K, Gruhn M, Hautala A. 2021 Mar 24. Minnesota Outdoor Recreation Task Force Recommendations.

Benotti M, Stanford B, Snyder S. 2010. Impact of Drought on Wastewater Contaminants in an Urban Water Supply. J Environ Qual. 39:1196–200. Doi:10.2134/jeq2009.0072.

Buturian L. 2018. The River is the Classroom. Open Rivers J. [accessed 2022 Dec 21]. ***https://openrivers.lib.umn.edu/article/the-river-is-the-classroom/***.

By Andrews, W.J., Fong, A.L., and Stark, J.R. 1997. Ground-Water Quality in the Northwestern Twin Cities Metropolitan Area, Minnesota. [accessed 2022 Dec 11]. ***https://mn.water.usgs.gov/nawqa/umis/publications/mwgc97.1.html***.

CDC/ATSDR. 2022. CDC/ATSDR SVI 2020 Documentation. ***https ://www.atsdr.cdc.gov/placeandhealth/svi/documentation/pdf/SVI2020Documentation_08.05.22.pdf***.

Dakota County. 2003. Hastings Area Nitrate Study. ***https://www.co.dakota.mn.us/Environment/WaterResources/WellsDrinkingWater/Documents/HastingsAreaNitrateStudy.pdf***.

Davis A, Matsumoto S. 2021 May 28. Minnesota looks to address disparities in outdoor recreation. MPR News. [accessed 2023 Jan 6]. ***https://www.mprnews.org/episode/2021/05/27/minnesota-looks-to-address-disparities-in-outdoor-recreation***.

Delin, G.H., Woodward, D.G. 1984. Hydrogeologic setting and the potentiometric surfaces of regional aquifers in the Hollandale Embayment, southeastern Minnesota, 1970-80. [accessed 2022 Dec 26]. ***http://pubs.er.usgs.gov/publication/wsp2219***.

Ek T. 2021. Hidden Waterways: Bassett Creek. Open Rivers J. [accessed 2022 Dec 21]. ***https://openrivers.lib.umn.edu/article/hidden-waterways-bassett-creek/***.

Engineering B, Council M. 2014. Twin Cities Metropolitan Area Groundwater Flow Model Version 3. :83.

Executive Order 21-35. 2021. Executive Order 21-35 Rescinding Executive Order 19-24. ***https://www.lrl.mn.gov/archive/execorders/21-35.pdf***

FDA. 2022 Mar 4. The Microbead-Free Waters Act: FAQs. FDA. [accessed 2022 Dec 23]. ***https://www.fda.gov/cosmetics/cosmetics-laws-regulations/microbead-free-waters-act-faqs***.

Ferraro, N. 2021. Dakota County passes stronger water regulations after company sought to ship water via rail to Southwest U.S.. Pioneer Press. [accessed 2023 May 5] ***https://www.twincities.com/2021/04/22/dakota-county-passes-stronger-water-regulations-after-company-sought-to-ship-water-via-rail-to-southwest-u-s/***.

Folkman S. 2018. Water Main Break Rates In the USA and Canada: A Comprehensive Study. Utah State Univ Buried Struct Lab.

Goetz EG, Lewis B, Damiano A, Calhoun M. 2019. THE DIVERSITY OF GENTRIFICATION: Multiple forms of gentrification in Minneapolis and St. Paul. Center for Urban and Regional Affairs: University of Minnesota.

Green E, Duever B, Pradhananga A. 2020. The Urban Mississippi: Valuing Connections in a Changing Climate. Open Rivers J. [accessed 2022 Dec 21]. ***https://openrivers.lib.umn.edu/article/the-urban-mississippi-valuing-connections-in-a-changing-climate/***.

Heck S. 2021. Greening the color line: historicizing water infrastructure redevelopment and environmental justice in the St. Louis metropolitan region. J Environ Policy Plan. 0(0):1–16. Doi:10.1080/1523908X.2021.1888702.

Homsy GC, Warner ME. 2020. Does public ownership of utilities matter for local government water policies? Util Policy. 64:101057. Doi:10.1016/j.jup.2020.101057.

Keeler BL, Derickson KD, Waters H, Walker R. 2020. Advancing Water Equity Demands New Approaches to Sustainability Science. One Earth. 2(3):211–213. Doi:10.1016/j.oneear.2020.03.003.

