Lower Minnesota River West (LMRWW)

Groundwater Restoration and Protection Strategies Report

July 2021

GRAPS Report 18

MINNESOTA

Lower Minnesota River West Watershed Groundwater Restoration and Protection Strategies Report

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The development of the GRAPS report was funded by money received from the Clean Water Fund through the Clean Water, Land, and Legacy Amendment. The goal of the Clean Water Fund is to protect, enhance, and restore Minnesota's lakes, rivers, streams, and groundwater.

Contributors

The following agencies dedicated staff time and resources toward the development of the Lower Minnesota River West Watershed GRAPS report:

- Minnesota Board of Water and Soil Resources (BWSR)
- Minnesota Department of Agriculture (MDA)
- Minnesota Department of Health (MDH)
- Minnesota Department of Natural Resources (DNR)
- Minnesota Pollution Control Agency (MPCA)

Photo Credit: The photo on the front page is in the Lower Minnesota River Watershed, courtesy of the Sibley Soil and Water Conservation District.

Summary

Groundwater is an important resource in the Lower Minnesota River West Watershed (LMRWW) One Watershed One Plan (1W1P) planning effort[1]. Permitted groundwater use increased from about 475 million gallons per year in 1990 to about 970 million gallons per year in 2009. Groundwater use slowly declined to about 820 million gallons per year in 2018. Approximately 60 percent of groundwater use is for water supply and 24 percent is used for industrial processing. In addition, groundwater accounts for 100 percent of the region's drinking water. It is important to ensure adequate supplies of high quality groundwater remain available for the region's residents, businesses, and natural resources.

Consumers in the LMNWW depend primarily on buried sand and gravel aquifers for drinking water. These aquifers are covered by fine-grained sediment deposited by glaciers during the most recent ice age. In the eastern half of the watershed, drinking water is also sourced from bedrock sandstone aquifers. To a far lesser extent, some consumers in the northeast corner of the watershed get their drinking water from bedrock carbonate units that are fractured enough to serve as aquifers.

Groundwater has a greater risk to contamination in areas of high pollution sensitivity[2]. Although the majority of the LMNWW is protected by layers of dense glacial till, the eastern edge of the watershed along the Minnesota River has permeable sand and gravel at the surface. Understanding pollution sensitivity is a key consideration to prevent groundwater pollution. Many land-use activities (including row crop agriculture, stormwater, septic systems, and tanks/landfills) within the watershed could contaminate groundwater if pollutants are not carefully managed, especially in areas of high pollution sensitivity.

Contamination, both naturally occurring and from human activity, is present in parts of the watershed groundwater, specifically:

- **Nitrate** – only 2 of the 1148 tested drinking water wells (less than one percent) had nitrate levels at or above the SDWA standard of 10 mg/L.
- **Arsenic** – 86 of the 320 tested drinking water wells had arsenic levels exceeding the SDWA of 10 µg/L. The EPA has set a goal of 0 µg/L for arsenic in drinking water because there is no safe level of arsenic in drinking water.
- **Contaminated sites –** there are 93 active tank sites that could leak chemicals into the environment and 6 leak sites that may cause localized groundwater pollution if not properly managed. The risk to groundwater is greatest in areas of high pollution sensitivity.

[1] For this report, the boundary of the LMRWW is the HUC 8 major watershed with no changes for planning purposes.

[2] Areas of high pollution sensitivity allow the rapid downward movement of water into surficial sands (water table) aquifers, increasing the risk for groundwater contamination from surface pollutants.

- One closed landfill with known groundwater contamination plume is found within the watershed.

These contaminants can affect both private wells and public water systems when levels exceed drinking water standards. About 52 percent of the people living in the watershed get their drinking water from a community public water supply system. Wellhead Protection Plans have been developed for 6 of the 10 community public water systems in the LMNWW and identify land use protections strategies for the approximately 5,400 acres in Drinking Water Supply Management Areas (DWSMAs).

Permitted groundwater is primarily sourced from buried sand and gravel aquifers, along with bedrock aquifers in the watershed. There are 21 active groundwater-level monitoring wells in the LMNWW, but none of them have yet reached the minimum 20 years of continuous recording needed to calculate a long-term trend.

Activities on the land surface can affect groundwater levels by reducing infiltration (groundwater recharge) especially in the southern portion of the watershed; these activities include changes in vegetation, increased areas of impervious surface, and changing surface water or stormwater flow.

The LMRWW includes significant natural features, including surface waters that depend on groundwater to sustain them. If groundwater quantity or quality is degraded, these resources are at risk. The following features occur within the watershed:

- One calcareous fen.
- There are 25 lakes in the LMRWW with a with a lake ratio of 10 or less and are considered groundwater dependent lakes, susceptible to changing aquifer levels.
- Wetland complexes across the entire watershed are susceptible to changing aquifer levels.
- There are ten kinds of native plant communities associated or dependent on groundwater in the LMRWW. They range from wet prairies and meadows to marshes, fens, seepage meadows, and floodplain forests. The watershed has lost almost all its native plant communities so those that remain are a high priority for preservation to achieve healthy groundwater systems.
    - Additionally, 13 species of birds, mussels, reptiles, and plants that are either state-listed endangered, threatened, or special concern plant and animal species connected to groundwater that are at risk to changing aquifer levels and degraded groundwater quality.

To address risks both from groundwater overuse and from the introduction of pollutants, this report outlines a broad range of strategies that can be implemented, as well as specific actions that individuals, local government, and other partners can take. The nine categories of strategies highlighted below were selected to address the key risks to groundwater and drinking water within the 1W1P planning area. Areas of higher pollution sensitivity is often an appropriate place to prioritize pollution prevention activities.

1. **Education and Outreach:** Educate landowners, private well users, and others about how their actions affect groundwater and how they can conserve, restore, and protect groundwater.
2. **SSTS Management:** Monitor, maintain, and/or upgrade SSTS to ensure proper operation and treatment.
3. **Irrigation Water Management:** Control the volume, frequency, and application rate of irrigation water to sustain groundwater.
4. **Land Use Planning and Management:** Use city or county government planning and regulations along with land management goals that implement best management practices (BMPs), conserve water, and educate stakeholders to protect groundwater levels, quality, and contributions to groundwater dependent features.

5. **Contaminant Planning and Management:** Use land use planning, ordinances, and collaboration with state regulatory agencies to protect groundwater and drinking water supplies from contaminant releases.
6. **Conservation Easements:** Maintain and expand the amount of land protected from being converted to high intensity uses, such as row crop agriculture.
7. **Cropland Management:** Encourage the implementation of voluntary practices to manage resource concerns while minimizing environmental loss.
8. **Nutrient Management:** Assure that application of crop fertilizer or manure follows guidelines for the right source, right rate, right time, and right place.
9. **Integrated Pest Management:** Implement a pest management approach that incorporates the many aspects of plant health care/crop protection in ways that mitigate harmful environmental impacts and protect human health.

This GRAPS report was designed to help prioritize and target local efforts to restore and protect groundwater resources in the watershed. Representatives from BWSR, MDA, MDH, DNR, and MPCA compiled existing state and regional data, and developed maps to establish a baseline understanding of groundwater conditions and associated resource management concerns for the 1W1P planning boundary. The team highlighted strategies and supporting actions that can be applied at a county or watershed-level to help restore and protect groundwater. To target local implementation, actions listed in this report are paired with those counties and subwatersheds (HUC-10) where risks have been identified. This report should be used in conjunction with the WRAPS report, which focuses on surface water issues and needs, to ensure that both groundwater and surface water are effectively addressed during the 1W1P planning process.[3]

[3] It is important to note that groundwater science lacks the predictive tools available for surface water analysis and as such cannot provide quantifiable strategies commonly found in WRAPS. BWSR recognizes this challenge and has provided guidance in the Setting Measurable Goals document (https://bwsr.state.mn.us/sites/default/files/2019-09/1W1P_guidebook.pdf) to meet the 1W1P measurability requirement.

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Introduction

What Is the GRAPS Report?

The State of Minnesota adopted a watershed approach to address the state's 80 major watersheds[4]. Major watersheds are denoted by an 8-digit hydrologic unit code (HUC). This watershed approach incorporates water quality assessment, watershed analysis, civic engagement, planning, implementation, and measurement of results into a 10-year cycle that addresses both watershed restoration and protection (Figure 1).

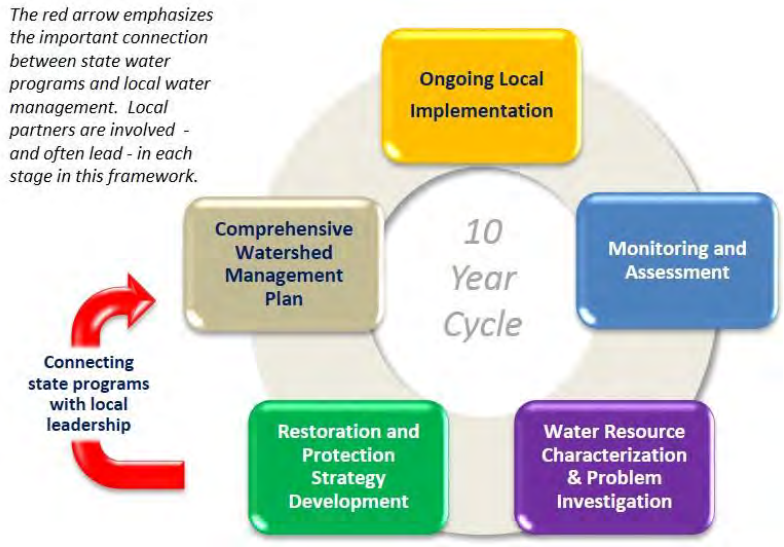

Figure 1: Watershed Approach Framework

Groundwater Restoration and Protection Strategies (GRAPS) reports are designed to help prioritize and target local efforts to restore and protect groundwater resources in the One Watershed One Plan (1W1P) planning process. While groundwater is not broken into watersheds like surface water, several state agencies have worked together to compile information and strategies for groundwater below surface water watersheds. A GRAPS report uses existing state data and information about groundwater and land-use practices that affect groundwater in the watershed to identify key groundwater quality and quantity concerns. The report also suggests targeted strategies and actions to restore and protect groundwater. GRAPS reports are meant to be used in conjunction with Watershed Restoration and Protection Strategies (WRAPS) reports in the development of 1W1P plans. WRAPS inform how to restore and protect surface water, and GRAPS inform how to restore and protect groundwater in the same geographic area.

WRAPS is initiated through an intensive monitoring effort to determine if a surface water body is meeting its designated use. WRAPS identify actions and the rate of adoption needed to restore water quality, as well as

[4] You can learn more about the Watershed Approach at Watershed approach to restoring and protecting water quality (www.pca.state.mn.us/water/watershed-approach-restoring-and-protecting-water-quality).

recognizing protection based activities to maintain the health of high quality surface waters. GRAPS is largely protection-based—identifying actions to maintain groundwater quality and quantity. However, if contaminants exist or overuse is suspected, the strategies and actions identified to address the issue can result in restoration as well as protection. In most cases it is very difficult determine the rate of BMP adoption needed to restore groundwater, therefore quantification is not part of GRAPS.

How to Use this Report

This report is a resource and tool for developing local water management plans. The report is divided into six parts to accommodate the different needs and information partners and agencies may seek. This report is not necessarily designed to be read cover to cover. Rather, you can flip to the parts that are most relevant to the issues facing your community. If you are accessing this document electronically, you can click on hyperlinks throughout the report to jump to related information and/or access webpages (all hyperlinks are in blue type).

The report is divided into the following parts:

1. Watershed Overview: This section provides a brief overview of the watershed.
2. Watershed Groundwater Issues and Concerns: This section highlights the main groundwater quality and quantity concerns, where each concern is most prevalent within the watershed, and general ways to address the concern.
3. Watershed Strategies and Actions to Protect and Restore Groundwater: This section provides tips for prioritizing and targeting restoration and protection strategies, makes suggestions about what strategies and actions would be most appropriate in which counties and subwatersheds, describes the suggested strategies, and provides information about existing programs and resources for each strategy.
4. Making Sense of the Regulatory Environment: This section provides an overview of the roles state agencies play in managing groundwater and drinking water.
5. Appendices

Lower Minnesota River West Watershed Overview

This report provides a brief overview of land use, geology, hydrogeology, pollution sensitivity, wellhead protection planning and drinking water, and water use and groundwater withdrawals affecting the Lower Minnesota River West Watershed (LMRWW) 1W1P planning boundary groundwater quality and quantity. You can find more detailed information about the LMRWW and groundwater through the following resources:

Restoration and Protection Plans

- MPCA watershed reports (www.pca.state.mn.us/water/watersheds/lower-minnesota-river)

The WRAPS report for the watershed identified land use, primarily agriculture, as a key contributor to water quality impairments. The report identified key strategies, including perennial vegetation, nutrient management, and soil health as key measures to address impairments. These same strategies are also effective in protecting groundwater resources, especially when in areas of highly pollution sensitivity.

The LMRWW is a rural agricultural landscape that is sparsely populated in southeastern Minnesota, encompassing most of Sibley County and parts of Renville, McLeod and Nicollet counties (Figure 2). The cities of Gaylord and Arlington are two of the largest communities in the watershed.

Of the roughly 18,600 people living in the watershed, approximately 9,575 (52 percent) utilize community public water and the remaining 48 percent obtain their drinking water from private wells.

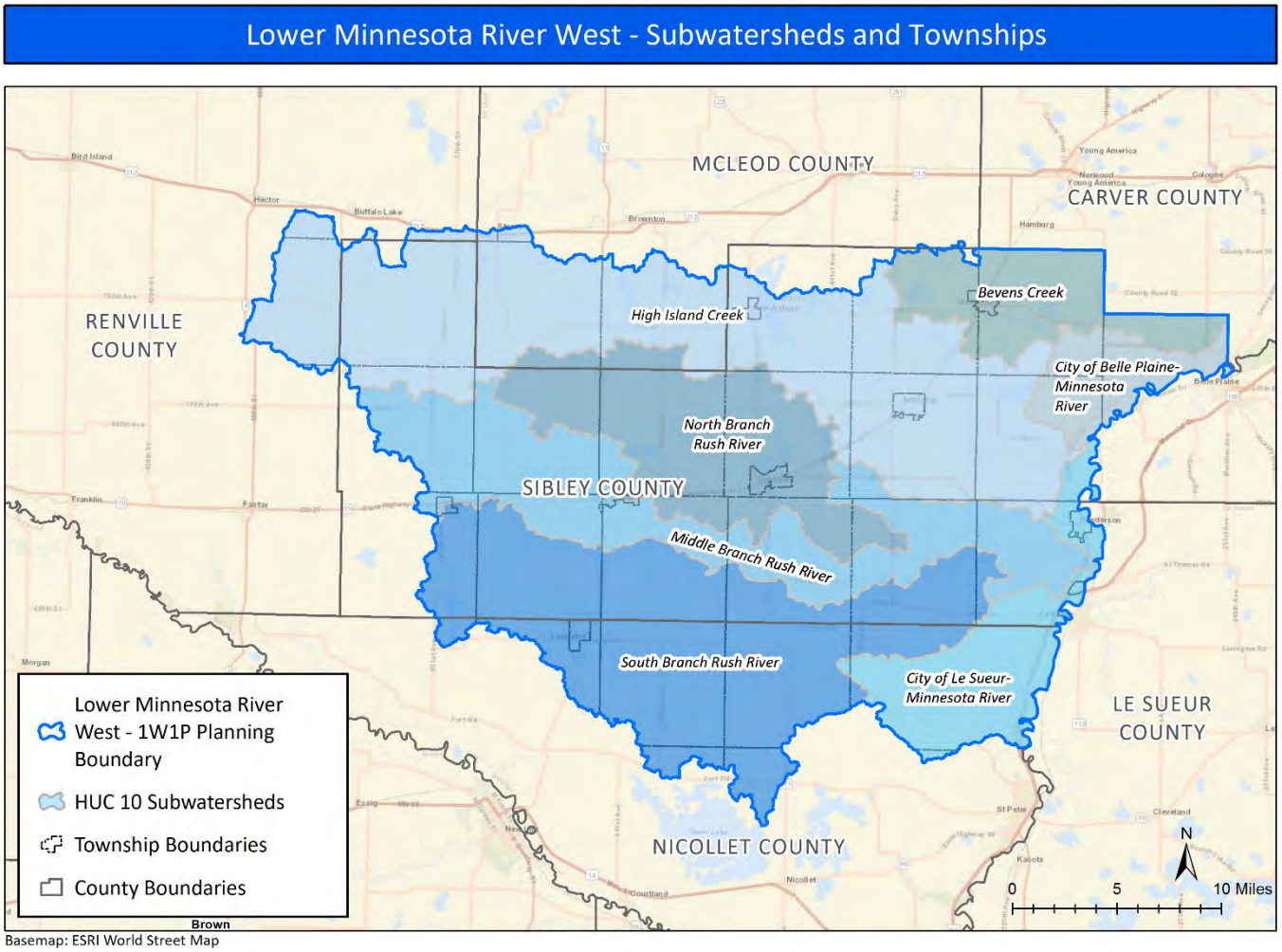

Figure 2: Lower Minnesota River West Watershed - is comprised of seven subwatersheds (HUC-10)

Land Use

The western two-fifths of the LMRWW is located in the Western Cornbelt Plains with the remaining part of the watershed in the North Central Hardwood Forest ecoregion. Land use is almost exclusively row-crop agriculture (Figure 3: Lower Minnesota River West Watershed - Land Cover. Row-crop agriculture is the predominant land cover in the watershed.).

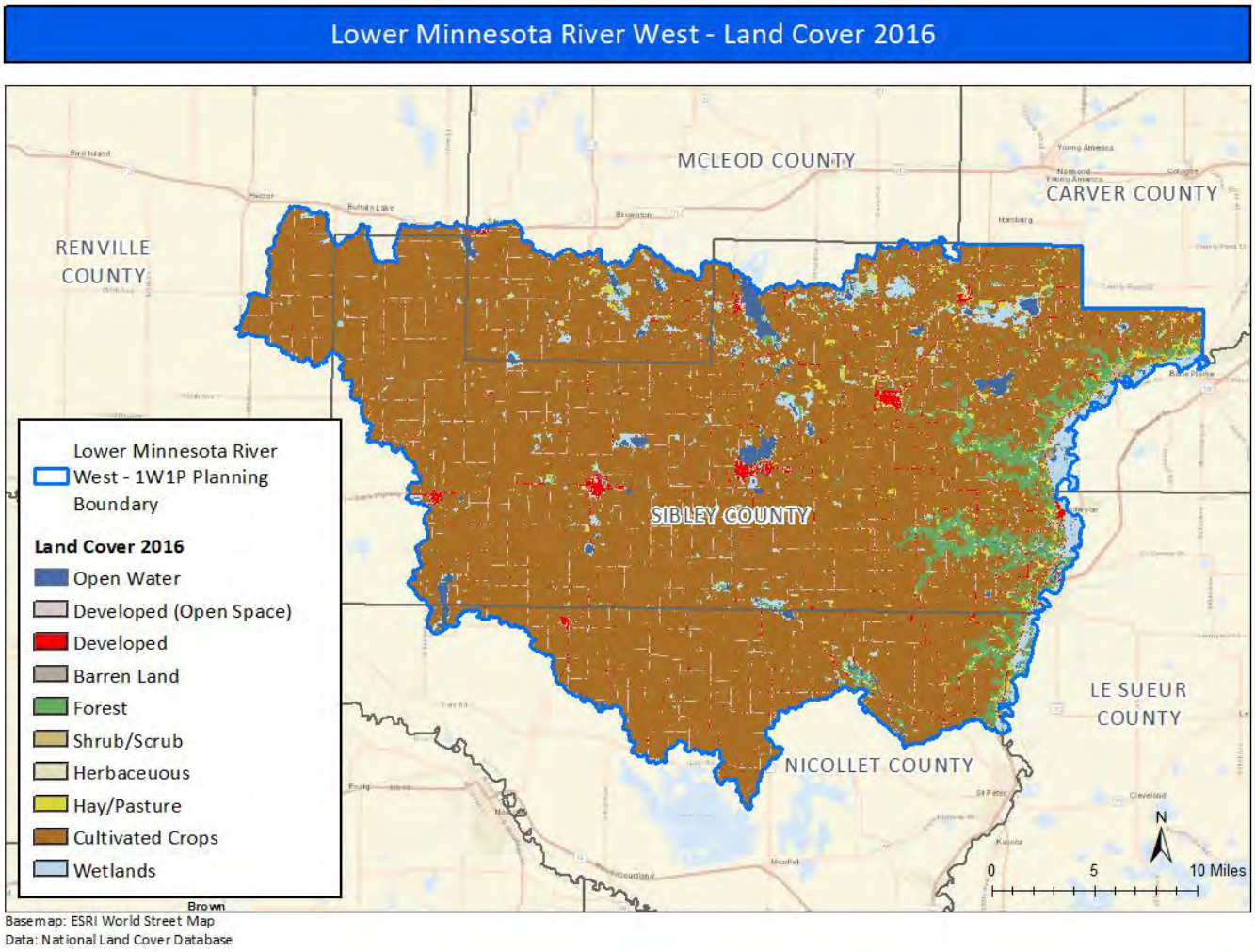

Figure 3: Lower Minnesota River West Watershed - Land Cover. Row-crop agriculture is the predominant land cover in the watershed.

Geology and Hydrogeology

Groundwater sources within the LMRWW vary according to the underlying geology, which is the result of igneous, metamorphic, sedimentary, and glacial processes that have taken place in the region over millions of years.

In the western half of the watershed, most of the bedrock is Precambrian crystalline formations, particularly gneiss and granite. Towards the eastern half of the watershed, the bedrock is sedimentary and younger (Cambrian) in age. The Cambrian layers include the Mt. Simon, Wonewoc, and Jordan Sandstones, which are permeable and can be used as aquifers. There are also a number of carbonate bedrock units in the eastern half of the watershed, some of which are fractured enough to serve as aquifers and some of which are impermeable aquitards.

Overlying the bedrock is sediment that reflects the advance and retreat of glaciers during the last ice age. Most of the land surface is covered in glacial till (unsorted sediment deposited directly by glacial ice). The high proportions of clay and silt in till deposits are an impediment to water infiltration, but buried underneath the surficial deposits of till there are sand and gravel beds deposited by glacial meltwater. These sand and gravel bodies form aquifers that supply water to most of the wells within the watershed. Along the eastern edge of the watershed, the surficial sediment is post-glacial sand and gravel deposited by the Minnesota River.

There are several main types of aquifers used for drinking water in the LMNW watershed:

- Buried sand and gravel aquifers of glacial origin. About 84% of wells with interpreted aquifer codes draw from these aquifers.
- Bedrock sandstone aquifers. About 13% of wells use these aquifers.
- Carbonate bedrock aquifers. About 2% of wells draw from these aquifers.

Figure 4 depicts a generalized map of aquifers in the watershed. More information on the bedrock and surficial geology can be found in the Geologic Atlases for Sibley, Nicollet, and McLeod Counties.