Lundy JR. 2010 Dec. Distribution of Radium in Minnesota Drinking Water Aquifers. :13.

Matteson S. 2018. Water Bar: Water is All We Have. Open Rivers J. [accessed 2022 Dec 21]. ***https://openrivers.lib.umn.edu/article/water-bar/***.

Mahron, Kirsti, 2022. Elko New Market's plan to tap aquifer for bottle water plant draws residents' ire. Minnesota Public Radio. [accessed 2023 May 8]. ***https://www.mprnews.org/story/2022/12/15/elko-new-markets-plan-to-tap-aquifer-for-bottled-water-plant-draws-residents-ire***

McDaris JR, Feinberg JM, Runkel AC, Levine J, Kasahara S, Alexander Jr. EC. 2022. Documentation and Prediction of Increasing Groundwater Chloride in the Twin Cities, Minnesota. Groundwater. 60(6):837–850. Doi:10.1111/gwat.13227.

McKay ČMS. 2020. Where We Stand: The University of Minnesota and Dakhóta Treaty Lands. Open Rivers J. [accessed 2022 Dec 21]. ***https://openrivers.lib.umn.edu/article/where-we-stand/***.

Metropolitan Council. 2015a. Master-Water-Supply-Plan,-Chapters-1-8.pdf. [accessed 2022 Dec 16]. ***https://metrocouncil.org/Wastewater-Water/Publications-And-Resources/WATER-SUPPLY-PLANNING/MASTER-WATER-SUPPLY-PLAN-2015/Master-Water-Supply-Plan,-Chapters-1-8.aspx***.

Metropolitan Council. 2015b. MCES Joint Water Utility Feasibility Study. ***https://metrocouncil.org/Wastewater-Water/Publications-And-Resources/WATER-SUPPLY-PLANNING/OTHER/Joint-Water-Utility-Feasibility-Study.aspx***.

Metropolitan Council. 2016 Dec. Twin Cities Regional Water Billing Analysis 2016. :42.

Metropolitan Council. 2018a. Regional Climate Vulnerability Assessment. ***https://metrocouncil.org/Communities/Planning/Local-Planning-Assistance/CVA/Files/CVA-Introduction.aspx***.

Metropolitan Council. 2018b. Sewer separation, inflow and infiltration reduction efforts are paying off. Metrop Counc. [accessed 2022 Dec 21]. ***https://metrocouncil.org/News-Events/Wastewater-Water/Newsletters/Sewer-separation,-inflow-and-infiltration-reductio.aspx***.

Metropolitan Council. 2018c. 2040 Water Resources Policy Plan. [accessed 2023 May 8]. ***https://metrocouncil.org/Wastewater-Water/Planning/2040-Water-Resources-Policy-Plan/WATER-RESOURCES-POLICIES/Water-Resources-Policy-Plan.aspx***

Metropolitan Council. 2019. MCES Wastewater Services and Integrated Planning -2019 Performance Report. ***https://metrocouncil.org/Wastewater-Water/Publications-And-Resources/MCES-INFORMATION/MCES-Performance-Report-2019.aspx***.

Metropolitan Council. 2020a. WATER SUPPLY PLANNING IN THE TWIN CITIES METROPOLITAN AREA. :44.

Metropolitan Council. 2020b. INTERACTIONS OF GROUNDWATER AND SURFACE WATER RESOURCES.

Metropolitan Council. 2021. Twin Cities Region Forecasted to Reach Four Million Residents by 2050 (2021 update). [accessed 2022 Dec 12]. ***https://metrocouncil.org/Data-and-Maps/Publications-And-Resources/MetroStats/Land-Use-and-Development/Twin-Cities-Forecasted-to-Reach-Four-Million-Resid.aspx***.

Metropolitan Council. 2022a. Source Water Protection. Metrop Counc. [accessed 2023 Jan 6]. ***https://metrocouncil.org***.

Metropolitan Council. 2022b. Water Supply Basics. Metrop Counc. [accessed 2023 Jan 6]. ***https://metrocouncil.org***.

Metropolitan Council. 2022c. Priority Waters List. Metrop Counc. [accessed 2022 Dec 22]. ***https://metrocouncil.org***.

Metropolitan Council. 2022d. Water Resources Policy Plan. :110.