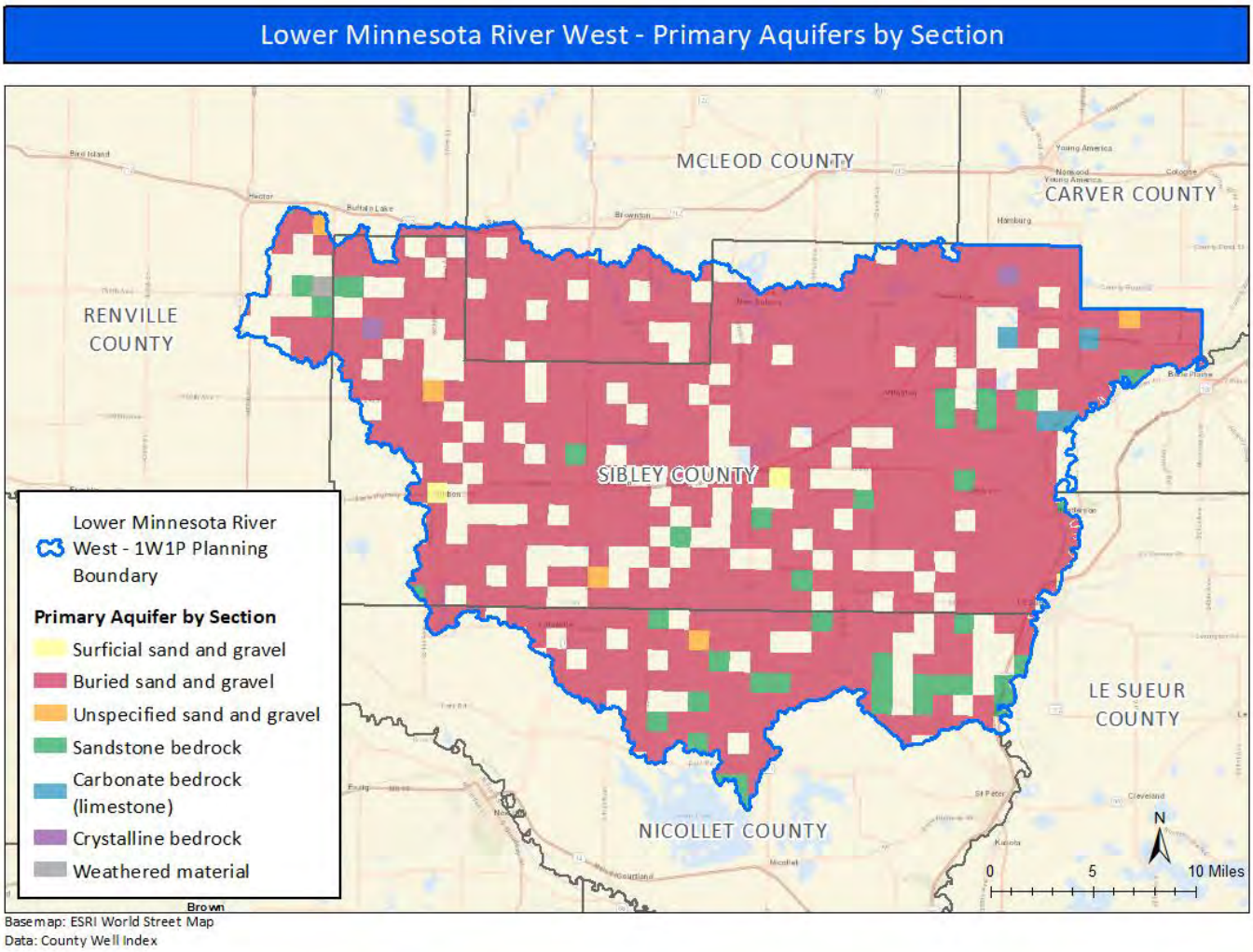

Figure 4: Lower Minnesota River West Watershed – Primary Aquifers by Section. Buried sand and gravel aquifers are the primary drinking water source for the watershed.

Pollution Sensitivity

Understanding pollution sensitivity is important for prioritizing and targeting implementation efforts. Pollution sensitivity (also known as aquifer vulnerability or geologic sensitivity) refers to the time it takes for groundwater to recharge and for contaminants at the ground surface to reach the underlying aquifer.

It is important to understand the target aquifer when assessing pollution sensitivity. Certain aquifers may be deeper and more geologically protected than others in a given area. Figure 5: Lower Minnesota River West Watershed - Pollution Sensitivity of Near Surface Materials depicts the pollution sensitivity of near-surface materials dataset developed by the DNR. This dataset only takes into account the top ten feet of soil and geologic material when assigning a sensitivity rating. This figure shows that the near-surface pollution sensitivity

rating is mainly “low” to “very low”, reflecting the dense tills covering most of the land surface. There are some areas of higher pollution sensitivity in the Minnesota River valley along the watershed’s eastern border.

More information on this dataset is available on the DNR website Minnesota Hydrogeology Atlas (MHA) (http://www.dnr.state.mn.us/waters/programs/gw_section/mapping/platesum/mha_ps-ns.html).

The pollution sensitivity of deeper aquifer materials depicted in Figure 7: Lower Minnesota River West Watershed - Pollution Sensitivity of Wells. was created by calculating the sensitivity at individual wells in the watershed and then interpolating between them to create a smooth layer. The wells used to make this figure vary in depth but overall provide a picture of the geologic sensitivity of aquifers below the water table. This method was employed due to the absence of an available statewide dataset depicting pollution sensitivity, or vulnerability, of aquifers. Figure 7 shows that the groundwater pollution sensitivity rating is mostly "low” throughout, with small areas of higher sensitivity reflecting the influence of individual shallow wells and localized stratigraphic complexity. Groundwater chemistry sampling by the DNR for County Geologic Atlases - Part B (www.dnr.state.mn.us/waters/groundwater_section/mapping/index.html) found very low pollution sensitivity for buried aquifers throughout Sibley County, except for samples taken from the Minnesota River valley, where aquifers are located closer to the land surface and overlain by surficial sand. More information on the geologic sensitivity calculations used to make this figure is included in the references section of this report as Figure 38 and Figure 39.

It is also important to understand how recharge travel time ratings (Figure 6 and Figure 8) for surficial water table aquifers differ from those used for deeper aquifers (Table 1). For example, a pollution sensitivity rating of ‘moderate’ for surficial materials reflects vertical travel times on the order of weeks (Figure 5: Lower Minnesota River West Watershed - Pollution Sensitivity of Near Surface Materials); whereas, for deeper aquifers more commonly used for drinking water, a rating of ‘moderate’ reflects travel times of years to decades (Figure 8). This difference stems from the fact that infiltrating water and contaminants reach surficial materials more quickly than deeper aquifers. Deeper aquifers often have protective clay layers that make travel time significantly longer. As noted above, this distinction is important when determining the potential impact of various contaminants on surficial materials and drinking water aquifers.

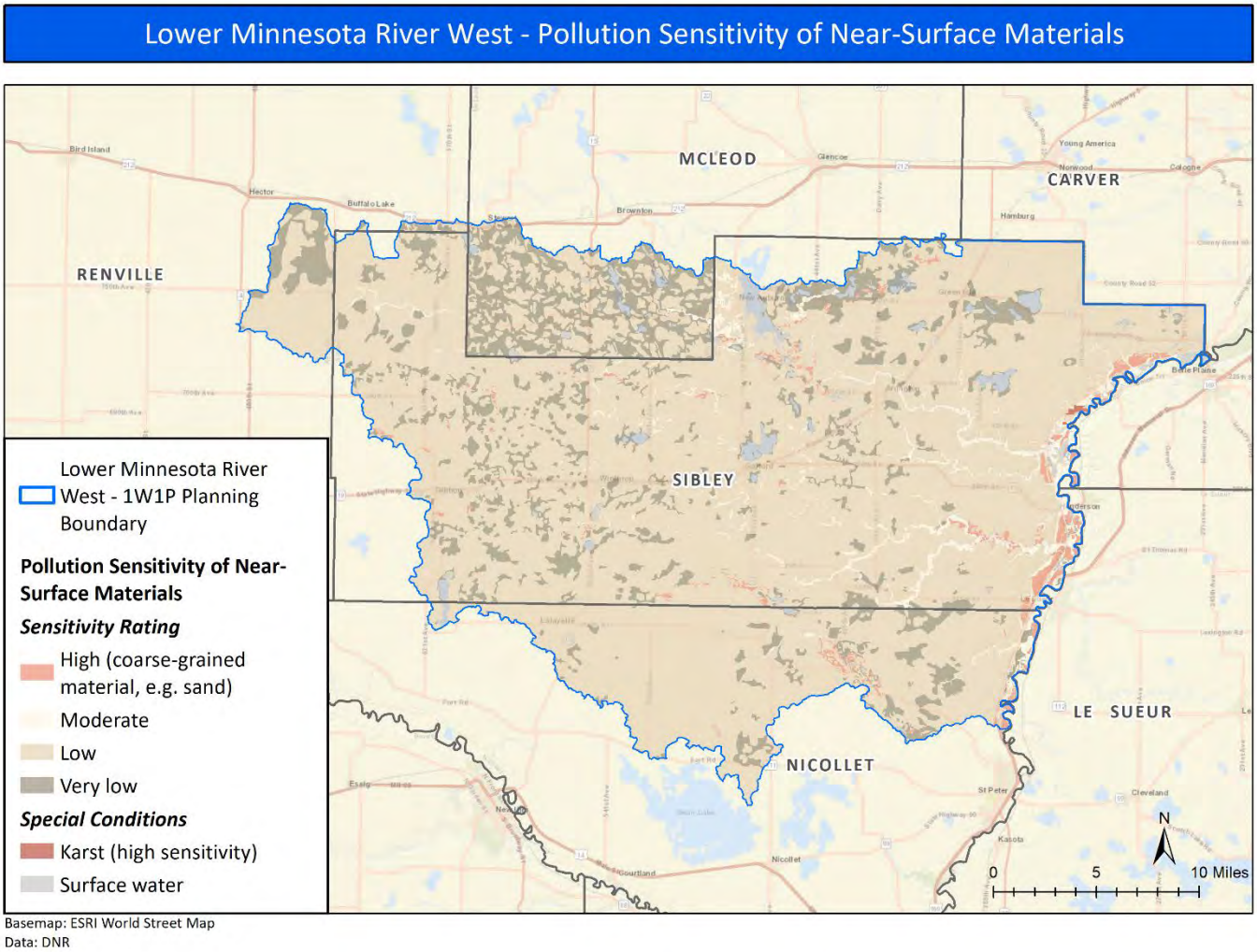

Figure 5: Lower Minnesota River West Watershed - Pollution Sensitivity of Near Surface Materials

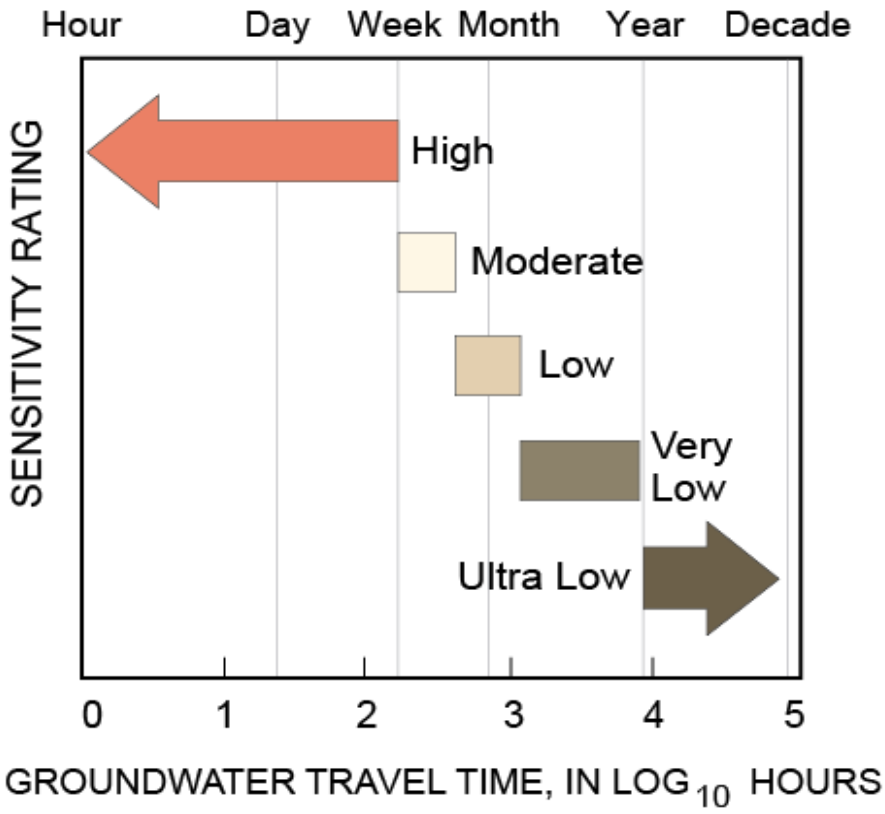

Figure 6: Recharge Travel Time for Near-Surface Materials

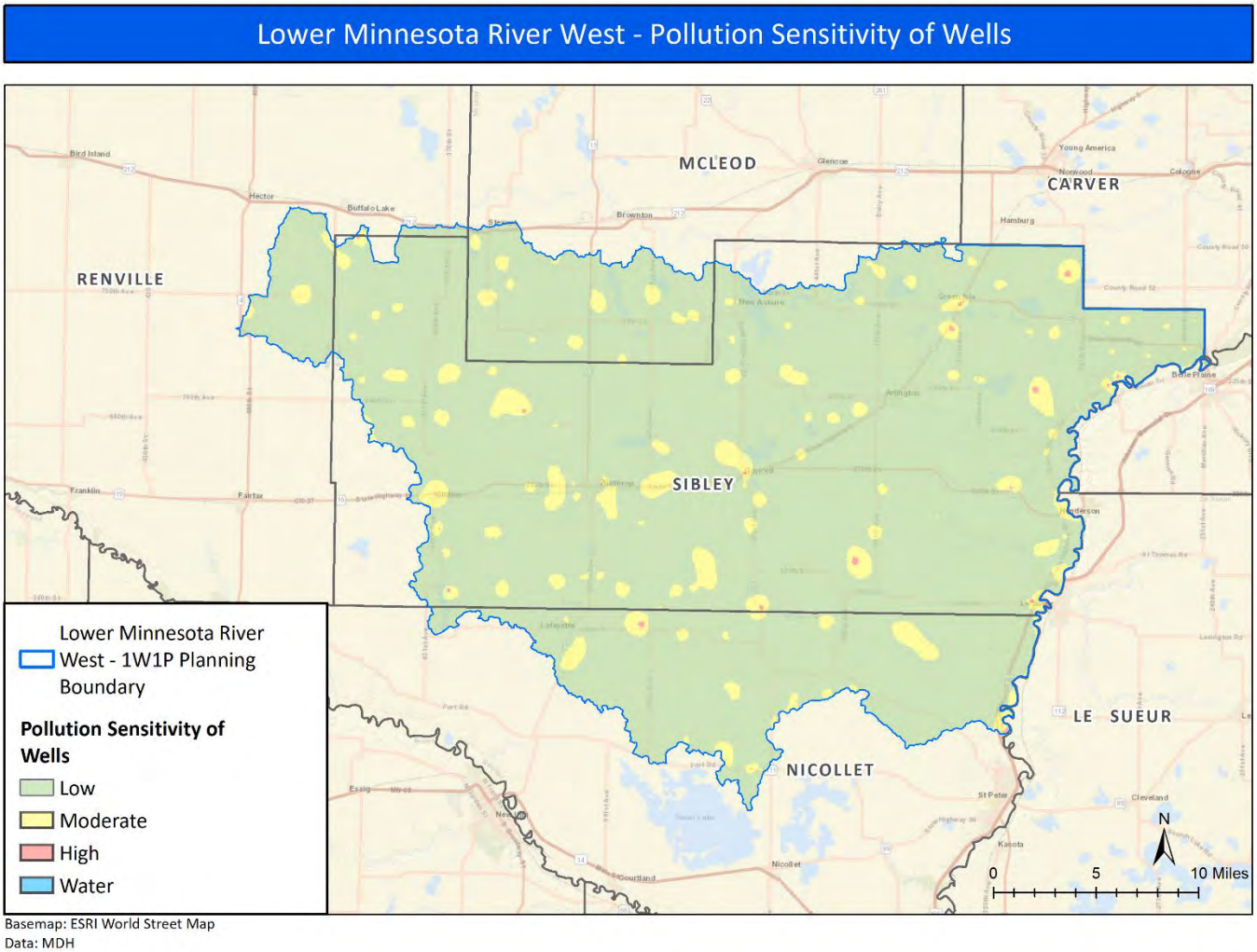

Figure 7: Lower Minnesota River West Watershed - Pollution Sensitivity of Wells.

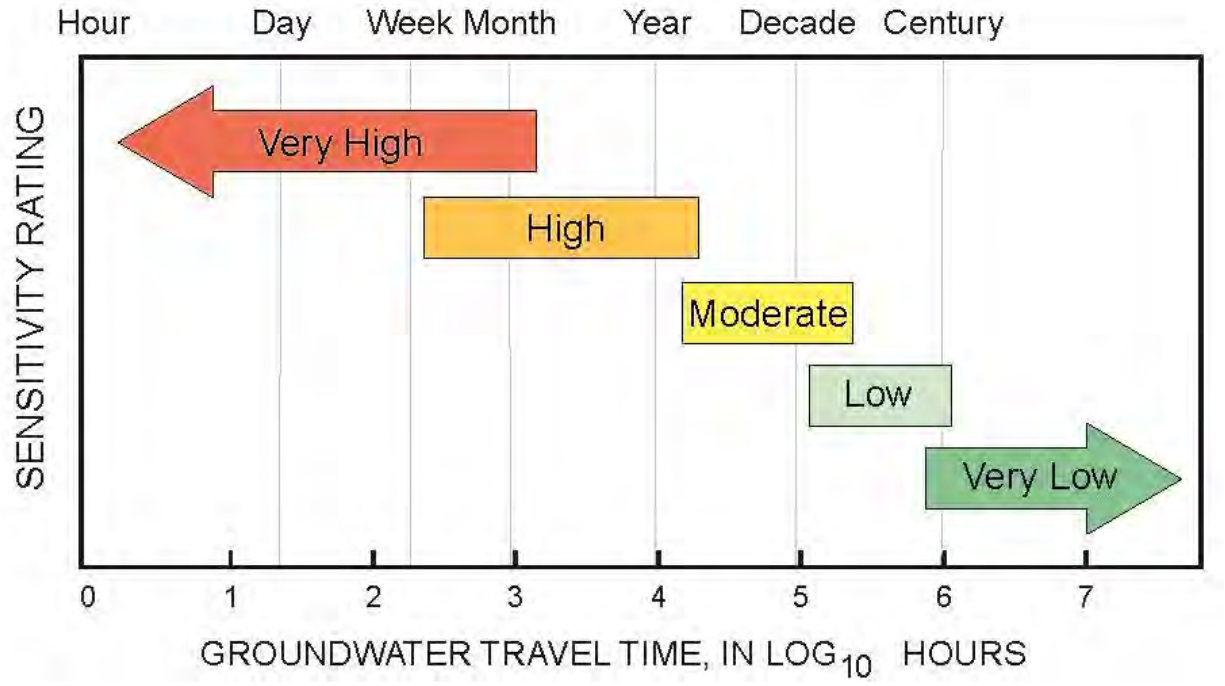

Figure 8: Recharge Travel Time for Buried Aquifers

Table 1: Sensitivity rating and the associated recharge travel times for surficial and buried aquifer

Pollution Sensitivity Rating	Aquifer Recharge Time Period[5] for Surficial Aquifers	Aquifer Recharge Time Period for Buried Aquifers
High	Hours to a week	Days to months
Moderate	A week to weeks	Years up to one or two decades
Low	Weeks to a year	Several decades to a century

[5] Aquifer recharge time periods refer to the time it takes aquifers to receive recharge from the land surface. Aquifer recharge rate informed by the Geologic Sensitivity Project Workgroup, 1991.

Wellhead Protection Planning and Drinking Water Supply Management Areas

Wellhead protection (WHP) planning is the process whereby public water systems examine land uses in the recharge area for their wells and develop strategies for land use management. The strategies are based on vulnerability and are appropriate for safeguarding drinking water supplies. Community public water supplies[6], including municipal and nonmunicipal systems, are required to prepare Wellhead Protection Plans. As part of this effort, the recharge area that contributes water to the public water supply well(s) is delineated based on physical and chemical characteristics of the aquifer being used. These areas, known as wellhead protection areas (WHPAs), provide an assessment of the aquifer vulnerability (sensitivity) of the public water supply wells. Once the WHPA is established, a Drinking Water Supply Management Area (DWSMA) is created to provide planning boundaries on the land surface in order to manage the groundwater below. Learn more about MDH Source Water Protection (www.health.state.mn.us/communities/environment/water/swp/index.htm).

The word 'sensitivity' is used to describe groundwater generally throughout the state; 'vulnerability' is the term used for wellhead protection planning to protect public sources of drinking water. While there are minor differences between how these words are used as described above, the words are essentially the same for the purposes of planning and management.

Aquifers and wells used for public water supplies vary widely. Some are very shallow and unprotected and easily contaminated by activities at the ground surface. Others are deeper or more protected by geologic materials; these tend to exhibit a low vulnerability to overlying land uses. The types of management activities required within WHPAs will vary based largely on the vulnerability assessments. Highly vulnerable WHPAs require a greater level of management to prevent potential contaminants at the ground surface from entering the aquifer. Whereas for WHPAs with low vulnerability the primary focus is on sealing unused/unsealed wells, since this is the primary pathway for contaminants to reach the aquifer. The PWSs within the LMNWW are all drawing from fairly protected aquifers (buried glacial aquifers or sandstone bedrock).

Six of the nine community public water systems within the LMNWW are engaged in the wellhead protection planning process or are implementing their plans. All six of the systems with approved plans have DWSMAs that are rated "low" or "very low" vulnerability. Figure 9: Lower Minnesota River West Watershed - Wellhead Protection Plan Development Status for Community Public Water Systems. Six of the nine community public water supply systems are engaged in the wellhead protection planning process or are implementing their plans. shows the status of wellhead protection planning for the public water supply systems in the watershed. Figure 10 shows the DWSMAs delineated at the time the report was compiled in the LMNWW, covering about 5,400 acres. It is important to note that WHP areas do not follow watershed boundaries and can be located in different watersheds.

[6] Community public water supplies serve at least 25 persons or 15 service connections year-round. Community public water supplies include municipalities (cities), manufactured mobile home parks, etc. Currently there are almost 1,000 community water supplies in Minnesota.

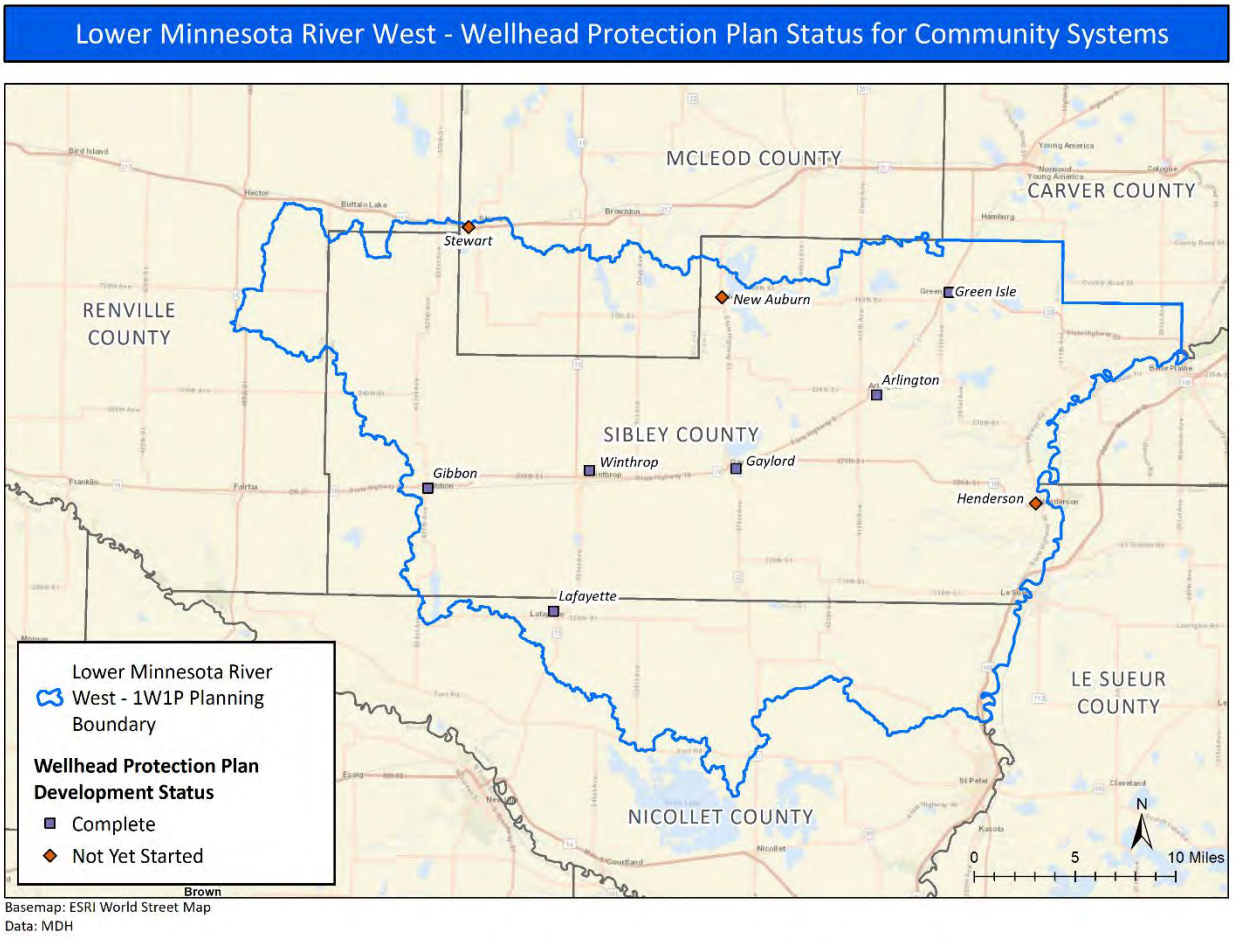

Figure 9: Lower Minnesota River West Watershed - Wellhead Protection Plan Development Status for Community Public Water Systems. Six *of the nine community public water supply systems are engaged in the wellhead protection planning process or are implementing their plans.*

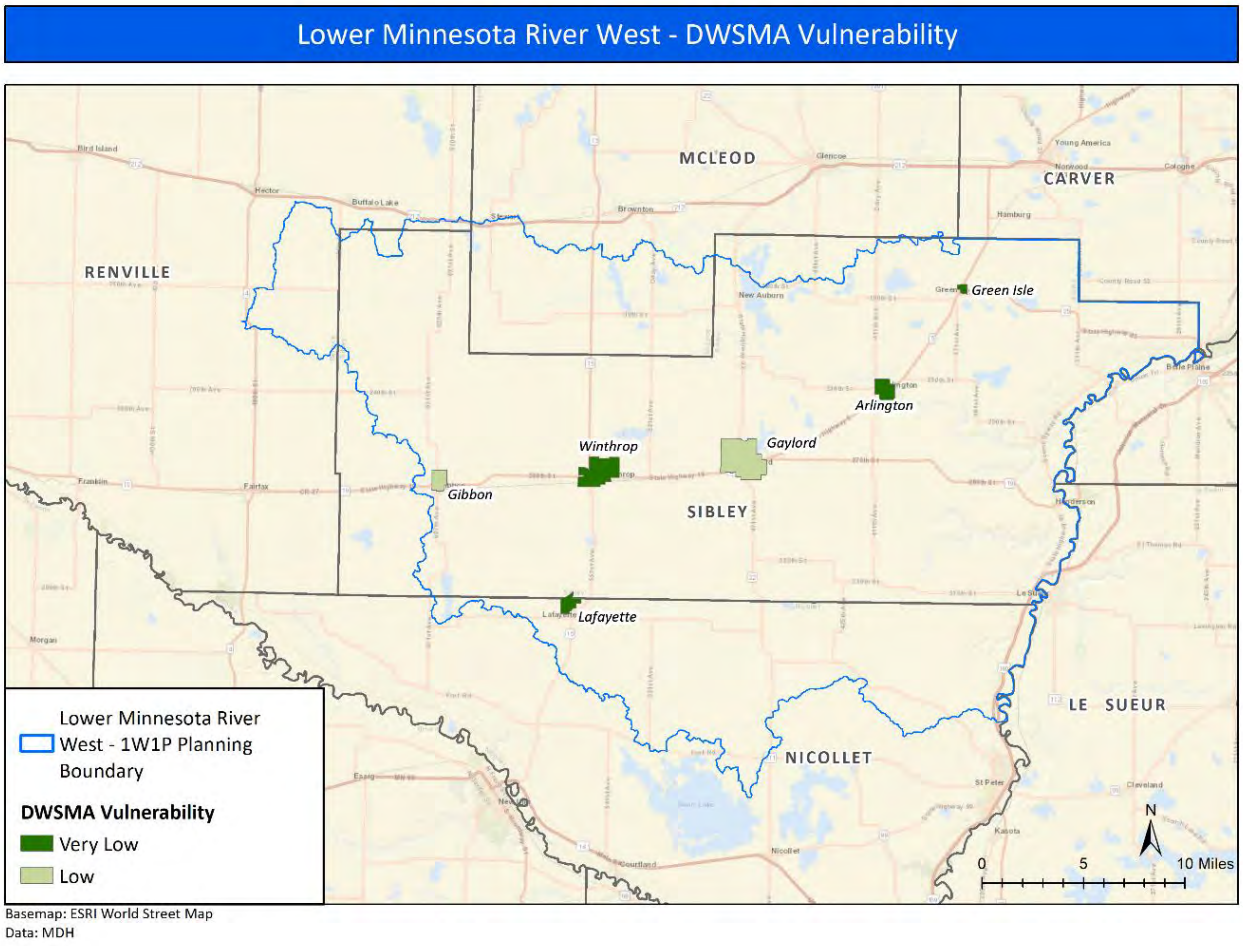

Figure 10: Lower Minnesota River West Watershed - Drinking Water Supply Management Areas. There are six approved Drinking Water Supply Areas (DWSMA) for community public water supply systems in the watershed.

Private Wells

The LMNWW has approximately 1,688 private wells with known locations, ranging from 37 feet to 709 feet deep with an average depth of 246 feet that provide drinking water to residents. Approximately one percent (17 wells) of private wells are in a highly vulnerable setting. Private well users are not afforded the same water quality safeguards as people who get their water from public water systems. While public water systems make sure water is safe for the end-user, private well users are responsible for making sure their water is safe for everyone in the household to drink.

The Minnesota Well Code ensures that private wells are properly located and constructed. However, once the well is put into service, private well users are responsible for properly maintaining their well, testing it regularly, and treating the water when necessary.

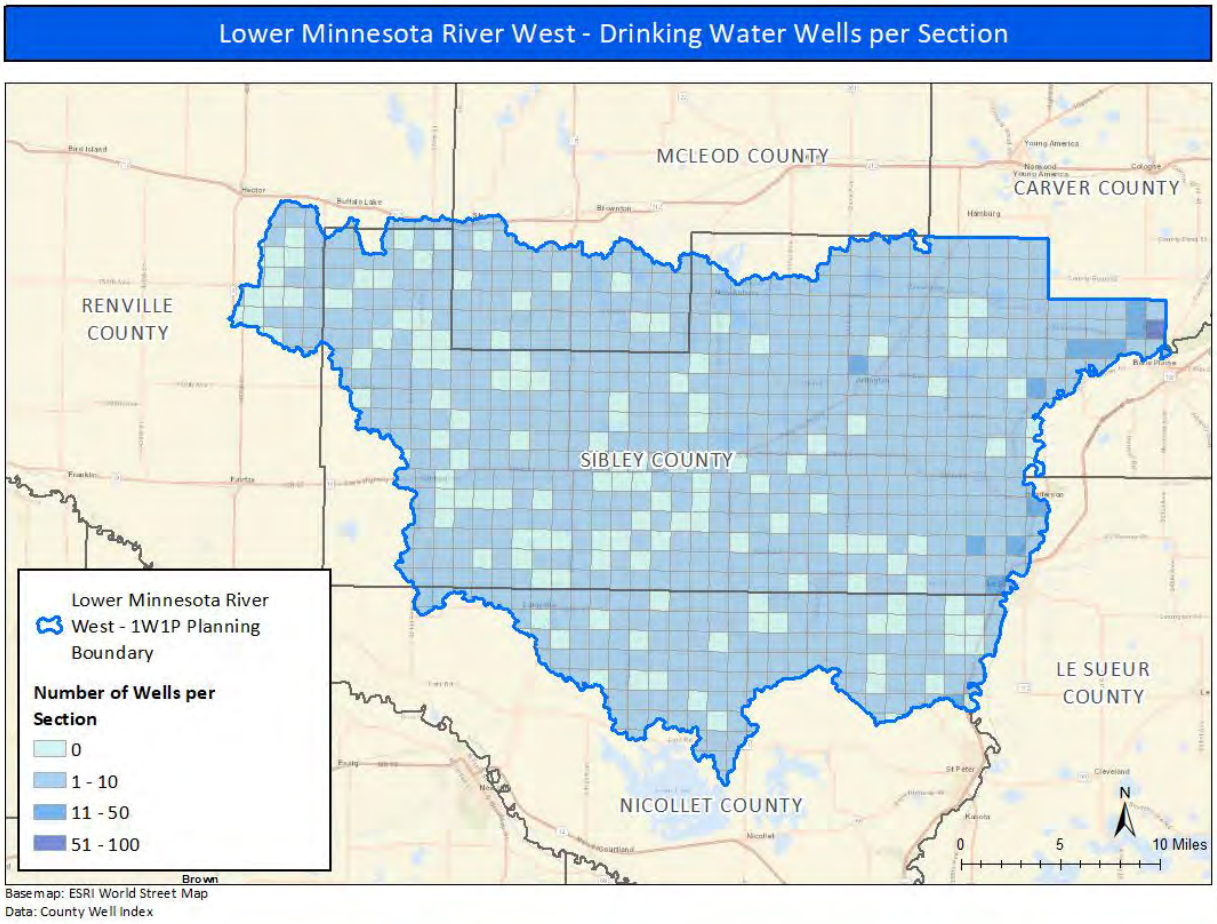

Figure 11: Lower Minnesota River West Watershed - Density of drinking water wells per section. There are 1,688 private wells identified.

Figure 11 illustrates well density and water use data in the LMRWW. This figure contains a grid that depicts the number of wells in each six by six-mile section of the watershed. Deeper colors correspond to a higher concentration of wells. Well density is variable across the watershed. Only wells used for drinking water were included in this analysis.

Extreme Weather

Climate records show that across Minnesota there has been an increase in average rainfall, as well as heavy precipitation events. As storms become more frequent and intense, flooding will be an ongoing challenge for public water systems and private wells. Flood events can threaten the safety and availability of drinking water by washing pathogens (bacteria, viruses, and parasites) and chemical contamination into source aquifers or by overwhelming the capacity of treatment systems to clean the water. The full extent of floodwater contamination depends on land use and associated infrastructure in the affected area. Figure 12 displays drinking water wells and flood zone risk to contamination in the LMRWW.

Extreme weather may also affect drought conditions by changing how and where precipitation falls. Increased rainfall over frozen ground and reduced snowpack from spring melt can decrease infiltration into groundwater when converted to runoff. The Groundwater Quantity Issues and Concerns section of the report assesses aquifer sustainability by evaluating long term monitoring well trends.

For more information on Climate and Health (www.health.state.mn.us/communities/environment/climate/) or visit the DNR's webpage Climate Change and Minnesota (www.dnr.state.mn.us/climate/climate_change_info/index.html).

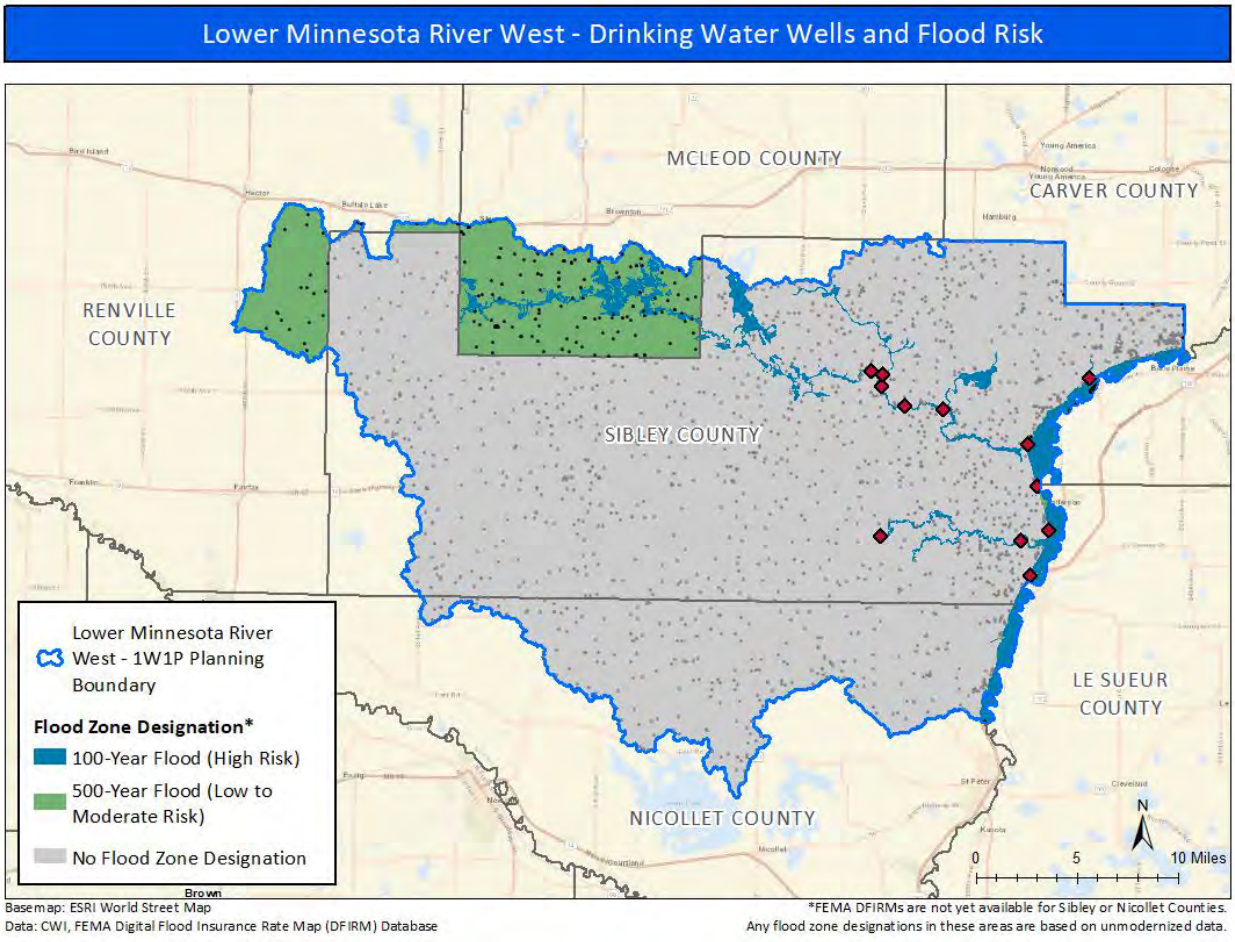

Figure 12: Lower Minnesota River West Watershed – Drinking water wells and flood zone risk to contamination.

Lower Minnesota River West Watershed Groundwater Issues and Concerns

This section of the report describes the key groundwater quality and quantity issues for the LMRWW. The descriptions each include an overview of the issue, where the issue is most prevalent, and a few key approaches to address the issue. The LMRWW Strategies and Actions to Protect and Restore Groundwater provides a more detailed list of actions to address groundwater issues and concerns.

Groundwater Quality Issues and Concerns

Both naturally occurring and human-made contaminants affect the LMRWW groundwater quality. Multiple state agencies monitor different types of groundwater wells and public water systems for contaminants. Nitrate, radium and arsenic have been detected in wells sampled in the LMRWW. This section provides context and data about these contaminants and their occurrence in the watershed. It also provides information about the following land uses: feedlots, row crop production, subsurface sewage treatment systems, contaminated sites (leaky tank sites and closed landfills), and household hazardous waste in the watershed that may affect groundwater quality.

All public water systems in the watersheds strive to meet Safe Drinking Water Act (SDWA)[7] requirements for the quality of water served to their customers. However, some public water systems may have water quality issues in their untreated source water that requires either blending or treatment to meet SDWA standards.

Nitrate

Nitrate-nitrogen (referred to as nitrate) is a compound that occurs naturally and has many human-made sources. When nitrate levels are above 3 milligrams per liter (mg/L)[8] in groundwater, human activity is the likely cause (State of Minnesota Workgroup). Human-induced sources of nitrate include animal manure, fertilizers used on agricultural crops, failing SSTS, fertilizers used at residences and commercially, and nitrous oxides from the combustion of coal and gas.

Nitrate is one of the most common contaminants of groundwater in Minnesota and is a public health concern where found in groundwater used for drinking water. The SDWA standard for nitrate in drinking water is 10 mg/L. Most of the samples taken from wells within the watersheds did not exceed the SDWA standard for nitrate. This dataset includes newly constructed wells, private wells, and other

[7] The Safe Drinking Water Act (SDWA) is the federal law that protects public drinking water supplies throughout the nation. Under the SDWA, EPA sets standards for drinking water quality; MDH is delegated to implement the program in MN to ensure drinking water safety.

[8] One milligram per liter is the same as 1 part per million (ppm).

drinking water supply wells. Sampling of newly constructed wells for nitrate began in 1974. Many older wells, pre-well code, are not included in this dataset. Table 2 shows nitrate test results for samples taken from these wells.

Table 2: Summary of nitrate results in drinking water wells of the Lower Minnesota River West Watershed.

Depth Completed Range (feet)	Total samples (nitrate)	Minimum concentration (mg/L)	Maximum concentration (mg/L)	Median concentration (mg/L)	Samples at or above 3 mg/L (%)	Samples at or above 10 mg/L (%)
< 50	6	0.025	0.1	0.025	0	0
50 - 99	49	0	36.1	0.3	4.1	2
100 - 149	136	0	8.9	0.5	2.2	0
150 - 199	133	0	6.01	0.5	1.5	0
>= 200	824	0	5.5	0.1	0.7	0
Total	1,148	0	36.1	0.2	1.1	0.1

Where Is Nitrate in Lower Minnesota River West Watershed?

High levels of nitrate are present in areas where there are both human-caused sources of nitrate and high pollution sensitivity. The LMRWW is comprised primarily of low and very low areas of pollution sensitivity therefore no ambient groundwater monitoring or MDAs Township Testing Program monitoring for contaminants is conducted within the watershed. The following image helps identify where nitrate is detected and at what levels in the watershed:

- Figure 13 compares nitrate levels in wells in the LMRWW. The absence of elevated nitrate concentrations throughout most of the watershed may be a function of low-impact land use near the wells or the presence of favorable geochemical conditions in the aquifers. Nitrate requires relatively oxidizing conditions to persist in groundwater, and the presence of locally reducing conditions can remove nitrate. The dataset used to create this figure is the same as that used in Table 2. These nitrate samples were taken from newly constructed wells, private wells, and other drinking water supply wells sampled by the Minnesota Department of Health (MDH).

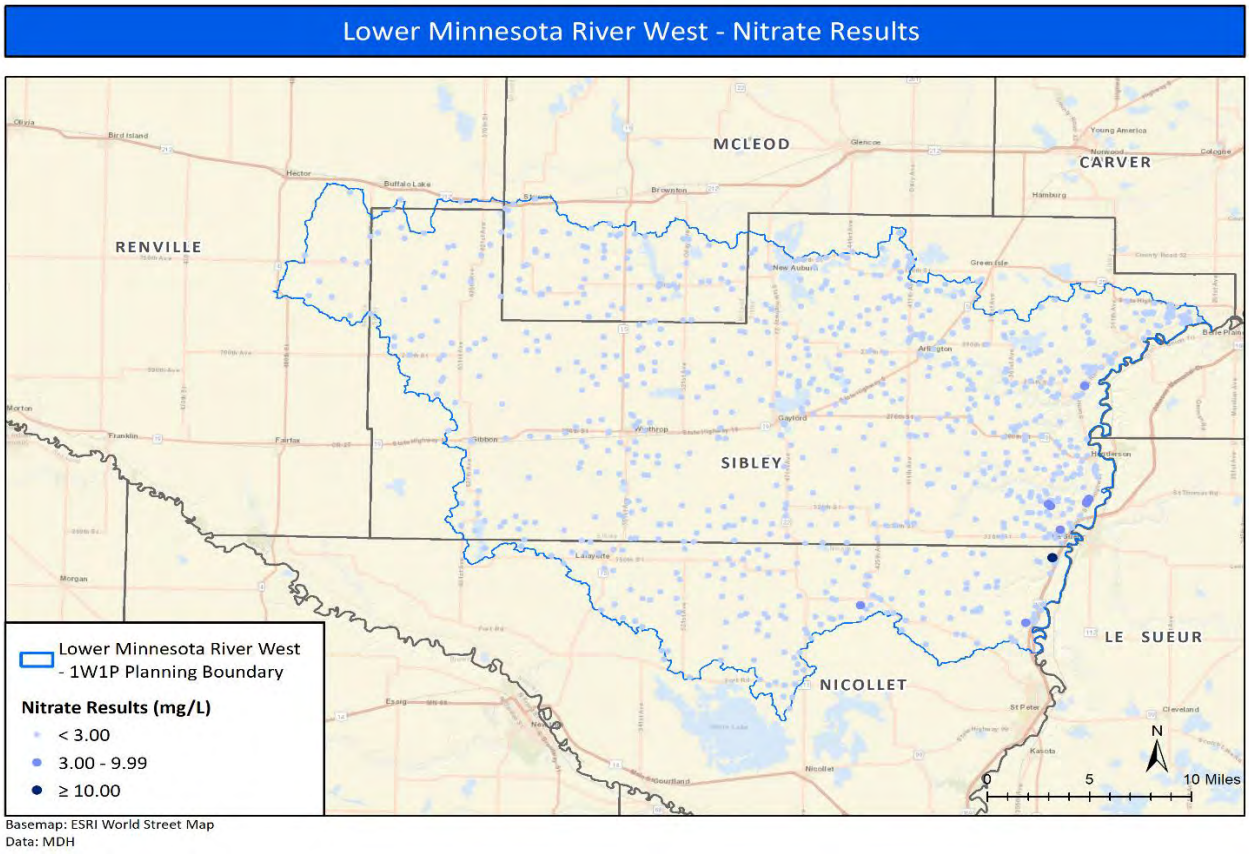

Figure 13: Lower Minnesota River West Watershed - Nitrate results from drinking water wells.

How to Address Nitrate in Groundwater

The Minnesota Groundwater Protection Act established a prevention goal that groundwater be maintained in its natural condition, free from any degradation caused by human activity. When degradation exists, it is important to understand the reflected level of management required based on the nitrate concentration. Table 3 provides a protection framework that identifies management priorities reflective of nitrate concentrations.

Table 3: Nitrate protection framework and associated land use management goals. Implementation activities should build as you move from one classification to the next.

Nitrate Protection Framework	Nitrate Concentration	Implementation Emphasis
Protection – Maintain	0 – 4.9 mg/L	Proactive and preventive; ▪ Maintain existing land cover by discouraging or preventing land conversion ▪ Contaminant source management on

Nitrate Protection Framework	Nitrate Concentration	Implementation Emphasis
		existing land uses (Agricultural BMPs, SSTS management, easements, forest management plans)
Protection – Threatened	5.0 – 9.9 mg/L	Contaminant source reduction or elimination; ▪ Shifting land uses away from those that may leach excess nitrogen (Alternative Management Tools[9], upgrade failing SSTS, easements)
Restoration – Treatment	10.0 mg/L and above	Active intervention required by public water supplies to avoid drinking water consumption (new sources; treatment) while still aiming for long term contaminant source mitigation through reduction and elimination

Table 9 provides a more comprehensive list of specific actions counties and subwatersheds in the LMRWW can take to restore and protect groundwater quality related to nitrate.

Pesticides

A pesticide is any substance or mixture of substances intended for preventing, destroying, repelling or lessening the damage of any pest and may be a chemical substance or a biological agent. Consuming water with different types of pesticides in it can cause a variety of health problems. MDA monitors for 'common detection pesticides' as a part of the MDA Pesticide Management Plan (www.mda.state.mn.us/protecting/waterprotection/pmp.aspx). Common detection pesticides are pesticides frequently used in row crop production and include acetochlor, alachlor, atrazine, metolachlor and metribuzin.

[9] MN Dept. of Agriculture developed Alternative Management Tools to protect groundwater quality from nitrate contamination. For more information, visit MDA Alternative Management Tools (www.mda.state.mn.us/chemicals/fertilizers/nutrient-mgmt/nitrogenplan/nitrogenmgmt/amts)

Where Are Pesticides in Lower Minnesota River West Watershed?

MDA has no monitoring wells in the LWRWW to monitor for common detection pesticides due to the lack of sensitive geology.