Metropolitan Council. 2022e. Localized Flood Risk. Metrop Counc. [accessed 2022 Dec 22]. ***https://metrocouncil.org***.

Metropolitan Council. 2022f. Inflow and Infiltration. Metrop Counc. [accessed 2022 Dec 23]. ***https://metrocouncil.org***.

Metropolitan Council. 2023. Community Profiles: Economy and Jobs [accessed 2023 May 8]. ***https://stats.metc.state.mn.us/profile/detail.aspx?c=R11000***

Metropolitan Council. Water Cycle. Metrop Counc. [accessed 2022 Dec 12]. ***https://metrocouncil.org***.

Minneapolis C of. 2022. Treatment and delivery process – Public Works Water Treatment & Distribution Services. [accessed 2022 Dec 20]. ***https://www2.minneapolismn.gov/government/departments/public-works/water-treatment-distribution/treat-deliver/***.

Minneapolis C of. Water Mains: Cleaning & Lining FAQ – Public Works Water Treatment & Distribution Services. ***https://www.minneapolismn.gov/media/-www-content-assets/documents/Water-Mains-Cleaning–Lining-FAQ.pdf***.

Minnesota Department of Agriculture. 2022. Phosphorus Lawn Fertilizer Law | Minnesota Department of Agriculture. [accessed 2022 Dec 21]. ***https://www.mda.state.mn.us/phosphorus-lawn-fertilizer-law***.

Minnesota Department of Health. 2019. Microplastics and Nanoplastics in the Environment. ***https://www.house.leg.state.mn.us/comm/docs/67f7ca46-d89f-42a1-9b2a-7bb777d32d2f.pdf***.

Minnesota Department of Health. 2022a. Consumer Confidence Reports – MN Dept. of Health. [accessed 2022 Dec 21]. ***https://www.health.state.mn.us/communities/environment/water/com/ccr.html***.

Minnesota Department of Health. 2022b. Iron in Well Water – MN Dept. of Health. [accessed 2022 Dec 12]. ***https://www.health.state.mn.us/communities/environment/water/wells/waterquality/iron.html***.

Minnesota Department of Health. 2022c. Manganese in Drinking Water. [accessed 2022 Dec 12]. ***https://www.health.state.mn.us/communities/environment/water/contaminants/manganese.html***.

Minnesota Department of Health. 2022d. Radium in drinking water in Minnesota: MNPH Data Access – MN Dept. of Health. MN Data. [accessed 2022 Dec 12]. ***https://data.web.health.state.mn.us/radium-messaging***.

Minnesota Department of Health. 2022e. Nitrate in Drinking Water. [accessed 2022 Dec 21]. ***https://www.health.state.mn.us/communities/environment/water/contaminants/nitrate.html***.

Minnesota Department of Health. Drinking Water Revolving Fund Project Priority List – MN Dept. of Health. [accessed 2023a Jan 4]. ***https://www.health.state.mn.us/communities/environment/water/dwrf/ppl.html***.

Minnesota Department of Health. BaP Information Sheet. ***https://www.health.state.mn.us/communities/environment/risk/docs/guidance/gw/bapinfosheet.pdf***.

Minnesota Department of Natural Resources. 2022. Minnesota Water Use Data. Minn Dep Nat Resour. [accessed 2022 Dec 11]. ***https://www.dnr.state.mn.us/waters/watermgmt_section/appropriations/wateruse.html***.

Minnesota Department of Natural Resources. 2022 Jun 1. DNR introduces all-terrain track chairs to Minnesota state parks. Minn Dep Nat Resour. [accessed 2023 Jan 6]. ***https://www.dnr.state.mn.us/news/2022/06/01/dnr-introduces-all-terrain-track-chairs-minnesota-state-parks***.

Minnesota Pollution Control Agency. 2022a. Water quality standards. Minn Pollut Control Agency. [accessed 2022 Dec 22]. ***https://www.pca.state.mn.us/business-with-us/water-quality-standards***.

Minnesota Pollution Control Agency. 2022b. Investing in East Metro drinking water | Minnesota 3M PFAS Settlement. [accessed 2023 Jan 6]. ***https://3msettlement.state.mn.us/investing-east-metro-drinking-water***.