How to Address Pesticides in Groundwater

General approaches to reduce the amount of pesticides that may enter groundwater include:

- Providing educational opportunities about pesticide and insecticide BMPs for both agricultural lands and residential/commercial lawns (turf)
- Increasing the adoption of water quality BMPs for pesticides and insecticides

Table 9 provides a more comprehensive list of specific actions the counties and subwatersheds in the LMRWW can take to restore and protect groundwater quality related to pesticides.

Arsenic

Over twenty-three percent of the 320 arsenic samples taken from located wells in the LMRWW have levels of arsenic higher than the SDWA standard of 10 micrograms per liter (µg/L)[10]. Arsenic occurs naturally in rocks and soil across Minnesota and can dissolve into groundwater. Consuming water with low levels of arsenic over a long time (chronic exposure) is associated with diabetes and increased risk of cancers of the bladder, lungs, liver and other organs. The SDWA standard for arsenic in drinking water is 10 µg/L; however, drinking water with arsenic at levels lower than the SDWA standard over many years can still increase the risk of cancer. The EPA has set a goal of 0 µg/L for arsenic in drinking water because there is no safe level of arsenic in drinking water.

Since 2008, the State of Minnesota has required that water from new water supply wells be tested for arsenic. Table 4 outlines the number of well water samples tested for arsenic in the LMRWW, using the dataset from the Minnesota Well Index (MWI) and well for newly constructed private wells. The table shows the percentage of samples with arsenic levels over the SDWA standard. It is important to remember that arsenic concentrations can be drastically different from nearly identical wells installed on adjoining properties.

Table 4: Summary of arsenic (As) concentrations in wells of the Lower Minnesota River West Watershed.

Depth Completed Range (feet)	Total samples (n)	Minimum concentration (µg/L)	Maximum concentration (µg/L)	Median concentration (µg/L)	Samples at or above 5 µg/L (%)	Samples at or above 10 µg/L (%)
< 50	2	0.62	4.9	2.76	0	0
50 - 99	16	0.0005	58.8	4.365	43.8	43.8
100 - 149	37	0.0005	48.9	5.73	56.8	40.5
150 - 199	39	0.0043	49.55	10.2	66.7	51.3
>= 200	226	0.0005	70	2.27	31.9	14.2
Total	320	0.0005	70	3.13	39.4	23.1

[10] One microgram per liter is the same as 1 part per billion (ppb).

Where Is Arsenic in the Lower Minnesota River West Watershed?

Figure 14 shows that arsenic is found in elevated concentrations throughout the watershed. The dataset used to create Figure 14 is the same information displayed in Table 4. Theses samples were taken from newly constructed domestic wells.

Arsenic is most prevalent in the glacial Quaternary Buried Artesian Aquifers (lenses of sand and gravel enclosed within clay-rich sediments). Typically, elevated arsenic in Minnesota groundwater is associated with glacial lobes originating from northwest Canada. Elevated arsenic is correlated with clay layers and reducing geochemical conditions that release arsenic into the groundwater (Erickson and Barnes, 2004 and 2005). Well depths with elevated arsenic range from 78 to 456 feet in the LMRWW. For wells with arsenic detected but below the drinking water standard, the wells were completed in the Quaternary Buried Artesian aquifer and some wells in the Tunnel City Group, Jordan, and Mt. Simon aquifers.

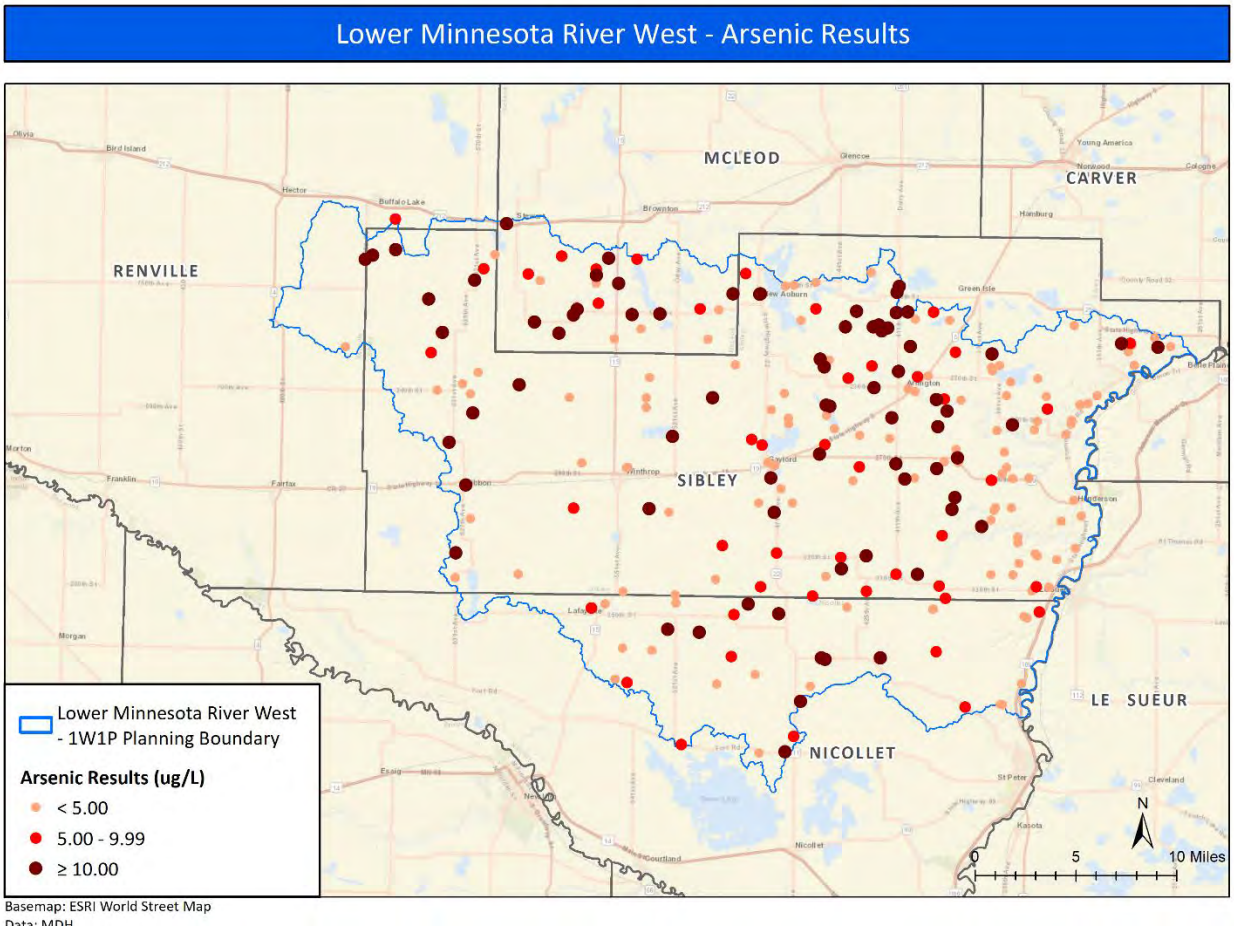

Figure 14: Lower Minnesota River West Watershed - Arsenic Results

How to Address Arsenic in Groundwater

Unlike nitrate and pesticides, human activity rarely causes arsenic in Minnesota groundwater, except for local releases of insecticides or wood preservatives into the environment. Therefore, few actions can reduce the amount of arsenic in groundwater. Implementation efforts should focus on making

private well users aware of the health risks associated with arsenic, encouraging them to test their water for arsenic, and providing them with treatment options to keep their drinking water safe when arsenic is present.

Radionuclides

Radioactive materials, also called radionuclides (Radium), are both naturally occurring and human-made. Drinking water that has radium exposes individuals to very low doses of radiation every day, increasing your risk of cancer if you drink water with radium in it every day for many years.

Concentrations of naturally occurring radioactive radium has been detected in some groundwater samples in the LMRWW. Of the 10 detections, 5 wells had combined radium 226/228 above the drinking water standard of 5 pCi/L. Wells with exceeding combined radium range in well depth from 686 to 832 feet, completed in the Mt. Simon aquifer. The exact source of these compounds is not well understood. They may originate in the clay-rich glacial sediments or may be part of the original mineral composition of the Mt. Simon or fractured Sioux Quartzite geologic units. What is known is that their presence in the groundwater is related to reducing geochemical conditions and the very slow rate of groundwater flow in theses bedrock layers (Szabo, Z., Fischer, J. M., Hancock, T. C., 2012).

Where are Radionuclides in the Lower Minnesota River West Watershed?

Not enough is known about radium (or other radionuclide) distribution in the aquifers beneath the LMRWW. The few results indicate combined radium may be a problem in wells drilled in the Mt. Simon aquifer at this time.

How to Address Radionuclides in Groundwater

Human activity is unlikely to be the cause of radionuclides in the LMRWW groundwater. Therefore, actions cannot reduce the amount of radionuclides present in groundwater. Implementation efforts should focus on awareness that radionuclides may be found in groundwater. The factors that contribute to the presence of radionuclides in the LMRWW groundwater are not well understood at this point. If private well users are concerned about radionuclides in their well, they can pay to have their water tested through an accredited laboratory. Water softeners and reverse osmosis are effective at removing radium from groundwater. Learn more at Radionuclides (Radium) in Drinking Water (https://www.health.state.mn.us/communities/environment/water/contaminants/radionuclides.html).

Ambient Groundwater Monitoring

The MPCA's Ambient Groundwater Monitoring Program monitors trends in statewide groundwater quality by sampling for a comprehensive suite of over 100 chemicals including nutrients, metals, anions and cations, and volatile organic compounds. The Ambient Groundwater Network currently consists of approximately 270 sites that represent a mix of deep domestic wells and shallow monitoring wells in non-agricultural regions across the state. The primary focus is on shallow aquifers that underlie urban areas, due to the higher tendency of sensitivity to pollution, and are predominately located in sand and gravel and Prairie du Chien-Jordan aquifers.

There are no MPCA ambient groundwater monitoring wells in the LMRWW.

MDH hosts information on a List of Contaminants in Water (www.health.state.mn.us/communities/environment/water/contaminants/index.html), as well as CECs (www.health.state.mn.us/communities/environment/risk/guidance/dwec/index.html).

Potential Contaminant Sources

Some land use practices make it easier for contaminants to get into groundwater. Key land uses that are potential contaminant sources in the LMRWW are described below.

Animal Feedlots

MPCA regulates the land application and storage of manure generated from animal feedlots in accordance with Minnesota Rule Chapter 7020. The MPCA Feedlots Program (https://www.pca.state.mn.us/quick-links/feedlots) requires that the land application and storage of manure be conducted in a manner that prevents nitrate contamination to both groundwater and surface water. Animal manure contains significant quantities of nitrogen and pathogens. Improper management of manure, especially in places with high pollution sensitivity, can contaminate groundwater.

MDA hosts an interactive map that provides information on local ordinances regulating animal agriculture in Minnesota's counties. The information includes the most common areas of regulations, such as setbacks and separation distances, conditional use permits, feedlot size limitations, and minimum acreage requirements. For more information, visit the Local Ordinances Regulating Livestock - Web Mapping (www.mda.state.mn.us/local-ordinances-regulating-livestock-minnesota).

MDA developed a new tool in collaboration with the National Weather Service called the Minnesota Runoff Risk Advisory Forecast (RRAF) system (www.mda.state.mn.us/protecting/cleanwaterfund/toolstechnology/runoffrisk). RRAF is designed to help farmers and commercial applicators determine the best time to apply manure to reduce the probability of off target movement of valuable nutrients and protect water resources.

Where Are Animal Feedlots in the Lower Minnesota River West Watershed?

The LMRWW has 604 active feedlots. Minnesota Rule 7020 allows the MPCA to transfer or 'delegate' regulatory authority and administration of certain parts of the feedlot program to a county. A delegated county regulates feedlots with less than 1,000 animal units; MPCA regulates anything above that threshold. County feedlot programs have responsibility for implementing state feedlot regulations including: registration, permitting, inspections, education/assistance and complaint follow-up. All counties in the LMRWW, except for Sibley, are delegated counties administering the feedlot program locally. Sibley County relies on the MPCA to execute the feedlot program within their jurisdiction.

Table 5: Number of registered feedlots and the delegated counties outlines the number of registered feedlots in the LMRWW for each county. Figure 15: Lower Minnesota River West Watershed – Active Feedlots. There are 604 active feedlots within the watershed contains a grid that depicts the number of active feedlots in each six by six-mile section of the watershed. Darker colors correspond to a higher concentration of active feedlots.

Table 5: Number of registered feedlots and the delegated counties

Counties	Number of Registered Feedlots per County	Delegated County
Mcleod	37	Yes
Nicollet	111	Yes
Renville	7	Yes
Sibley	449	No

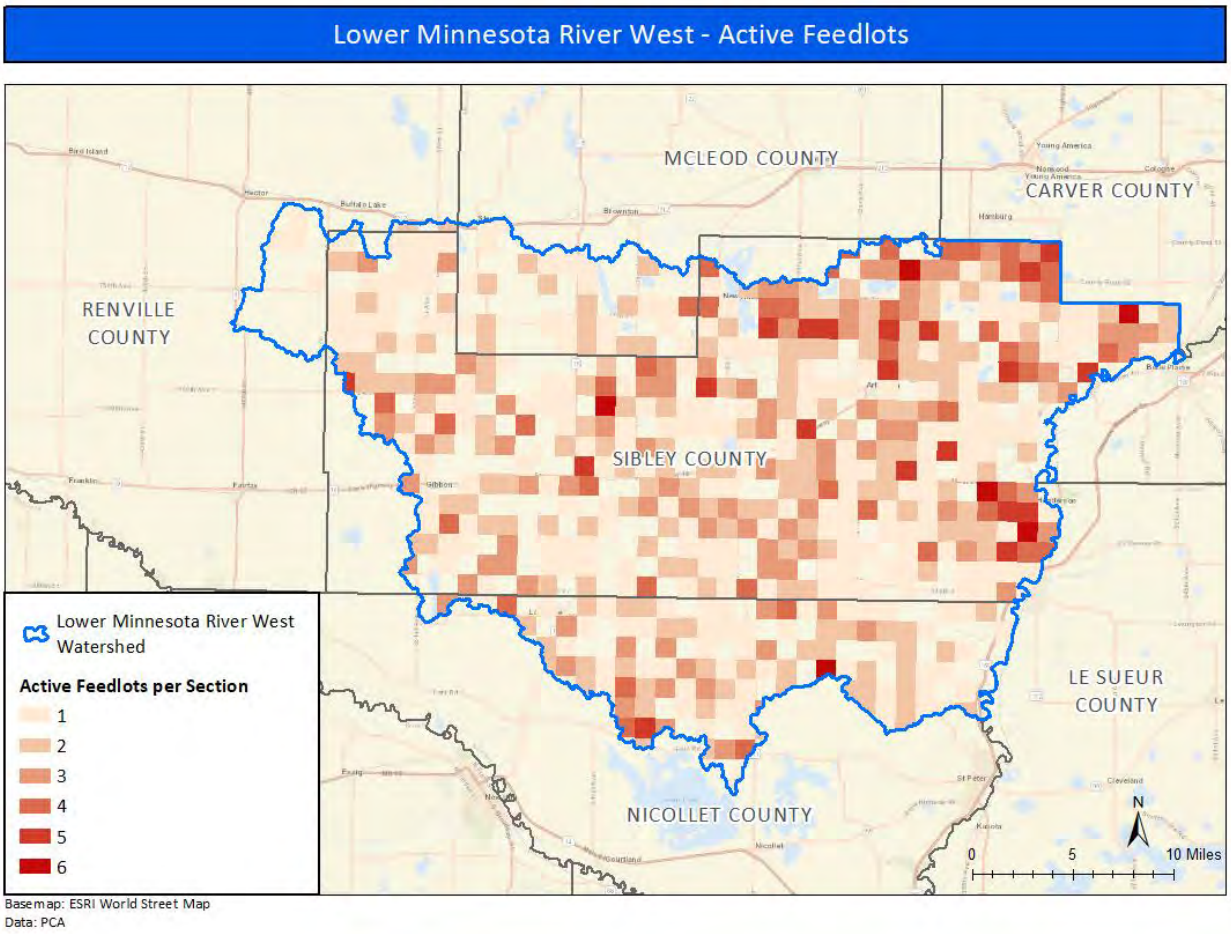

Figure 15: Lower Minnesota River West Watershed – Active Feedlots. There are 604 active feedlots within the watershed.

How to Protect Groundwater from Contamination

Manure management plans, feedlot inspections, permitting, technical assistance and record keeping are all used to manage nitrogen impacts to water quality. It is important to prioritize activities in the areas most sensitive to groundwater first. Table 9 provides a more comprehensive list of specific actions partners in can take to protect groundwater from nitrate and pathogen contamination.

Row Crop Agriculture

Row crop agriculture or cultivated crops (Figure 3) are the largest land cover within the LMRWW covering over 90 percent of the watershed. Impacts from row crop production to water resources include nitrogen loss in the form of nitrate to groundwater, which can move downward to aquifers or be laterally dispersed to lakes and rivers. Tile drainage is another pathway for nitrogen to reach surface water systems, however this is not a focus of the GRAPS report being the TMDL and WRAPS reports assess impacts. Agricultural chemicals, including pesticides, are another risk for groundwater contamination from row crop agriculture. Both nitrate and pesticides are addressed in the **Groundwater Quality Issues and Concerns** section of this report.

Subsurface Sewage Treatment Systems (SSTS)

Of the approximately 450,000 SSTS (commonly called septic systems) across the state, slightly over 100,000 of them are estimated to be failing. As more time passes, additional systems are likely to fail. Failing SSTS can pollute both surface and groundwater. A failing system is one that does not provide adequate separation between the bottom of the drain field and seasonally saturated soil. The wastewater in SSTS contains bacteria, viruses, parasites, nutrients, and some chemicals. SSTS infiltrate treated sewage into the ground, which ultimately travels to groundwater.

Where Are SSTS in the Lower Minnesota River West Watershed?

SSTS are found in all four counties in the LMRWW. Information reported by counties indicate a relatively small to high number of failing SSTS in the watershed (Table 6). State regulations require each county to adopt a local SSTS ordinance and that eminent health threats or failing systems be replaced and brought up to current standards. Even with a required ordinance, some counties still have identified gaps in their SSTS program, ranging from lack of records on treatment system age, type or function, known unsewered communities, and lack of a point of sale requirement triggering an inspection through a property sale.

Table 6: Reported number of failing SSTS in each county within the Lower Minnesota River West Watershed

County	Estimated number of failing SSTS per 1,000 acres
Mcleod	4 – 7.7
Nicollet	1 - 2
Renville	0 - -1
Sibley	0 - 1

How to Protect Groundwater from SSTS Contamination

SSTS must be properly sited, designed, constructed and maintained to minimize the potential for disease transmission and groundwater contamination. Each county carries out permitting, inspections and operation of the SSTS program locally. Table 9 provides a more comprehensive list of specific actions the LMRWW can take to assure SSTS do not contaminate groundwater. You can find more information about building and maintaining SSTS at Subsurface Sewage Treatment Systems (https://www.pca.state.mn.us/water/subsurface-sewage-treatment-systems).

Contaminated Sites

The MPCA identified 93 active tank, 6 leak sites and one closed landfill in the LMRWW. These types of contaminated sites (also referred to as point sources) have the potential to contaminate groundwater with a variety of chemicals.

Where Are Contaminated Sites in the Lower Minnesota River West Watershed?

Figure 16, maps active tank and leak sites compared to pollution sensitivity of near-surface materials in the LMRWW. Figure 17 provides a map of the closed landfill in the LMRWW. The following sites also provide maps to help identify contaminated sites.

- What's in My Neighborhood (https://www.pca.state.mn.us/data/whats-my-neighborhood)**:** This app identifies potential contamination sites for water quality, feedlots, hazardous waste, investigation and clean up, air quality and solid waste.
- Landfill Cleanup Act Participants (http://mpca.maps.arcgis.com/apps/Solutions/s2.html?appid=6470bb44bd83497993da5836333d1cb3): This site has an interactive map that shows closed landfills and the corresponding groundwater plumes and groundwater areas of concern.

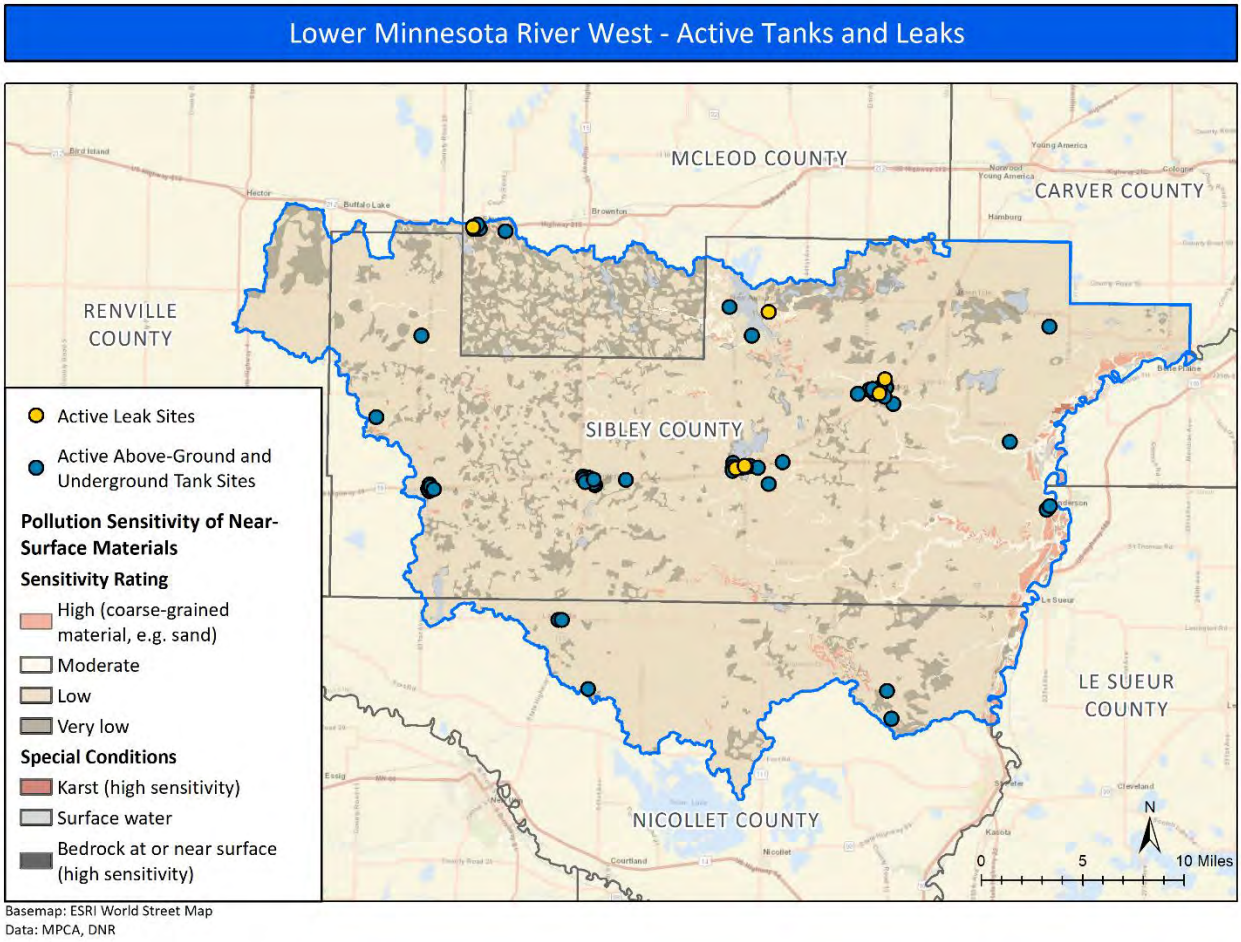

Figure 16: Lower Minnesota River West Watershed - MPCA Active Tank and Leak Sites and Pollution Sensitivity of Near-Surface Materials

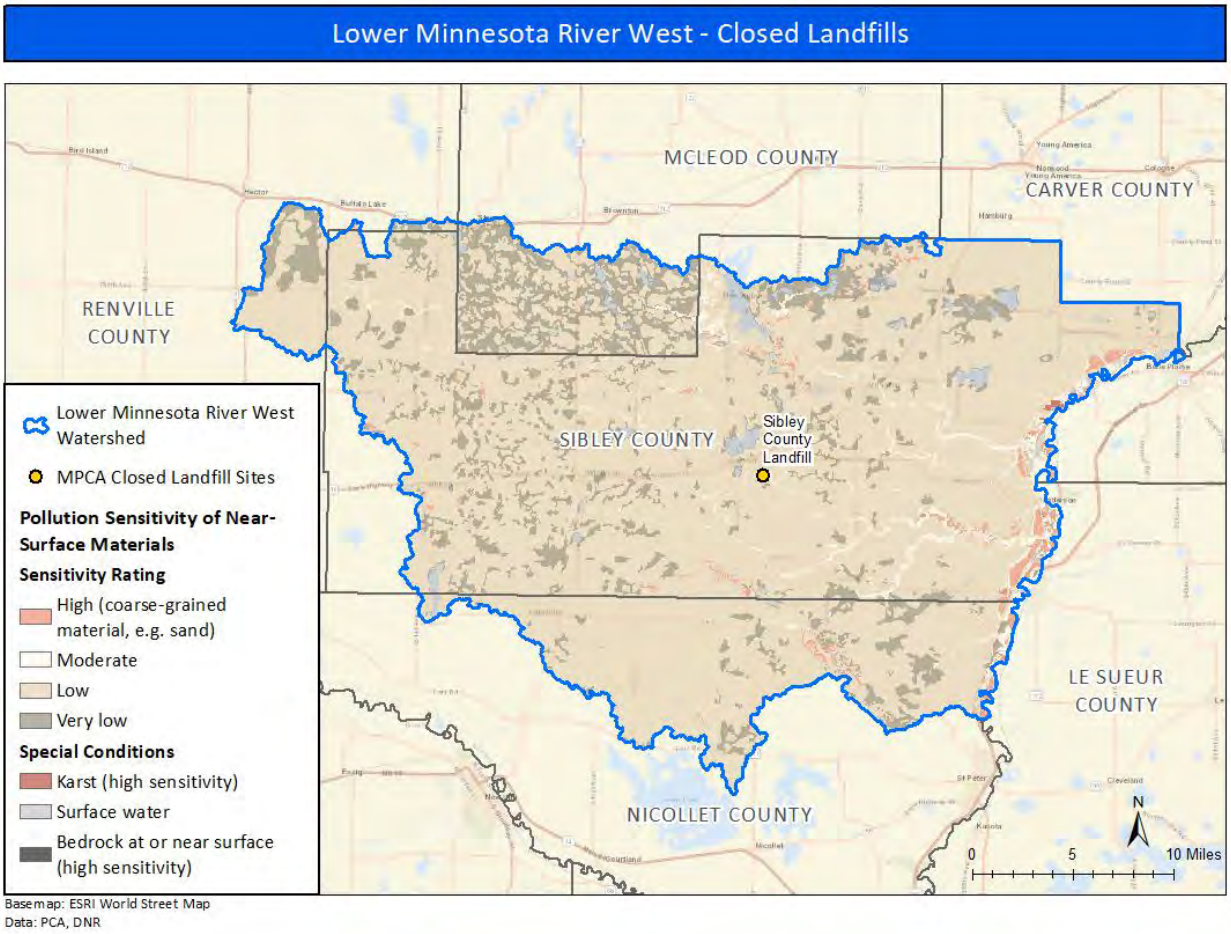

Figure 17: Lower Minnesota River West Watershed - MPCA Closed Landfill

How to Protect Groundwater from Contaminated Sites

Contaminated sites should be identified before making or changing any land use plans, zoning maps, and/or ordinances. Table 9 provides a more comprehensive list of specific actions the LMRWW can do to assure contamination sites do not further contaminate groundwater.