Minnesota Pollution Control Agency. 2022c. Minnesota Groundwater Contamination Atlas. [accessed 2023 Jan 6]. ***https://webapp.pca.state.mn.us/cleanup/search/superfund?siteId=189593-AREA0000000002***.

Minnesota Pollution Control Agency. 2022d. .

Minnesota Pollution Control Agency. 2022e. Developing water-quality criteria for PFAS. Minn Pollut Control Agency. [accessed 2022 Dec 23]. ***https://www.pca.state.mn.us/air-water-land-climate/developing-water-quality-criteria-for-pfas***.

Minnesota Pollution Control Agency. Minnesota Statewide Chloride Management Plan. Report No.: wq-s1-94. ***https://www.pca.state.mn.us/sites/default/files/wq-s1-94.pdf***.

Volatile organic compounds (VOCs). Minn Pollut Control Agency. [accessed 2022 Dec 23]. ***https://www.pca.state.mn.us/pollutants-and-contaminants/volatile-organic-compounds-vocs***.

Minnesota Pollution Control Agency. Minnesota Conceptual Drinking Water Supply Plan. [accessed 2023a Jan 3]. ***https://3msettlement.state.mn.us/investing-east-metro-drinking-water***.

Minnesota Pollution Control Agency. Minnesota 3M PFAS Settlement – Community Toolkit. [accessed 2023b Jan 3]. ***https://3msettlement.state.mn.us/community-toolkit***.

Minnesota Pollution Control Agency. Twin Cities Metropolitan Area Chloride Management Plan.

Minnesota Statutes § 473.145. (2022). https://www.revisor.mn.gov/statutes/cite/473.145

Minnesota Statutes § 473.157 (2022). https://www.revisor.mn.gov/statutes/cite/473.157

Minnesota Statutes § 473.1565. (2022). https://www.revisor.mn.gov/statutes/cite/473.1565

Morgenson, Gretchen. 2021. Some locals say a bitcoin mining operation is ruining one of the Finger Lakes. Here's how. NBC News. [accessed 2023 May 3]. ***https://www.nbcnews.com/science/environment/some-locals-say-bitcoin-mining-operation-ruining-one-finger-lakes-n1272938***.

Morrison D. 2021. Why Canoes? An Exhibit at the University of Minnesota's Northrop Gallery. Open Rivers J. [accessed 2022 Dec 21]. ***https://openrivers.lib.umn.edu/article/why-canoes/***.

Mossler, J.H. 2008. PALEOZOIC STRATIGRAPHIC NOMENCLATURE FOR MINNESOTA. [accessed 2022 Dec 26]. ***https://conservancy.umn.edu/bitstream/handle/11299/58940/RI65%5b1%5d.pdf?sequence=1&isAllowed=y***.

Mossler JH, Tipping RG. 2000. Bedrock geology and structure of the seven-county Twin Cities metropolitan area, Minnesota. [accessed 2022 Dec 26]. ***https://conservancy.umn.edu/bitstream/handle/11299/57005/M-104.pdf?sequence=2&isAllowed=y***.

MPRNews. 2022 Oct 31. Minnesota readies high-tech effort to clean up “forever chemicals.” MPR News. [accessed 2022 Dec 21]. ***https://www.mprnews.org/story/2022/10/31/minnesota-cleanup-forever-chemicals-pfas***.

Nesterak, Max, 2020. Becker bags $20.5 million from state spending package for business park. Minnesota Reformer. [accessed 2023 May 8]. ***https://minnesotareformer.com/briefs/becker-bags-20-5-million-from-state-spending-package-for-business-park/***

O’Hare WP. 2019. Differential Undercounts in the U.S. Census: Who is Missed? Cham: Springer International Publishing (SpringerBriefs in Population Studies). [accessed 2022 Dec 20]. ***http://link.springer.com/10.1007/978-3-030-10973-8***.

Overbo A, Heger S, Kyser S, Asleson B, Gulliver J. Chloride Contributions from Water Softeners and Other Domestic, Commercial, Industrial, and Agricultural Sources to Minnesota Waters.

Patel M, Kumar R, Kishor K, Mlsna T, Pittman CUJr, Mohan D. 2019. Pharmaceuticals of Emerging Concern in Aquatic Systems: Chemistry, Occurrence, Effects, and Removal Methods. Chem Rev. 119(6):3510–3673. doi:10.1021/acs.chemrev.8b00299.