Stormwater

The MPCA Stormwater Program (https://www.pca.state.mn.us/water/stormwater) regulates the discharge of stormwater and snowmelt runoff from municipal separate storm sewer systems (MS4s), construction activities and industrial facilities, mainly through the administration of the National Pollutant Discharge Elimination System (NPDES)/State Disposal System (SDS) Program. MS4s in Minnesota must satisfy the requirements of the MS4 general permit if they are located in an urbanized area and used by a population of 1,000 or more or owned by a municipality with a population of 10,000 or more, or a population of at least 5,000 and the system discharges to specially classified bodies of water. Entities with an MS4 permit require the treatment and management of stormwater runoff.

The management of stormwater runoff is increasingly reliant on the infiltration of stormwater into the soil to control the volume of runoff. Several stormwater practices concentrate runoff and force infiltration into the soil where it can recharge groundwater aquifers. The impacts of these practices on groundwater quality have not been thoroughly evaluated.

How to Manage Potential Stormwater Infiltration Risk

Caution should be observed when infiltrating stormwater, especially in areas with vulnerable drinking water sources. Use the MDH Stormwater Guidance for Sites in Drinking Water Supply Management Areas (https://stormwater.pca.state.mn.us/images/d/d3/Flow_Chart_-_MDH_Stormwater_Guidance_for_Sites_in_Drinking_Water_Supply_Management_Areas.pdf) to better understand when infiltration is appropriate in wellhead protection areas. Table 9 provides a more comprehensive list of additional actions the LMRWW can take to prevent stormwater infiltration from contaminating groundwater.

Household Hazardous Waste

Many household products you use to clean your home, maintain your yard, and control animals and insects contain hazardous materials. When these products are disposed of improperly, it may lead to groundwater contamination.

Minnesota's household hazardous waste (HHW) program is a partnership with the MPCA and the counties. Together, they provide education about HHW storage and disposal as well as maintain a network of regional, local and mobile facilities to collect HHW statewide. In addition, many counties offer temporary collection sites, including one-day events. The MPCA has a searchable database to find HHW collection sites for your county, Household Hazardous Waste Collection Sites (https://www.pca.state.mn.us/living-green/find-your-household-hazardous-waste-collection-site).

Similar to the partnership for HHW, MDA partners with counties to provide a means to safely dispose of unwanted and unusable pesticides through the Waste Pesticide Collection Program. Through this program, pesticide users in every county around the state have opportunities to dispose of unwanted agricultural pesticides through county HHW facilities, mobile collection events or by attending MDA schedule events. Participants can drop off up to 300 pounds free of charge. MDA manages a waste pesticide collection schedule to learn about partnerships and scheduled events, MDA Waste Pesticide Collection Schedule (www.mda.state.mn.us/chemicals/spills/wastepesticides/schedule.aspx).

How to Protect Groundwater from Household Hazardous Waste Contamination

Promote HHW and the pesticide collection program availability to residents, and evaluate opportunities to expand services to increase participation. Table 9 provides a more comprehensive list of specific actions the LMRWW can take to assure consumer products do not contaminate groundwater.

Pharmaceuticals

The presence of pharmaceuticals in water is of increasing concern because they may cause harm to humans and aquatic life. Pharmaceuticals enter rivers, lakes and groundwater when human waste, animal waste or discarded medications move from stormwater systems, sewer systems or septic tanks into water. Wastewater and drinking water treatment may not completely remove pharmaceuticals. As a result, these chemicals can be found in drinking water sources.

How to Protect Groundwater from Pharmaceutical Contamination

Do not flush old or unwanted prescription or over the counter medications down the toilet or drain, and do not put them in the trash. There are more than 240 medication collection boxes located at law enforcement facilities and pharmacies in Minnesota. These collection sites do not charge for disposal. You can use the Earth 911 website to identify collection sites by zip code, *Locations that take medications (https://search.earth911.com/?what=Medications&where=MN)*. If a disposal site is not available, follow the MPCA guidance to minimize risk to the environment, *Medication Disposal Guidance (https://www.pca.state.mn.us/living-green/managing-unwanted-medications)*.

Groundwater Quantity Issues and Concerns

Permitted groundwater use increased from about 475 million gallons per year in 1990 to about 970 million gallons per year in 2009. Groundwater use then slowly declined to about 820 million gallons per year in 2018. Approximately 60 percent of groundwater use is for water supply and 24 percent is used for industrial processing. There are eight well nests in the watershed where wells with different depths are monitored together. Five of those well nest were installed in the last 5 years. All DNR groundwater-level monitoring wells have less than 20 years of record which means that statistical trends cannot be calculated.

Groundwater Use

A water-use appropriation permit is required from the DNR for groundwater users withdrawing more than 10,000 gallons of water per day or 1 million gallons per year. This provides the DNR with the ability to assess which aquifers are being used and for what purpose. Permits require annual water-use reporting. This information is recorded using Minnesota Permitting and Reporting System (MPARS), which helps the DNR track the volume, source aquifer, and type of water use. The DNR has records of reported water use from 1988 to the present.

Figure 18 - Figure 20 show graphs of reported water use by calendar year from 1988 to 2018. A summary of reported 2018 water use by use category versus source aquifer is shown in Table 7. Figure 21 and Figure 22 show the distribution of permitted wells with reported 2018 water use, categorized by use category and aquifer type, respectively.

Annual groundwater use in the LMRWW had a minimum of approximately 475 million gallons in 1990. Groundwater use increased to about 970 million gallons per year in 2009 and has gently declined to about 820 million gallons per year in 2018 (Figure 18).

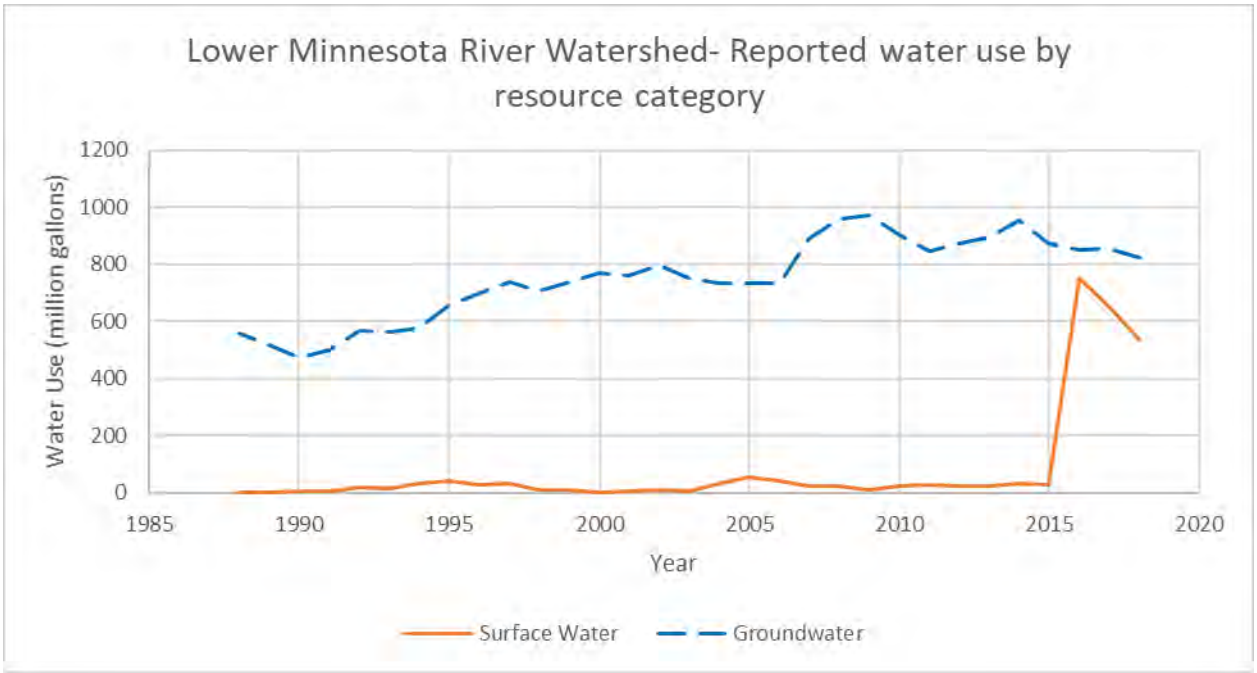

Figure 18: Reported water use from the DNR permit holders by resource category. Groundwater use increased from about 475 million gallons per year in 1990 to about 970 million gallons per year in 2009 and then gently declined to about 820 million gallons per year in 2018.

Most permitted groundwater withdrawals are pumped from buried sand and bedrock aquifers (Figure 19). Most permitted groundwater use is for water supply (Figure 21).

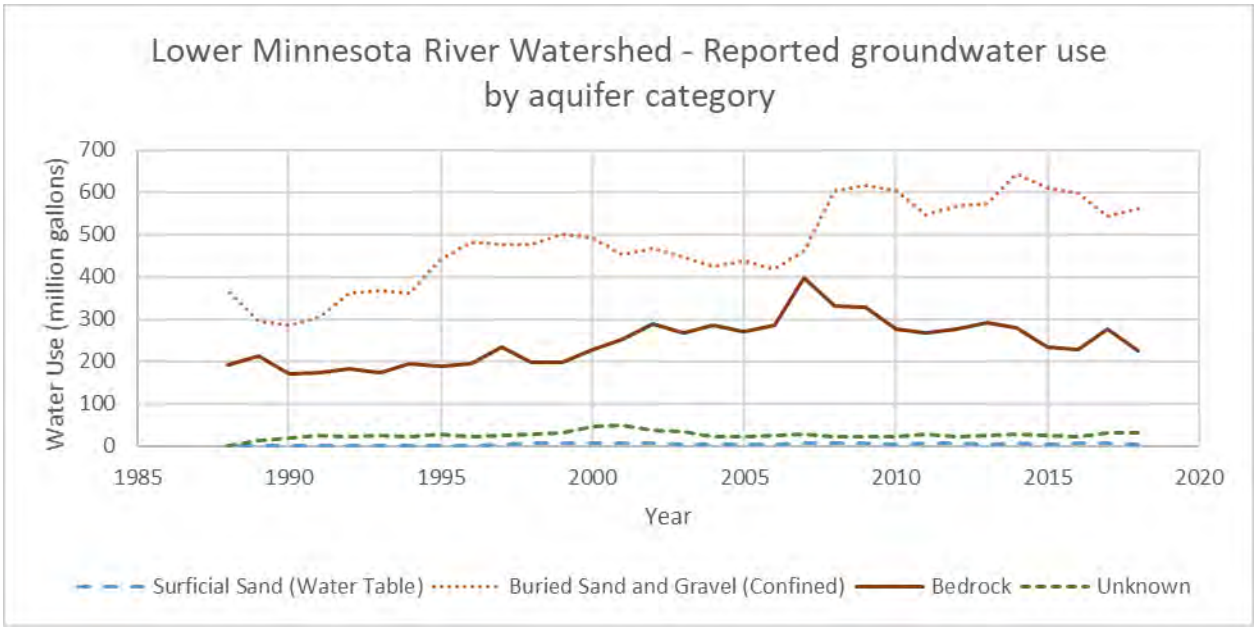

Figure 19: Reported groundwater use from DNR permit holders by aquifer category. Most permitted groundwater use is drawn from the buried sand and gravel and bedrock aquifers. Pumping from buried sand and gravel aquifers rose from about 290 million gallons per year in 1990 to about 600 million gallons per year in 2014, then declined slightly.

In 2018, approximately 60 percent of permitted groundwater use was for water supply, approximately 24 percent was used for industrial processing, 13 percent for other categories, and the remainder spread among other use categories (Table 7). Approximately 68 percent of permitted groundwater was sourced from the buried sand aquifer and 28 percent from bedrock aquifers.

Figure 20 shows the distribution of groundwater appropriation permits for 2018 by volume reported and use category. Figure 21 shows the same information by volume reported and aquifer category. The largest water users are the City of Gaylord in the east central part of the watershed, the City of Winthrop in the west central part of the watershed, and an ethanol plant between the two cities.

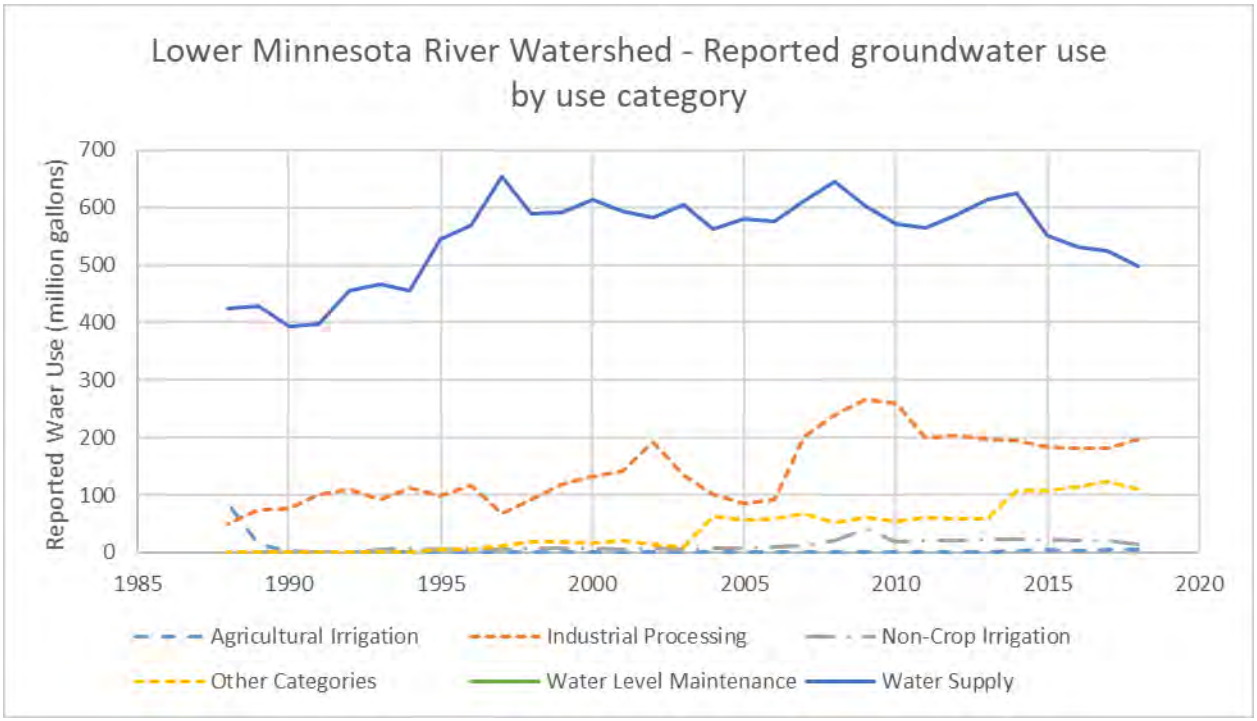

Figure 20: Reported groundwater use from DNR permit holders by use category. Most permitted groundwater withdrawals are used for water supply. Pumping for water supply rose from approximately 400 million gallons per year in 1990 to approximately 600 million gallons per year in 1997, stayed level until 2014, and then slowly declined.

Table 7 [11]: Reported 2017 water use from DNR groundwater permit holders in million gallons per year.

Use Category	Surficial Sand Aquifer (Water Table)	Buried Sand and Gravel Aquifer (Confined)	Bedrock Aquifer	Unknown	Total (mgy)	Total (percent)
Agricultural Irrigation	—	—	—	5.5	5.5	0.7
Heating/Cooling	—	—	—	—	—	—
Industrial Processing	—	97.0	98.0	2.1	197.1	23.9
Non-Crop Irrigation	—	8.3	5.0	—	13.3	1.6
Other Categories	4.6	66.6	16.8	22.3	110.3	13.4
Power Generation	—	—	—	—	—	—
Water Level Maintenance	—	—	—	—	—	—
Water Supply	—	390.6	106.4	—	497.0	60.4
Total (mgy)	4.6	562.6	226.2	29.9	823.3	—
Total (percent)	0.6	68.3	27.5	3.6	—	100 *

[11] Data from MPARS; mgy, million gallons per year; dash marks (-) indicate no use in those categories; * percentages may not equal 100 due to rounding.

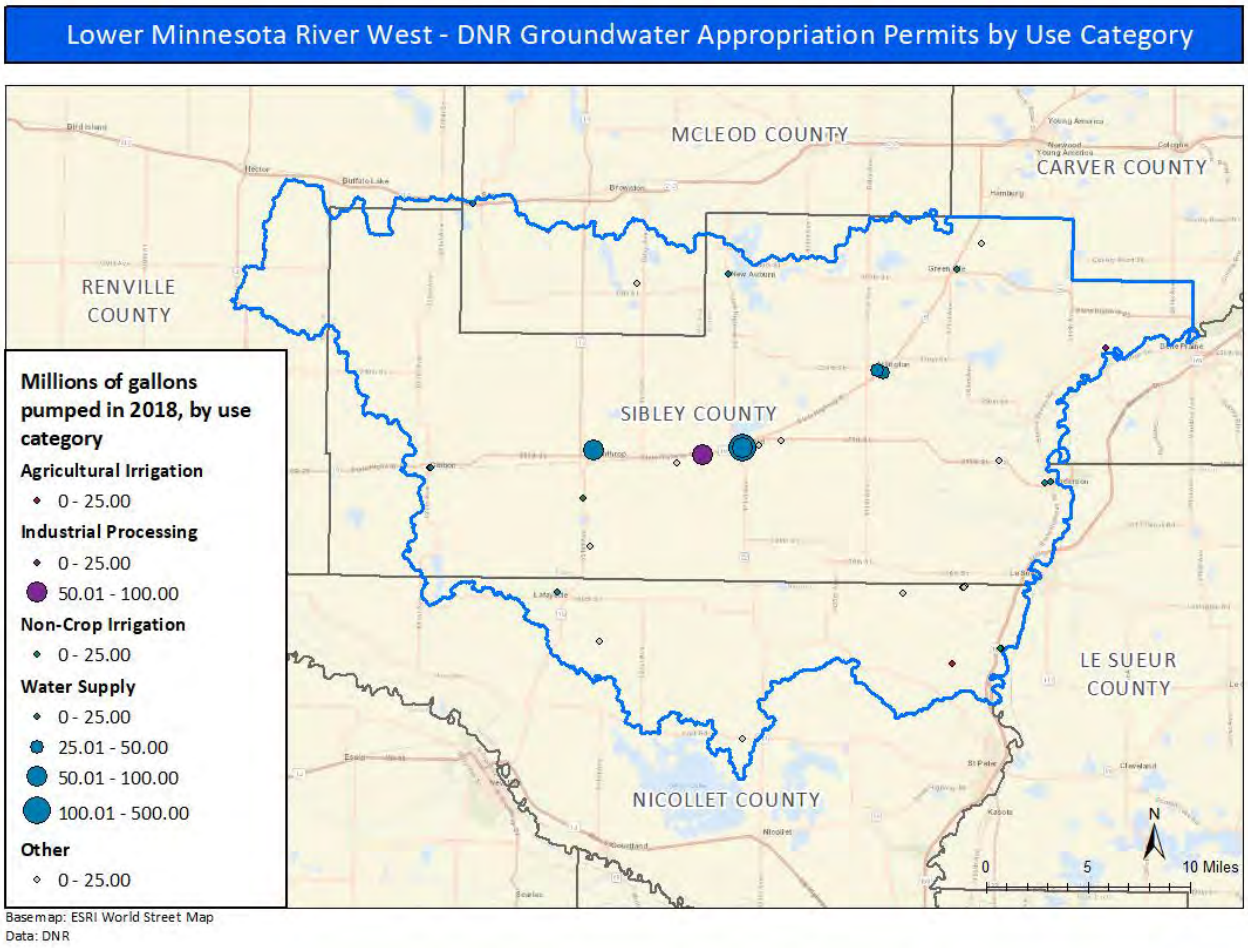

Figure 21: Lower Minnesota River West Watershed - Distribution of groundwater appropriation permits for 2018 by volume reported and use category. The largest water users in the watershed are the cities of Winthrop and Gaylord and an ethanol plant.

Groundwater Level Monitoring

The DNR maintains a statewide groundwater-level monitoring program for assessing groundwater resources, determining long-term trends, interpreting impacts of pumping and climate, planning for water conservation, evaluating water conflicts, and managing water resources.

There are 19 active groundwater-level monitoring wells in the planning area and two wells monitored for permit compliance (Figure 23). Of these 21 wells, eight wells have been monitored since the 2000s and 13 wells since the 2010s.

None of the groundwater-level monitoring wells have long enough records of water-level data to calculate a statistical trend. Hydrographs from 15 of the wells are shown in Figures 25 through Figure 30.