Pradhananga A, Davenport M, Green E. 2019. Cultural Narratives on Constraints to Community Engagement in Urban Water Restoration. J Contemp Water Res Educ. 166(1):79–94. doi:10.1111/j.1936-704X.2019.03303.x.

Reddy AS, Nair AT. 2022. The fate of microplastics in wastewater treatment plants: An overview of source and remediation technologies. Environ Technol Innov. 28:102815. doi:10.1016/j.eti.2022.102815.

Roman Kanivetsky. 2000. ARSENIC IN MINNESOTA GROUND WATER: HYDROGEOCHEMICAL MODELING OF THE QUATERNARY BURIED ARTESIAN AQUIFER AND CRETACEOUS AQUIFER SYSTEMS. [accessed 2022 Dec 11]. ***https://conservancy.umn.edu/bitstream/handle/11299/58792/RI55%5b1%5d.pdf?sequence=2&isAllowed=y***.

Rosinger AY, Herrick KA, Wutich AY, Yoder JS, Ogden CL. 2018. Disparities in plain, tap and bottled water consumption among US adults: National Health and Nutrition Examination Survey (NHANES) 2007–2014. Public Health Nutr. 21(8):1455–1464. doi:10.1017/S1368980017004050.

Rosinger AY, Young SL. 2020. The toll of household water insecurity on health and human biology: Current understandings and future directions. WIREs Water. 7(6). doi:10.1002/wat2.1468. [accessed 2022 Dec 7]. ***https://onlinelibrary.wiley.com/doi/10.1002/wat2.1468***.

Roth S, Davenport M, Keeler B. 2022. Urban Water Values in the Twin Cities Phase 1 Survey Research. University of Minnesota-Twin Cities: Water Resources Center and Center for Changing Landscapes.

Runkel, A.C., Tipping, R.G., Alexander, E.C., Green, J.A. 2003. HYDROGEOLOGY OF THE PALEOZOIC BEDROCK IN SOUTHEASTERN MINNESOTA. [accessed 2022 Dec 26]. ***https://conservancy.umn.edu/bitstream/handle/11299/58813/RI_61%5b1%5d.pdf?sequence=4&isAllowed=y***.

Runkel AC, Tipping RG, Mossler JH. 2003. GEOLOGY IN SUPPORT OF GROUNDWATER MANAGEMENT FOR THE NORTHWESTERN TWIN CITIES METROPOLITAN AREA.

Sanocki CA, Langer SK, Menard JC. 2008. Potentiometric Surfaces and Changes in Groundwater Levels in Selected Bedrock Aquifers in the Twin Cities Metropolitan Area, March–August 2008 and 1988–2008. Scientific Investigations Report.

Shandilya R, Bresciani E, Runkel A, Jennings C, Lee S, Kang P. 2022. Aquifer-scale mapping of injection capacity for potential aquifer storage and recovery sites: Methodology development and case studies in Minnesota, USA. J Hydrol Reg Stud. 40. doi:10.1016/j.ejrh.2022.101048.

SMSC. 2022a. SMSC Stewards of the Environment. Shakopee Mdewakanton Sioux Community. [accessed 2022 Dec 22]. ***https://shakopeedakota.org/culture/our-environmental-stewardship/***.

SMSC. 2022b. SMSC Water Reclamation Facility. Shakopee Mdewakanton Sioux Community. [accessed 2022 Dec 22]. ***https://shakopeedakota.org/land/water-reclamation-facility/***.

St. Paul C of. 2022a. Story of our Water - St.Paul. [accessed 2022 Dec 20]. ***https://stpaul.maps.arcgis.com/apps/Cascade/index.html?appid=e7404d2e4ac848d8a1672aedc63817ef***.

St. Paul C of. 2022b. About Your Water - St.Paul. St Paul Minn. [accessed 2022 Dec 20]. ***https://www.stpaul.gov/departments/saint-paul-regional-water-services/about-your-water***.

St. Paul C of. 2022c. Water Treatment Process. St Paul Minn. [accessed 2022 Dec 27]. ***https://www.stpaul.gov/water-treatment-process***.

St. Paul C of. Pipelining: Investing in the Future. St Paul Minn. [accessed 2022 Dec 23]. ***https://www.stpaul.gov/departments/public-works/sewer-utility-division/pipelining-investing-future***.