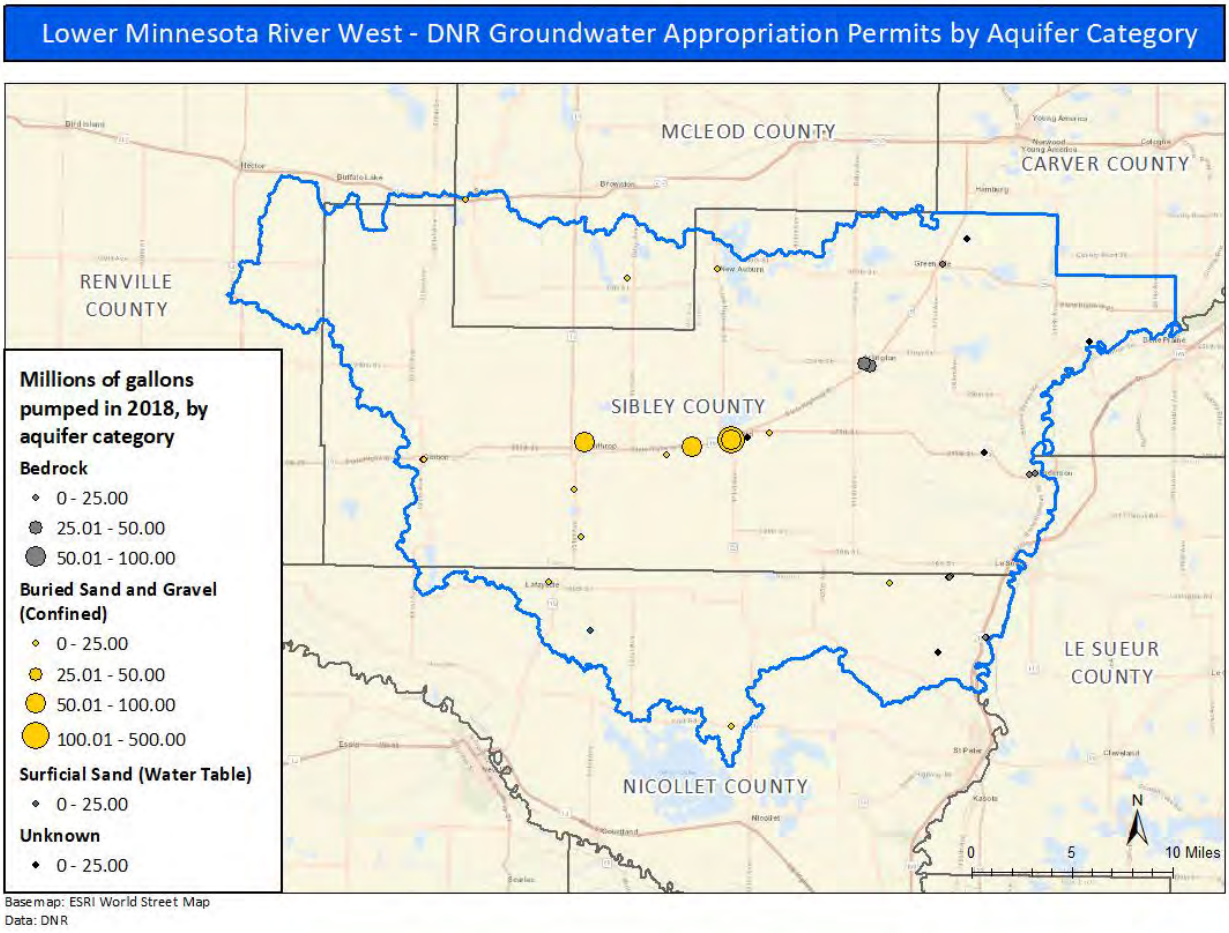

Figure 22: Lower Minnesota River West Watershed – Distribution of groundwater appropriation permits for 2018 by volume reported and aquifer category.

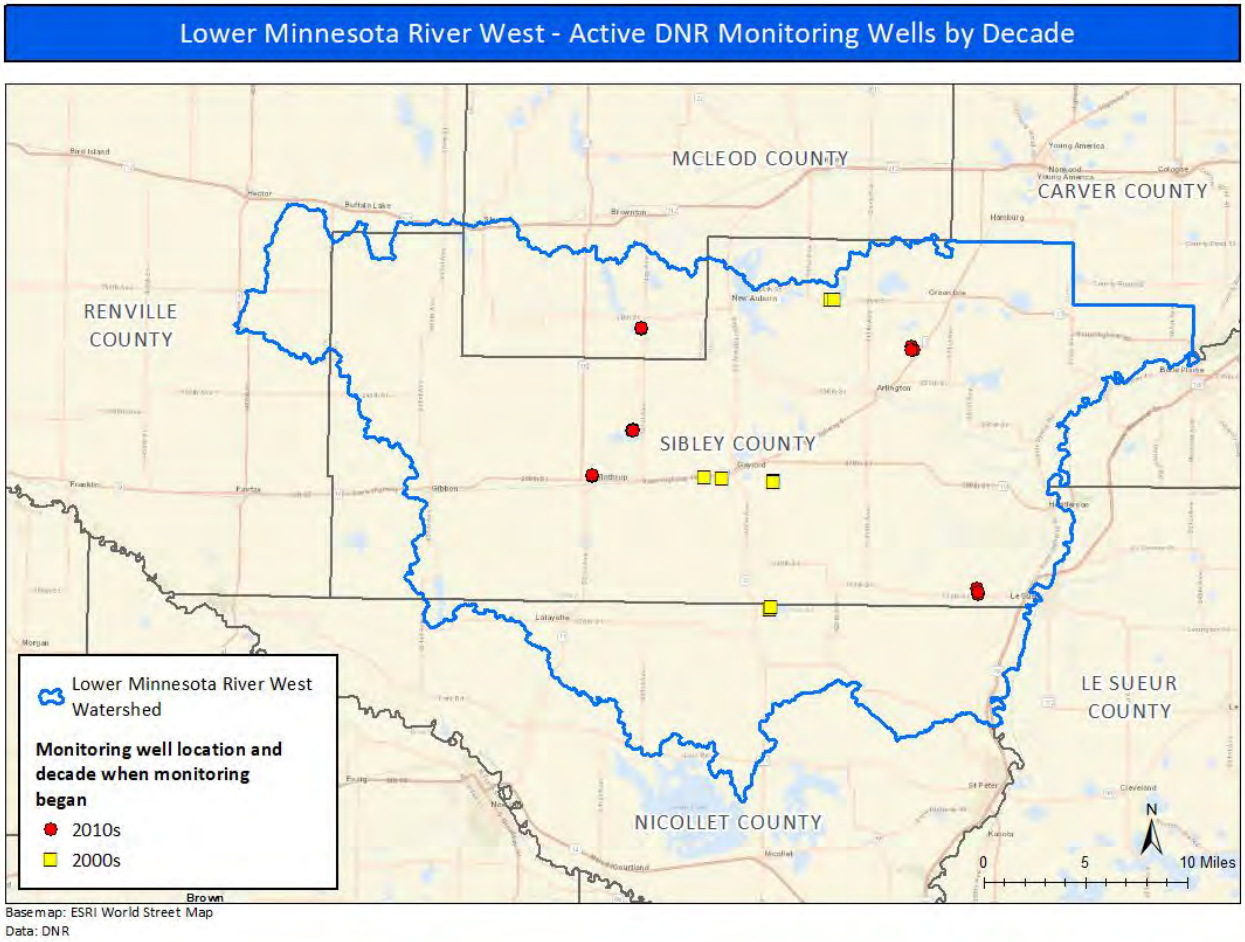

Figure 23: Lower Minnesota River West Watershed – Active Groundwater-Level Monitoring Wells in the Lower Minnesota River West Watershed by decade monitoring started. Twenty-one wells are measured for groundwater levels in the watershed. Nineteen of these wells are part of the Cooperative Groundwater Monitoring Network and 2 wells are compliance wells to record levels near permitted pumping wells. Eight of the groundwater-level monitoring wells in the watershed have been monitored since the 2000s. Thirteen wells were added in the 2010s, all as part of a well nest, where the wells are built next to each other, but completed in aquifers at different depths.

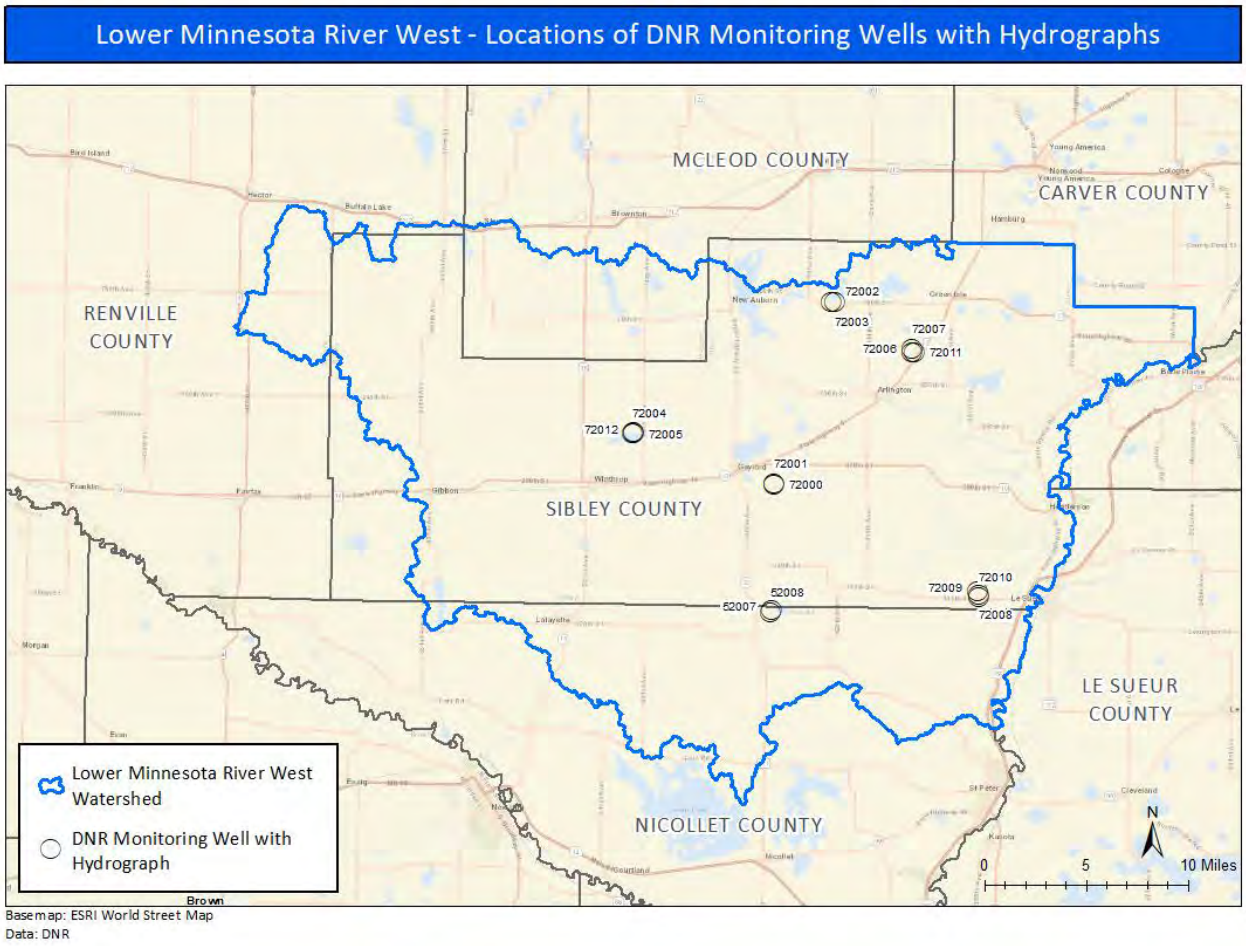

Figure 24: Location of active groundwater-level monitoring wells with hydrographs. No groundwater-level monitoring wells had sufficient length of record of water-level data to calculate a long-term trend, which requires a minimum of 20 continuous years of data.

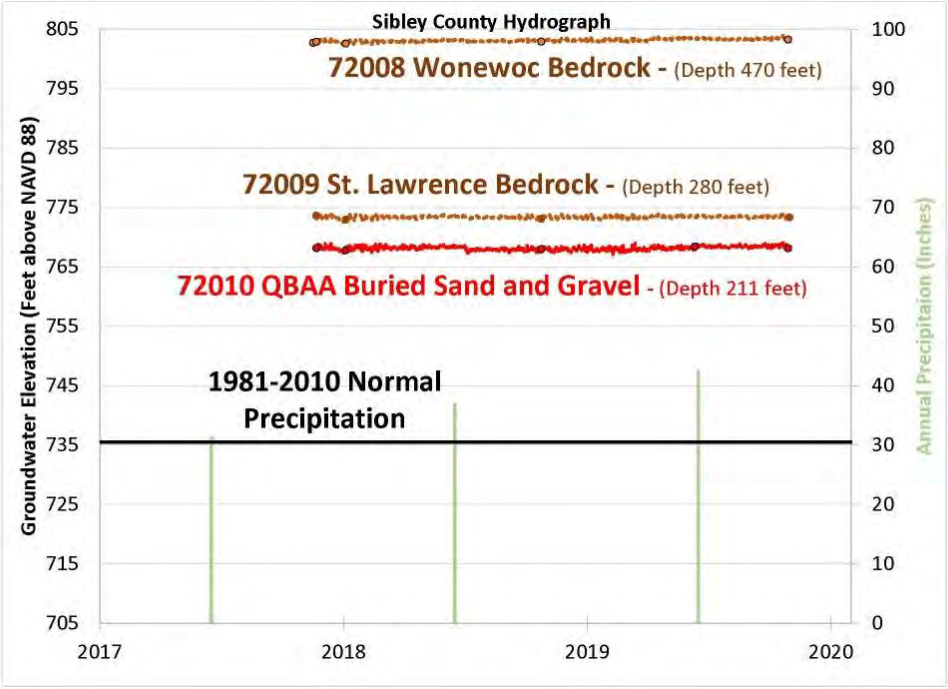

Figure 25: Hydrograph of wells 72008, 72009, and 72010 compared to precipitation. Water levels are highest in the Wonewoc (deepest) aquifer and lowest in the buried sand and gravel (shallowest) aquifer. These wells are three miles west of the Minnesota River, and the aquifers discharge to the river.

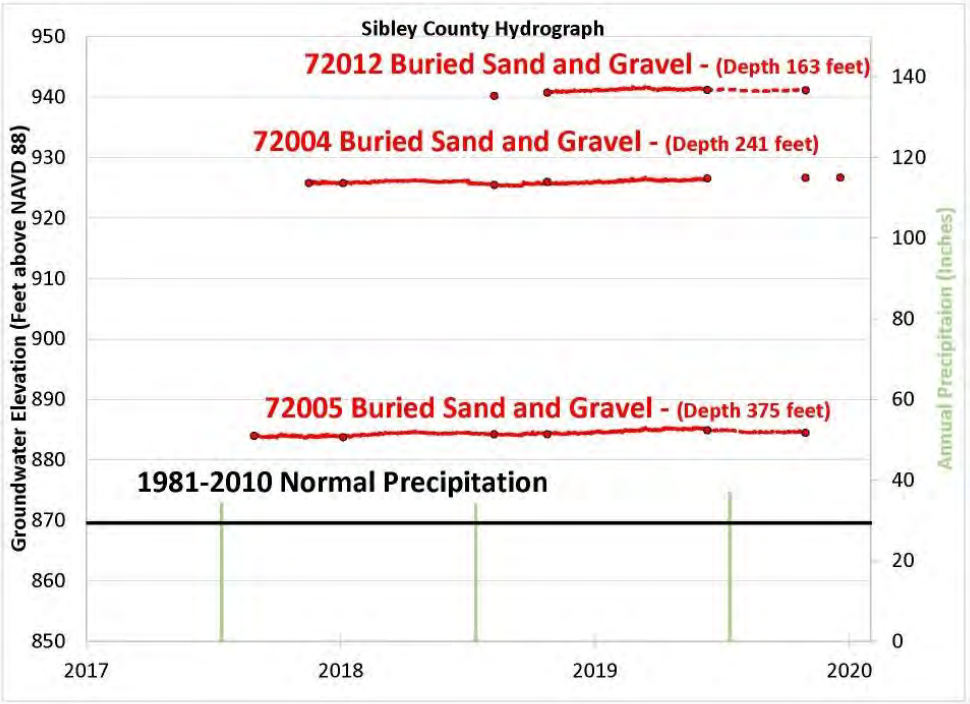

Figure 26: Hydrographs of wells 72012, 72004, and 72005 compared to precipitation. This is an area of groundwater recharge where shallow aquifers have higher groundwater elevations than deeper aquifers.

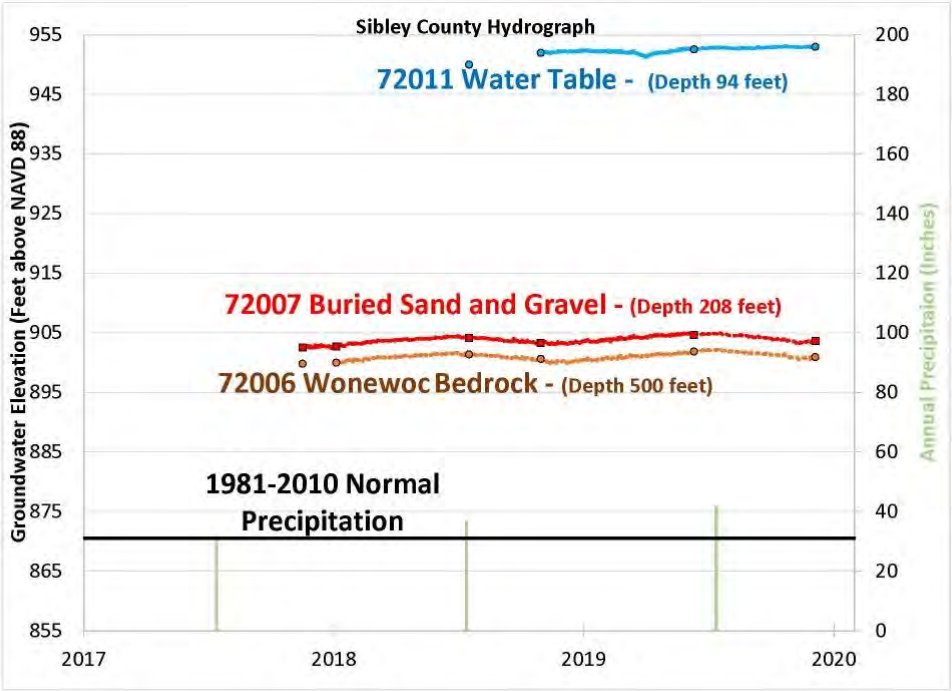

Figure 27: Hydrograph of wells 72011, 72006, 72007 compared to precipitation. This is an area of groundwater recharge where shallow aquifers have higher groundwater elevations than deeper aquifers.

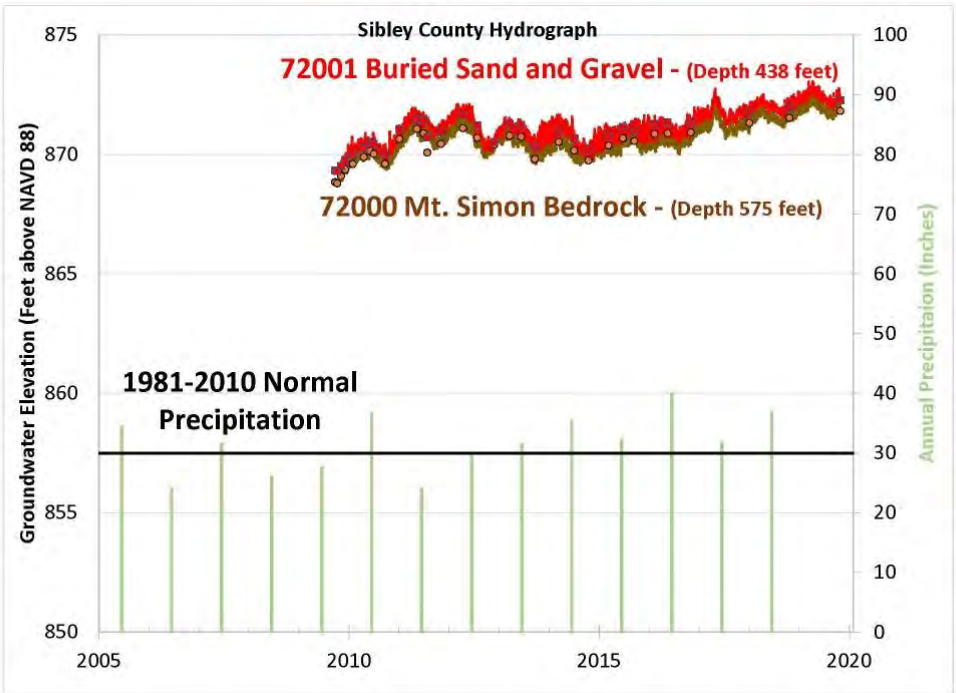

Figure 28: Hydrograph of wells 72000 and 72001 compared to precipitation. The buried sand and gravel aquifer has slightly higher water levels that the Mt. Simon aquifer. This implies that deeper groundwater is either moving downward or laterally. The annual fluctuations in water levels are likely due to seasonal groundwater pumping.

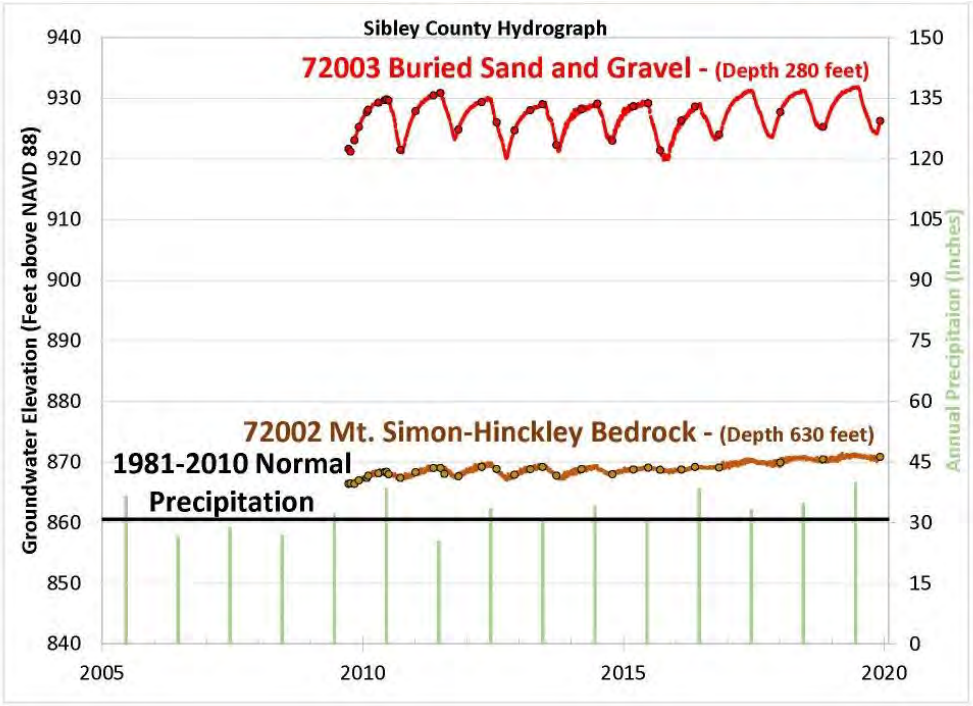

Figure 29: Hydrographs of wells 72002 and 72003 compared to precipitation. The buried sand and gravel aquifer has higher water levels than the deeper Mt. Simon aquifer. This indicates that groundwater is moving downward and recharging deeper aquifers. The annual fluctuations in water levels in well 72003 are likely due to seasonal groundwater pumping.

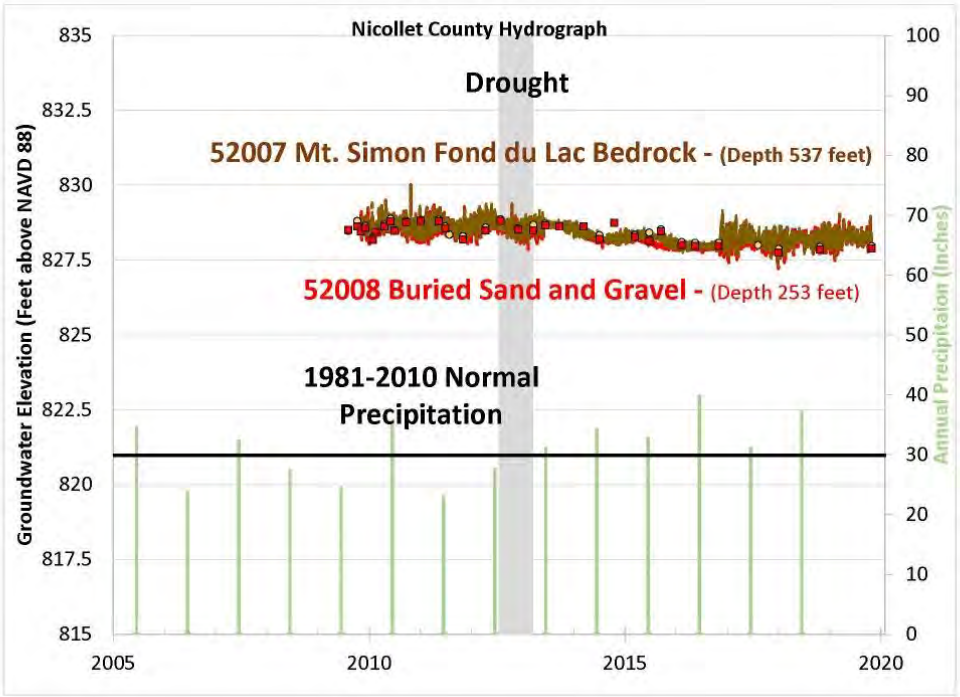

Figure 30: Hydrograph of wells 52007 and 52008 compared to precipitation. The buried sand and gravel aquifer and the Mt. Simon aquifer have very similar water levels. This implies that deeper groundwater is moving laterally.

Groundwater Connected Natural Features at Risk

The LMRWW boundary includes significant natural features, including surface waters that depend on groundwater to sustain them (Figure 31). Groundwater appropriations and land-use changes can impact the health of these natural resources. If groundwater quantity or quality is degraded, these resources are at risk. The following features occur within the LMRWW:

- Wetland complexes across the entire area
- Lakes that may be susceptible to changing aquifer levels
- Ten kinds of native plant communities connected to groundwater
- Thirteen rare plant and animal species connected with groundwater that are listed as threatened, special concern, or species of greatest conservation need in the state of Minnesota
- Two animal clusters that are vulnerable to a single catastrophic event
- Other significant natural features that help maintain a healthy, functional landscape occur in the watershed, but are not included in this report.

The LMRWW retains a small percentage of its groundwater-connected native systems. Integrating native systems into our land and water use is extremely important for maintaining healthy, resilient watersheds that are able to provide for current and future generations.

Rare Natural Features Connected with Groundwater in the Lower Minnesota River West Watershed

Rare features can include species of unique plants and animals as well as native plant communities (habitats) (www.dnr.state.mn.us/npc/index.html) and geologic features. In Minnesota, rare species (www.dnr.state.mn.us/ets/index.html) are categorized as endangered, threatened, special concern, and species of greatest conservation need based on how uncommon the species is (its rarity), their distribution in the state, and their vulnerability to extinction. Rare natural features (Figure 31 and Figure 32) contribute to the health of our environment. Some even contribute directly to local economies in the form of recreation—including hunting/fishing, wildlife viewing, and camping. These resources are at risk if groundwater quantity or quality is disrupted.

There is one designated calcareous fen (https://files.dnr.state.mn.us/natural_resources/water/wetlands/calcareous_fen_fact_sheet.pdf) in the LMRWW Calcareous fens are rare and distinctive peat-accumulating wetlands. They depend on a constant supply of upwelling groundwater rich in calcium and other minerals. This calcium-rich environment supports highly diverse and unique rare plants that tolerate low oxygen conditions, calcium carbonate deposits, low nutrient availability, and relatively cold organic soils (peat)—the calcareous fen ecosystem. Because these types of wetlands are one of the rarest natural communities in the United States, they are specially protected from harm under Minnesota Statute (103G.223). Fens are connected to a larger groundwater system. They are good indicators of groundwater sustainability, contribute to improved water quality and ecological diversity, and are an invaluable part of Minnesota's rich natural heritage. Once lost, these communities cannot be replaced.

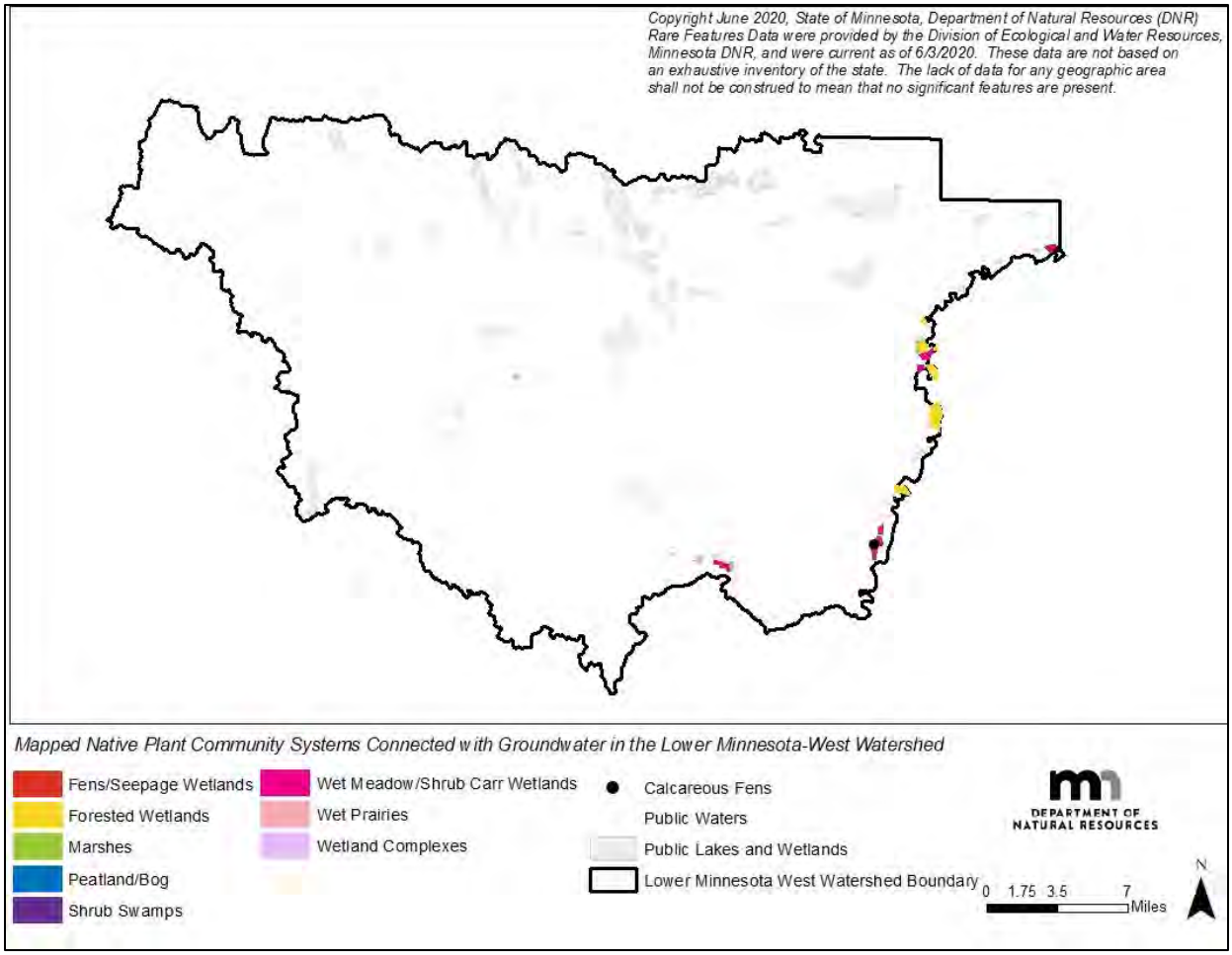

Figure 31: Lower Minnesota River West Watershed – Native Plant Communities Connected with Groundwater

There are ten kinds of native plant communities associated or dependent on groundwater in the LMRWW Figure 31 . They range from wet prairies and meadows to marshes, fens, seepage meadows, and floodplain forests. The LMRWW has lost almost all of its native plant communities so those that remain are a high priority for preservation in order to achieve healthy groundwater systems. Of those still present on the landscape, only two are considered secure, all others are classified as critically imperiled, imperiled, or vulnerable to extirpation. There are thirteen species of birds, mussels, reptiles, and plants that are either threatened, special concern, or a state listed "Species in Greatest Conservation Need," and two animal clusters that are vulnerable to a single catastrophic event. These species and animal clusters are connected to habitats with groundwater or groundwater seepage areas for all or part of their life cycles, which means these habitats are important refuges in the LMRWW. A detailed list of native plant communities and rare features is available in the Additional Resources section at the end of the report in Table 11 through Table 12.

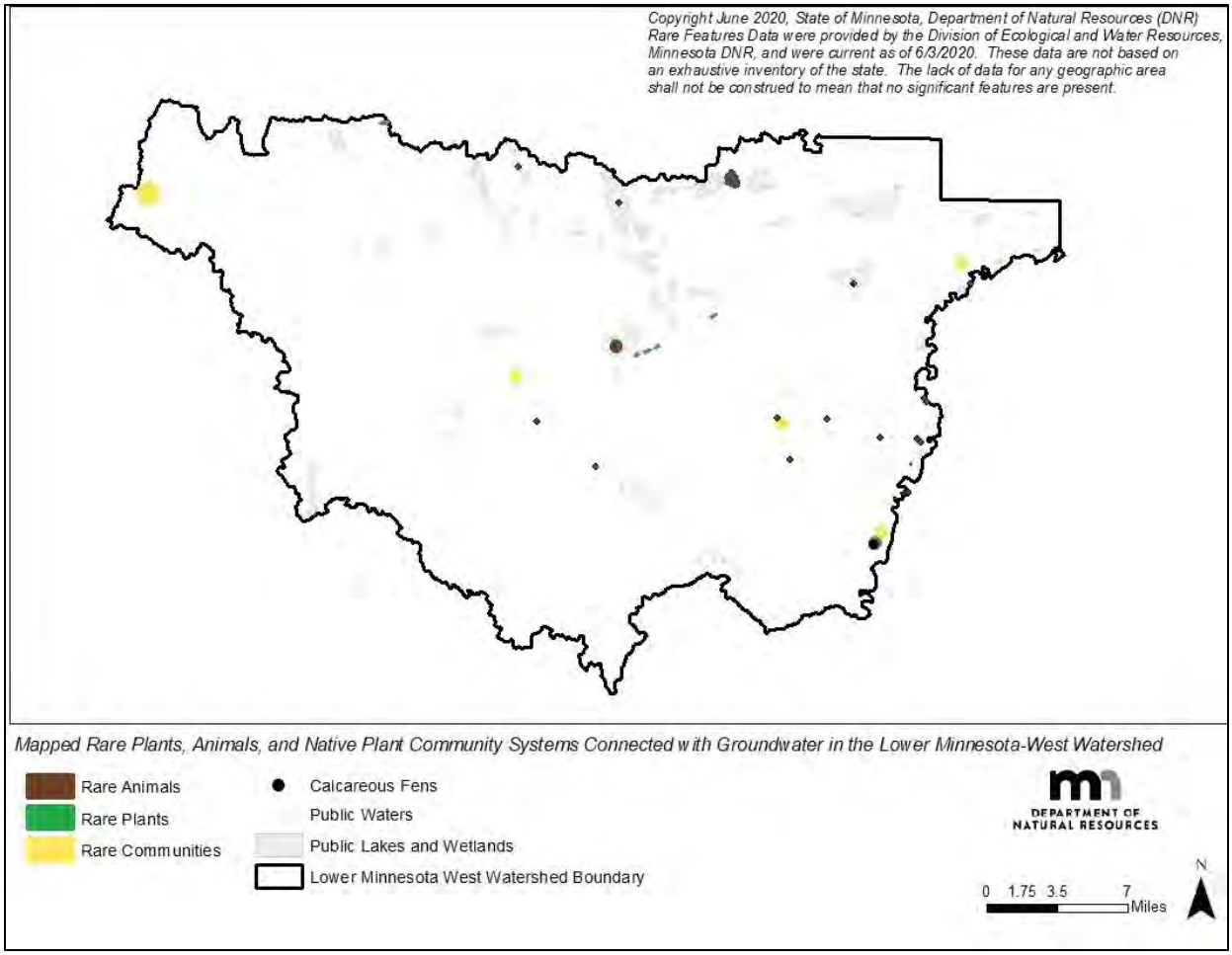

Figure 32: Lower Minnesota River West Watershed - Rare Plants, Animals, and Native Plant Communities Connected with Groundwater

Groundwater connections to wildlife species are many and often complex. Wildlife groups as diverse as birds, bats, spiders, snakes, turtles, frogs, toads, fishes, and snails all contain species that require some form of surface water body to complete their life cycles and persist on the landscape. If groundwater fluctuations or depletions affect a significant number of surface water features in this area, important wildlife habitats may be impacted or lost.

Groundwater Flow Dominated Lakes

All lakes are connected to groundwater, but the specific interaction between lake water and groundwater depends on the geology, topography, and volume of surface-water inflow and outflow associated with the lake. There are three basic lake types (Petersen and Solstad, 2007):

1. Lakes dominated by surface water inflow and outflow resulting from a large ratio of contributing surface watershed area to lake area.
2. Lakes dominated by groundwater inflow and outflow resulting from a smaller ratio of contributing surface watershed area to lake area (10 or less). This lake type is often landlocked with no surface outlet. Although for the purposes of this GRAPS report, the lake level outlet

elevation has not been studied. Lakes have been put into this classification solely by watershed to lake area ratio.

3. Lakes intermediate between the first and second types. This applies to lakes that typically have a large watershed to lake area ratio, but during times of drought, the lake level will drop below the outlet level. Groundwater often becomes a significant part of the inflow to these lakes during extended dry periods.

Only the groundwater-dominant lakes as defined in type 2 above are shown in this report (Figure 33). There are 25 groundwater-flow dominated lakes in the LMRWW. Large-scale groundwater pumping near a lake will likely have more impact to groundwater-flow dominated lakes than to surface water-flow dominated lakes.

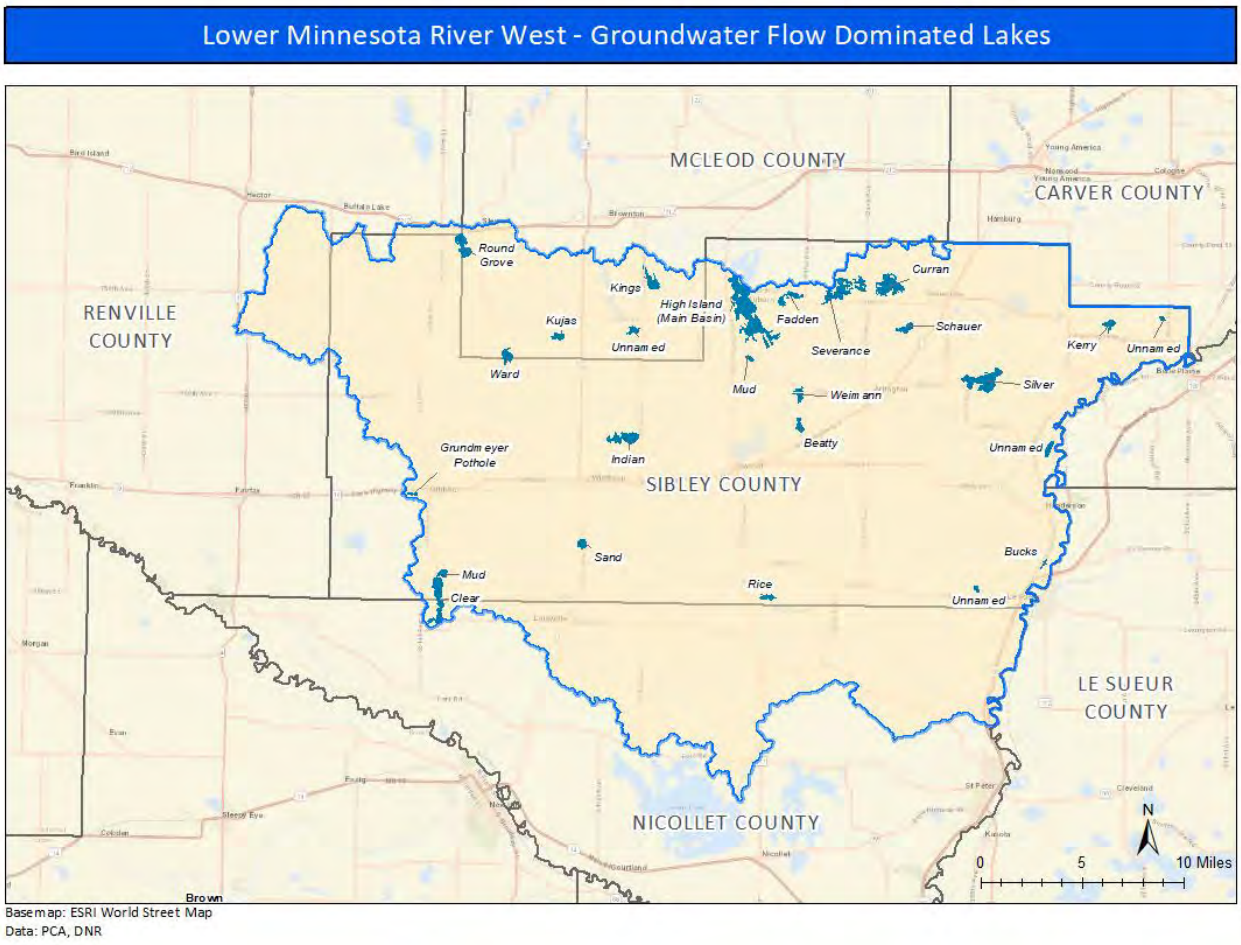

Figure 33: Groundwater-Dominated Lakes in the Lower Minnesota River West Watershed. There are 25 groundwater-flow dominated lakes in the planning area.

How to Address Groundwater Quantity Issues

Most groundwater quantity (sustainability) issues are the result of overuse of groundwater and/or reduction in recharge to the underlying aquifer. Therefore, the strategies to address water quantity issues are similar, regardless of the groundwater quantity issue. The two primary goals to assure water sustainability are:

- **Water conservation:** Reduce or limit the amount of groundwater used
- **Promote or protect recharge:** Find ways for water to infiltrate back into the ground

There are a variety of strategies to help meet water conservation and recharge goals. The type of strategy used depends on the primary factor affecting quantity in the area in question. Strategies include: conservation easements, cropland management, education and outreach, irrigation water management and land use planning and management. (Table 9) provides a more comprehensive list of specific actions the LMRWW can take to conserve water and promote recharge.

Lower Minnesota River West Watershed Strategies and Actions to Restore and Protect Groundwater

This section provides tips for prioritizing and targeting restoration and protection strategies and makes suggestions about what strategies and actions would be most appropriate within different areas of the watershed. Information on the geological, ecological and sociological conditions for each county and subwatershed (HUC-10) informs which strategies and actions would be effective for each HUC-10 and county.

Tips for Prioritizing and Targeting Strategies and Actions

Determine Your Goal

You may decide to address an issue because of known instances or threats in an area, or maybe you are working in a geographic area because of jurisdiction or some other factors. The Actions and Strategies Table (Table 9) will help you focus on the goal, for instance, reducing nitrate in groundwater. Then you will need to decide, using the table, if you would like to focus on conservation easements, outreach and education, nutrient management, or some other strategy.

Match the Right Action with the Right Location

The Actions and Strategies Table (Table 9) will help you determine where the actions would be most effective. For instance, an activity that reduces nitrate in groundwater may be more valuable in sensitive areas or vulnerable wellhead protection areas. Or, if you are focused on a limited geography, the table will help you determine what actions are applicable to that area. Considering the sensitivity combined with the presence of drinking water wells and vulnerable wellhead protection areas can help further focus efforts. In another example, factors such as the presence of groundwater dependent features and a concentration of large appropriation wells can help determine where efforts to promote conservation and recharge would be most effective.

Know the Pollution Sensitivity

Groundwater quality is impacted by both point and non-point source pollution. These potential contaminant sources need to be managed according to the pollution sensitivity of the aquifer (Figure 5: Lower Minnesota River West Watershed - Pollution Sensitivity of Near Surface Materials). Examining the sensitivity of the aquifer as it relates to contamination risk helps determine the level of management necessary to protect groundwater quality. For example, a failing septic system has a greater potential to contaminate the aquifer in a highly sensitive setting with coarse textured material than an area with low sensitivity that has a protective clay layer that retards the movement of water into the aquifer.

Consider Multiple Benefits

Oftentimes, the restoration and protection strategies identified for both groundwater and drinking water positively influence other ecosystem services, such as surface waters, habitat, and pollinators, among others. Managing water as 'one water', rather than parceling it out to reflect the different aspects of water as it moves through the hydrologic cycle, allows for better planning and allocation of resources. The far right columns of the Actions and Strategies Table (Table 9) identifies the multiple benefits that could result from implementing the action.

Leverage Other Programs and Practices

Utilize existing Federal and State programs that are already working in the LMRWW to conserve land, prevent erosion and protect or improve surface water quality. Many of the practices that are being implemented have a benefit for groundwater. You can further target some of these efforts based on the information provided in this report to maximize the benefits by protecting groundwater. (Table 9) includes a column that identifies which agencies can assist with a specific action; the listed agencies typically have some type of program in place that you can leverage. The Descriptions of Supporting Strategies section of this report lists existing programs and resources for each of the suggested strategies.

Emphasize Protection

There is often a bias in groundwater management towards strategies that emphasize protection because of the cost and difficulty of remediating already-contaminated resources. In contrast to surface water bodies, groundwater:

- is difficult to access;
- cannot be observed, sampled or measured easily;
- travels slowly, often along complex pathways and through aquifer media that can absorb and store contaminants over long time periods; and
- is very difficult and expensive to treat if contaminated.

Timeframes associated with groundwater cleanup activities are often measured in decades and cost millions of dollars. Groundwater management strategies that emphasize prevention and protection are critical.

Although the tide is changing within water resources management in Minnesota, many funding streams and priorities are focused on restoration activities that can show measurable outcomes. Even though it is difficult to demonstrate 'improvements' from protection strategies, it is important to stress the need to take a balanced approach and protect groundwater resources.

Strategies and Actions for Lower Minnesota River West Watershed

This section provides a table of strategies and actions local partners in the LMRWW can take to restore and protect groundwater resources. Many of the proposed actions require the participation of a willing landowner to execute. Other actions reflect opportunities to manage land use through local controls. Many of the proposed strategies and actions align with strategies to protect surface waters.

Each action aligns with one or more supporting strategies and goals.

- **Goals** identify how an action helps restore and/or protect groundwater.
- **Supporting Strategies** are key approaches to achieving the goal.
- **Recommended Groundwater Actions** are specific actions prescribed to a specific county or HUC-10 within the watershed that will help achieve the goal and pertains to the supporting strategy.

Figure 34 provides a visual representation of the relationship between goals, supporting strategies, and recommended groundwater actions. Note that each goal is supported by many supporting strategies, and each supporting strategy may have a variety of recommended groundwater actions.