Stanley, Greg. 2023. DNR: *Bottled water plant proposed for Elko New Market poses no threat to environment. Star Tribune.* [accessed 2023 May 3]. https://www.startribune.com/dnr-bottled-water-plant-proposed-for-elko-new-market-poses-no-threat-to-environment/600255167/

State of Minnesota. 2018. Lower St. Croix River Watershed (LSCRW) Groundwater Restoration and Protection Strategies Report. [accessed 2022 Dec 12]. ***https://www.health.state.mn.us/communities/environment/water/docs/cwf/grapslscrw.pdf***.

St. Louis Park. 2022. Minnetonka Boulevard Watermain Breaks | St. Louis Park, MN. [accessed 2022 Dec 21]. ***https://www.stlouisparkmn.gov/our-city/in-the-news/minnetonka-boulevard-water-main-break***.

Timmons B. 2021 Feb 19. Task force suggests Minnesota needs a new outdoors office. Star Trib. [accessed 2023 Jan 6]. ***https://www.startribune.com/task-force-suggests-minnesota-needs-a-new-outdoors-office/600024731/***.

Tuser C. 2021 Sep 9. What is One Water? Water Waste Dig. ***https://www.wwdmag.com/editorial-topical/one-water/article/10940010/what-is-one-water***.

US EPA O. 2013 Mar 12. The Sources and Solutions: Agriculture. [accessed 2022 Dec 21]. ***https://www.epa.gov/nutrientpollution/sources-and-solutions-agriculture***.

US EPA O. 2015 Oct 13. Surface Water Treatment Rules. [accessed 2022 Dec 21]. ***https://www.epa.gov/dwreginfo/surface-water-treatment-rules***.

US EPA O. 2015 Sep 3. Drinking Water Regulations and Contaminants. [accessed 2023 Jan 3]. ***https://www.epa.gov/sdwa/drinking-water-regulations-and-contaminants***.

US EPA O. 2016 Jul 12. WaterSense. [accessed 2023 Jan 6]. ***https://www.epa.gov/watersense***.

US EPA O. 2018 Nov 15. Report: EPA Unable to Assess the Impact of Hundreds of Unregulated Pollutants in Land-Applied Biosolids on Human Health and the Environment. [accessed 2022 Dec 21]. ***https://www.epa.gov/office-inspector-general/report-epa-unable-assess-impact-hundreds-unregulated-pollutants-land***.

US EPA O. 2021 Oct 14. Our Current Understanding of the Human Health and Environmental Risks of PFAS. [accessed 2022 Dec 21]. ***https://www.epa.gov/pfas/our-current-understanding-human-health-and-environmental-risks-pfas***.

US Water alliance. 2022. The Path to Universally Affordable Water Access: Guiding Principles for the Water Sector.

USGS. 2018. Pharmaceuticals in Water | U.S. Geological Survey. [accessed 2022 Dec 23]. ***https://www.usgs.gov/special-topics/water-science-school/science/pharmaceuticals-water***.

USGS. 2022a. Integrated Water Availability Assessments (IWAAs). [accessed 2022 Dec 22]. ***https://www.usgs.gov/mission-areas/water-resources/science/integrated-water-availability-assessments-iwaas***.

USGS. 2022b. USGS Minnesota Water Projects. [accessed 2022 Dec 21]. ***https://mn.water.usgs.gov/projects/EACWWTP/index.html***.

Vue L. 2022. Water Memories: Exploring Our Relationship with Water. Open Rivers J. [accessed 2022 Dec 21]. ***https://openrivers.lib.umn.edu/article/water-memories/***.

Walker RH. 2021. Engineering gentrification: urban redevelopment, sustainability policy, and green stormwater infrastructure in Minneapolis. J Environ Policy Plan. 23(5):646–664. doi:10.1080/1523908X.2021.1945917.

Why Treaties Matter. 2022. 1837 Land Cession Treaties with the Ojibwe & Dakota. [accessed 2022 Dec 14]. ***http://treatiesmatter.org/treaties/land/1837-ojibwe-dakota***.

Xia P. 2021 May 29. Environmental Impacts of Chloride Contamination. ArcGIS StoryMaps. [accessed 2023 Jan 3]. ***https://storymaps.arcgis.com/stories/f998c640cc7d4fc9bca0d0aba8adffeb***.