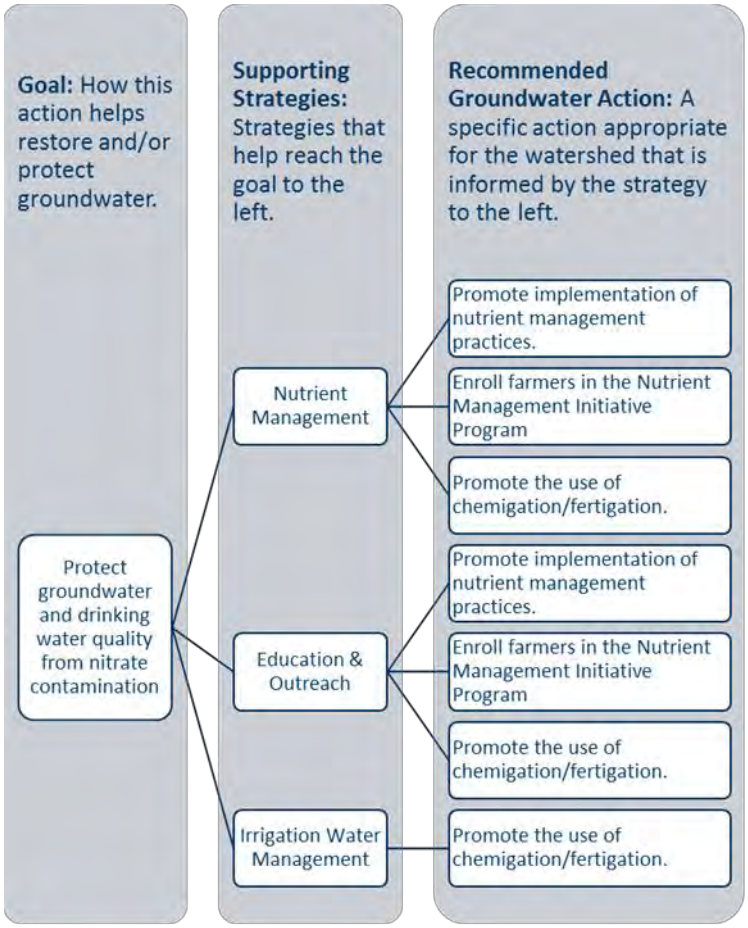

Figure 34: Visual representation of the relationship between goals, supporting strategies, and recommended groundwater action.

How to Use the Table of Actions and Strategies

The Table of Actions and Strategies (Table 9) is designed so that you can find actions and strategies related to whatever your priorities may be when it comes to restoring and protecting groundwater. There are a variety of columns to facilitate the following:

- finding actions for specific geographic areas (counties or HUC-10s);
- finding actions or strategies that would help achieve a specific goal;
- learning the additional benefits of implementing a specific action; and

- tips for determining where to target a specific action if you cannot implement the action in the entire recommended area.

The following list defines what each of the columns in Table 9 represent:

- **Goal:** How the action in this row helps restore and/or protect groundwater. The goals have been sorted alphabetically as much as possible. Each goal identifies the main objective—such as whether it protects groundwater quality or sustains the amount of water available—and includes a keyword to explain how the goal is achieved. For example, a goal that is listed as 'Protect Groundwater and Drinking Water Quality: Closed Landfills' can be interpreted as: Protect groundwater and drinking water quality from landfill contamination.
- **Supporting Strategies**: Identifies and links you to general strategies that help accomplish the goal for the action in this row. Each strategy is hyperlinked to a section of the report that provides more information about the strategy and connects you with existing tools and programs that may assist you in implementing this strategy or implementing actions related to this strategy.
- **Recommended Groundwater Action**: A specific action you can take to help achieve the goal to the left in the row and is informed by the strategy to the left in the same row.
- **Target _____ Co.:** The 'X's' denote which counties should consider using the action described in the corresponding row. An 'X' denotes the action would be most beneficial for that county. The addition of the counties helps to further prioritize and target where recommended groundwater actions should be implemented, narrowing the focus from a larger subwatershed to a specific geographic area. For example, many of the subwatersheds identify the need to work with irrigators; by adding the additional filter of counties, you are able to eliminate specific counties that do not have irrigators, targeting where implementation should occur. It also works as a quick reference to identify groundwater actions specific to the county in which you work.
- **HUC-10s Involved**: This column denotes which HUC-10 subwatershed(s) within the LMRWW to consider using the action described in the corresponding row. There are 19 HUC-10s within the watershed. Table 8 provides the name and the HUC-10 number assigned to each major watershed. Figure 2 is a map of the HUC-10s.
- **Agencies that can assist**[12]**:** This column lists agencies that may be able to assist with implementing the strategy through existing programs or providing more information or technical assistance.
- **Tips for Targeting & *Helpful Maps:*** This column helps identify the areas that should be targeted for the specific action if it is not feasible to implement the action in all the recommended counties or HUC-8s. The column also includes links to maps within the GRAPS report that may be helpful in identifying which specific areas within a county or HUC-8 to target. The maps are listed in *italicized font.* You can click on the *blue text* that says the figure number for the map to hyperlink directly to the map being referenced.

[12] BWSR=Board of Soil and Water Resources; FSA=Farm Service Agency; MDA=Minnesota Department of Agriculture; MDH=Minnesota Department of Health; MPCA=Minnesota Pollution Control Agency; NRCS=Natural Resources Conservation Service; UMN=University of Minnesota Extension (*not a comprehensive list of agencies/partners*)

- **Benefit:_____**[13]**:** This series of 'X' marks whether the corresponding action may have additional benefits. An 'X' denotes the action could create the described additional benefit.

Table 8: HUC 10 subwatersheds within the Lower Minnesota River West Watershed

HUC-10 Name	Reference Name in Implementation Table	HUC-10 Number
Bevens Creek	Bevens	0702001207
City of Belle Plain-Minnesota River	Belle Plain	0702001209
City of Le Sueur-Minnesota River	Le Sueur	0702001205
High Island Creek	High Island	0702001206
Middle Branch Rush River	Middle Branch	0702001204
North Branch Rush River	North Branch	0702001202
South Branch Rush River	South Branch	0702001203

Summary of Key Findings and Issues

Below is a summary of key groundwater quality and quantity findings found in the LMRWW. This summary can be used to help target groundwater actions during the 1W1P exercise.

Key Groundwater Quality Findings and Issues

- **Nitrate** – only 2 of the 1148 tested drinking water wells (less than one percent) had levels at or above the SDWA standard of 10 mg/L.
- There are no MDA ambient monitoring wells in the watershed.
- There are no MDA TTP samples collected in the watershed.
- There are no MPCA ambient groundwater monitoring wells in the LMRWW.
- **Arsenic** – 86 of the 320 tested drinking water wells had levels exceeding the SDWA standard of 10 µg/L. The EPA has set a goal of 0 µg/L for arsenic in drinking water because there is no safe level of arsenic in drinking water.
- **Pesticides –** there are no MDA ambient monitoring wells within the watershed.
- **DWSMAs** cover over 5,400 acres in the watershed. Six of the nine community public water suppliers are engaged in the wellhead protection planning process or are implementing their plans. All six of the systems with approved WHP plans have DWSMAs that are rated "low" or "very low" vulnerability.
- Nearly 52 percent of the people living in the watershed get their drinking water from a community public water supply system.
- **Private wells** – there are 1,688 private drinking water wells with known locations ranging from 37 ft. to 709 ft. deep, with an average depth of 245 ft. Approximately one percent (17 wells) of private wells are in a highly vulnerable setting.

[13] Habitat=Improve/Protect Habitat, including pollinators; GWCF=Improve/Protect Groundwater Connected Features; Soil Health=Improve/Protect Soil Health; Erosion=Control Erosion; Carbon=Carbon Sequestration; Nutrient Runoff=Control Nutrient Runoff, including pesticides (*The multiple benefits achieved are dependent on the placement and type of BMPs implemented; seed mixes planted; and other site conditions*).

- **Flood events** can threaten the safety and availability of drinking water by washing pathogens and chemical contamination into source aquifers. Only Renville and Mcleod County have flood zone designation to evaluate flood risk.
- **Animal feedlots – t**here are 604 active feedlots in the watershed, mainly in Sibley County. All counties have a delegated feedlot program, expect for Sibley County who relies on the MPCA to administer the feedlot rule.
- **Row crop agriculture** – land cover is almost exclusively row-crop agriculture in the watershed. In areas with high pollution sensitivity, agricultural inputs can contaminate the underlying aquifer.
- **SSTS** are found throughout the watershed. Information reported by counties indicate Mcleod County has the highest number of failing SSTS at four to seven per 1,000 acres. Renville and Sibley County reported the fewest number of failing SSTS.
- **Contaminated sites –** there are 93 active tank sites that could leak chemicals into the environment and 6 leak sites that may cause localized groundwater pollution if not properly managed. The risk to groundwater is greatest in areas of high pollution sensitivity.
- One closed landfill in Sibley County with a known groundwater contamination plume is found within the watershed.

Key Groundwater Quantity Findings and Issues

- In 2018, approximately 60 percent of permitted water use was for water supply, approximately 24 percent was used for industrial processing, 13 percent for other use categories, and the remainder spread among irrigation. Approximately 68 percent of permitted groundwater was sourced from the confined buried sand and gravel aquifer and 27 percent from bedrock aquifers.
- There are eight well nests in the watershed where wells with different depths are monitored together. Five of those well nests were installed in the last five years. All DNR groundwater level monitoring wells have less than 20 years of record which means that statistical trends cannot be calculated.
- LMRWW has one designated calcareous fen.
- There are 25 lakes in the LMRWW with a watershed to lake ratio of 10 or less and are considered groundwater-flow dominated lakes, susceptible to changing aquifer levels.
- Wetland complexes across the entire watershed are susceptible to changing aquifer levels.
- There are ten kinds of native plant communities associated or dependent on groundwater in the LMRWW. They range from wet prairies and meadows to marshes, fens, seepage meadows, and floodplain forests. The watershed has lost almost all of its native plant communities so those that remain are a high priority for preservation in order to achieve healthy groundwater systems.
    - Additionally, 13 species of birds, mussels, reptiles, and plants that are either state-listed endangered, threatened, or special concern plant and animal species connected to groundwater that are at risk to changing aquifer levels and degraded groundwater quality.

Table of Actions and Strategies to Restore and Protect Groundwater

Table 9: Actions and Strategies to Restore and Protect Groundwater

Goal	Supporting Strategy	▪ **Recommended Groundwater Actions**	Target Mcleod Co.	Target Nicollet Co.	Target Renville Co.	Target Sibley Co.	HUC-10s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWCF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
Protect Private Well Users: Arsenic	Education and Outreach	▪ Educate well users about the health risks of elevated arsenic levels in drinking water. ▪ Promote testing of private wells through education or cost share. ▪ Provide information from MDH about arsenic in Minnesota's well water to private well users to help answer health related questions and information on arsenic removal.	X	X	X	X	All	MDH Well MGMT	Prioritize areas with a high density of private wells and areas with evidence of high levels of arsenic in private wells. *Arsenic Map (Figure 14)* *Drinking Water Wells Map (Figure 11)*						
Protect Private Well Users: Well Testing	Education and Outreach	Make information available to private well users about local drinking water quality and well testing. Host a well testing clinic or provide resources to well users to have their water tested for: ▪ Coliform Bacteria (every year) ▪ Nitrate (every other year) ▪ Arsenic (at least once) ▪ Lead (at least once) ▪ Manganese (at least once)	X	X	X	X	All	MDH Well MGMT	Prioritize areas with a high density of private wells, high pollution sensitivity and/or where there are known groundwater contaminants. *Pollution Sensitivity Map (Figure 5)* *Pollution Sensitivity Wells (Figure 7)* *Arsenic Map (Figure 14)* *Drinking Water Wells Map (Figure 11)* *Nitrate Map (Figure 13)*						

Goal	Supporting Strategy	▪ **Recommended Groundwater Actions**	Target Mcleod Co.	Target Nicollet Co.	Target Renville Co.	Target Sibley Co.	HUC-10s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWCF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
Protect Private Well Users: Manage Wells **Protect Groundwater and Drinking Water Quality:** Manage Wells	Education and Outreach	Promote proper management of wells through MDH tools, such as the 'Well Owners Handbook' in landowner outreach efforts.	X	X	X	X	All	MDH Well MGMT	Prioritize areas with a high density of private wells *Drinking Water Wells Map (Figure 14)*						
Protect Groundwater and Drinking Water Quality: Well Sealing	Education and Outreach	▪ Provide cost share to well owners for sealing of unsealed, unused wells. ▪ Provide educational materials on well sealing.	X	X	X	X	All	MDH Well MGMT	Prioritize areas with a high density of private wells and DWSMAs. *Drinking Water Wells Map (Figure 11)* *DWSMA Map (Figure 10)*						
Protect Groundwater and Drinking Water Quality: Well Inventory	Land Use Planning and Management	To understand water quality trends, establish a well inventory to record baseline data or changes in groundwater quality. An example of a successful model is the Southeast MN Domestic Well Network.	X	X	X	X	All	MDH Well MGMT	*N/A*						
Protect Groundwater and Drinking Water Quality: Closed Landfills	Contaminant Planning and Management	▪ Identify MPCA closed landfill locations and groundwater areas of concern in comprehensive land use plans, zoning maps and ordinances. Identifying the location will help assure drinking water and public				X	North Branch	MPCA CLP Land Manager	*Closed Landfill Map (Figure 17)*						

Goal	Supporting Strategy	▪ **Recommended Groundwater Actions**	Target Mcleod Co.	Target Nicollet Co.	Target Renville Co.	Target Sibley Co.	HUC-10s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWCF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
	Land Use Planning and Management	health implications are considered when evaluating future growth or development near these sites. ▪ Consult and review the MPCA Closed Landfill Program to make sure any proposed changes in zoning districts or new land use planning proposals are not in conflict with the State Closed Landfill Plan. ▪ Contact the MPCA Closed Landfill Program for current information and any concerns or changes to the groundwater area of concern when considering land use changes or developments near the area. Request to be notified regarding any changes in the migration or movement of contaminants. ▪ Educate residents about the proper disposal of HHW, pharmaceuticals and personal care products that can contaminant landfills.												
Protect Groundwater and Drinking Water Quality: Leaky Tanks	Contaminant Planning and Management	▪ Identify leaky and active tank sites in your area in comprehensive land use plans, zoning maps and ordinances. Identifying these locations will help assure drinking water and public health implications are considered				X	Le Sueur	MPCA Tanks Program	Focus in areas with high pollution sensitivity and highly vulnerable DWSMAs. *Pollution Sensitivity Map (Figure 5)*						

Goal	Supporting Strategy	▪ **Recommended Groundwater Actions**	Target Mcleod Co.	Target Nicollet Co.	Target Renville Co.	Target Sibley Co.	HUC-10s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWCF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
	Land Use Planning and Management	when evaluating future growth or development near these sites. ▪ Contact the MPCA Tank Compliance and Assistance Program for current information and any concerns or changes to the groundwater area of concern when considering land use changes or developments near these areas. Request to be notified regarding any changes in the migration or movement of contaminants.							*Pollution Sensitivity Wells (Figure 7)* *Primary Aquifers by Section (Figure 4)* *DWSMA Map (Figure 10)* *Tank & Leak Site Map (Figure 16)*						
Protect Groundwater and Drinking Water Quality: Feedlots	Contaminant Planning and Management	Prioritize feedlot inspections, regardless of size, in areas of greatest risk to pollution, to minimize the loss of nitrate and harmful bacteria.		X		X	Bevens Belle Plain Le Sueur High Island Middle Branch North Branch South Branch	MPCA Feedlot Program	*Focus in areas with high pollution sensitivity and highly vulnerable DWSMAs.* *Pollution Sensitivity Map (Figure 5)* *Pollution Sensitivity Wells (Figure 7)* *Primary Aquifers by Section (Figure 4)* *DWSMA Map (Figure 10)* *Active Feedlot Map (Figure 15)*						X
Protect Groundwater and Drinking Water Quality:	Education and Outreach	▪ In delegated counties, all feedlots that apply manure in areas of high risk will conduct a Level 2 records		X			Le Sueur South Branch	MPCA Feedlot Program	Focus in areas with high pollutions sensitivity and highly vulnerable DWSMAs.			X	X		X

Goal	Supporting Strategy	▪ **Recommended Groundwater Actions**	Target Mcleod Co.	Target Nicollet Co.	Target Renville Co.	Target Sibley Co.	HUC-10s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWCF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
Manure Management	Nutrient Management	review completed regardless of the size of facility. ▪ In delegated counties, conduct annual Level 3 review of manure acres in areas of high risk. ▪ Assist feedlot owners, especially sites with 300 or fewer animal units, in the development of a manure management plan. ▪ Host field days that promote; emergency response training, manure crediting, calibration of equipment, and the manure testing process. ▪ Evaluate local ordinances and revise to include manure timing guidelines to protect from nitrate loss. Follow the UMN Extension guidelines, including no summer application and fall application only after soil temperature is below 50 degrees.							*Pollution Sensitivity Map (Figure 5)* *Pollution Sensitivity Wells (Figure 7)* *Primary Aquifers by Section (Figure 4)* *DWSMA Map (Figure 10)* *Active Feedlot Map (Figure 15)*						
Protect Groundwater and Drinking Water Quality: Manure Management	Education and Outreach Nutrient Management	Promote actions to prepare for field application of manure: ▪ Inspect equipment to ensure everything is functioning properly to avoid leaks or spills		X		X	Bevens Belle Plain Le Sueur High Island	MPCA Feedlot Program	Focus in areas with high pollution sensitivity and highly vulnerable DWSMAs. *Pollution Sensitivity Map (Figure 5)* *Pollution Sensitivity Wells (Figure 7)*			X	X		X

Goal	Supporting Strategy	▪ **Recommended Groundwater Actions**	Target Mcleod Co.	Target Nicollet Co.	Target Renville Co.	Target Sibley Co.	HUC-10s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWCF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
	Contaminant Planning and Management	▪ Get manure sampled and analyzed for nutrient availability ▪ Plan applications for each field ▪ Determine any setbacks needed in fields and mark locations of sensitive features to avoid ▪ Use the Minnesota Runoff Risk Advisory Forecast system tool to determine the best time to apply manure. ▪ Put together an emergency action plan that identifies leak and spill containment					Middle Branch North Branch South Branch		*Primary Aquifers by Section (Figure 4)* *DWSMA Map (Figure 10)* *Active Feedlot Map (Figure 15)*						
Protect Groundwater and Drinking Water Quality: Nitrate	Nutrient Management Education and Outreach	Promote implementation of nutrient management practices to improve farm profitability and reduce nitrogen loss. Practices include: ▪ Improve nitrogen efficiency by practicing the 4 R's of nitrogen stewardship (right source, right rate, right timing, and right place) ▪ Adopt and use of the UMN 'Best Management Practices for Nitrogen use in Minnesota ▪ Properly credit nitrogen sources (soil/manure tests, past crops, & mineralization)		X		X	Bevens Belle Plain High Island Le Sueur Middle Branch North Branch South Branch	MDA Pesticide & Fertilizer Division	Focus on areas with high pollution sensitivity and highly vulnerable DWMSAs. *Pollution Sensitivity Map (Figure 5)* *Pollution Sensitivity Wells (Figure 7)* *Primary Aquifers by Section (Figure 4)* *DWSMA Map (Figure 10)*						X

Goal	Supporting Strategy	▪ **Recommended Groundwater Actions**	Target Mcleod Co.	Target Nicollet Co.	Target Renville Co.	Target Sibley Co.	HUC-10s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWCF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
		▪ Implement comprehensive nutrient management plans to improve nitrogen crediting, equipment calibration, and record keeping ▪ Spoon feed nitrogen to sync with plant growth through side dressing and split fertilizer application													
Protect Groundwater and Drinking Water Quality: Nitrate	Nutrient Management Education and Outreach	Increase the number of farmers enrolled in the Nutrient Management Initiative Program to evaluate alternative nutrient management practices.		X		X	Bevens Belle Plain High Island Le Sueur Middle Branch North Branch South Branch	MDA Pesticide & Fertilizer Division	Focus on areas with high pollution sensitivity, and highly vulnerable DWMSAs. *Pollution Sensitivity Map (Figure 5)* *Pollution Sensitivity Wells (Figure 7)* *Primary Aquifers by Section (Figure 4)* *DWSMA Map (Figure 10)*						X
Protect Groundwater and Drinking Water Quality: Nitrate	Nutrient Management Education and Outreach Cropland Management	Identify programs and opportunities for growers to test and implement new nitrogen practices, innovative technology or cropping systems that protect groundwater quality that prevent or reduce nitrogen loss. (E.g. Cover Crops, Alternative Crops, Precision Ag / New Technologies, Nutrient Management Initiative, etc.)		X		X	Bevens Belle Plain High Island Le Sueur Middle Branch	MDA Pesticide & Fertilizer Division	Focus on areas with high pollution sensitivity, and highly vulnerable DWMSAs. *Pollution Sensitivity Map (Figure 5)* *Pollution Sensitivity Wells (Figure 7)* *Primary Aquifers by Section (Figure 4)*	X		X		X	X

Goal	Supporting Strategy	▪ **Recommended Groundwater Actions**	Target Mcleod Co.	Target Nicollet Co.	Target Renville Co.	Target Sibley Co.	HUC-10s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWCF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
							North Branch South Branch		*DWSMA Map (Figure 10)*						
Protect Groundwater and Drinking Water Quality: Nitrate	Nutrient Management Education and Outreach	Promote the adoption of cover crops for scavenging nutrients under row crops.		X		X	Bevens Belle Plain High Island Le Sueur Middle Branch North Branch South Branch	MDA Pesticide & Fertilizer Division	Focus on areas with high pollution sensitivity, irrigated row crops, and highly vulnerable DWSMAs. *Pollution Sensitivity Map (Figure 5)* *Pollution Sensitivity Wells (Figure 7)* *Primary Aquifers by Section (Figure 4)* *DWSMA Map (Figure 10)* *Drinking Water Wells Map (Figure 11)*	X		X	X	X	X
Protect Groundwater and Drinking Water Quality: Nitrate **Groundwater Sustainability:** Water Conservation	Education and Outreach Nutrient Management Cropland Management	Promote the benefits of farming using soil health principles that increase soil moisture holding capacity, organic matter, and nutrient cycling.		X		X	Bevens Belle Plain High Island Le Sueur Middle Branch North Branch South Branch	NRCS Field Office	Focus on areas with high pollution sensitivity, and highly vulnerable DWMSAs. *Pollution Sensitivity Map (Figure 5)* *Pollution Sensitivity Wells (Figure 7)* *Primary Aquifers by Section (Figure 4)* *DWSMA Map (Figure 10)* *Nitrate in Wells Maps (Figure 13)*			X	X	X	X

Goal	Supporting Strategy	▪ **Recommended Groundwater Actions**	Target Mcleod Co.	Target Nicollet Co.	Target Renville Co.	Target Sibley Co.	HUC-10s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWCF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
Protect Groundwater and Drinking Water Quality: Nitrate **Groundwater Sustainability:** Water Conservation	Education and Outreach Nutrient Management Cropland Management	Contact state and federal agency resource partners and coordinate opportunities for local field days, training and outreach for farmers, co-ops, and crop consultants. Focus on alternative nitrogen management practices, soil health, and second crops.		X		X	Bevens Belle Plain High Island Le Sueur Middle Branch North Branch South Branch	MDA Pesticide & Fertilizer Division	Focus on areas with high pollution sensitivity, and highly vulnerable DWMSAs. *Pollution Sensitivity Map (Figure 5)* *Pollution Sensitivity Wells (Figure 7)* *Primary Aquifers by Section (Figure 4)* *DWSMA Map (Figure 10)* *Nitrate in Wells Maps (Figure 13)*						
Protect Groundwater and Drinking Water Quality: Nitrate **Protect Groundwater and Drinking Water Quality:** Pesticides	Education and Outreach Cropland Management Integrated Pest Management	Promote the benefits of crop diversity and rotation, which include high yields for each crop in the rotation, pest and weed control, and enhanced soil fertility.		X		X	Bevens Belle Plain High Island Le Sueur Middle Branch North Branch South Branch	MDA Pesticide & Fertilizer Division	Focus on areas with high pollution sensitivity, and highly vulnerable DWMSAs. *Pollution Sensitivity Map (Figure 5)* *Pollution Sensitivity Wells (Figure 7)* *Primary Aquifers by Section (Figure 4)* *DWSMA Map (Figure 10)* *Nitrate in Wells Maps (Figure 13)*		X	X	X	X	X
Protect Groundwater and Drinking	Education and Outreach	Provide information on best practices for turf management to the public. Include information on fertilizer application, crediting				X	Belle Plain Le Sueur	UMN Lawns & Turfgrass MGMT Team	Focus in MS4 communities and residential developments with high pollution sensitivity, along with highly vulnerable DWSMAs.			X	X	X	X

Goal	Supporting Strategy	▪ **Recommended Groundwater Actions**	Target Mcleod Co.	Target Nicollet Co.	Target Renville Co.	Target Sibley Co.	HUC-10s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWCF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
Water Quality: Nitrate **Protect Groundwater and Drinking Water Quality:** Pesticides **Groundwater Sustainability:** Water Conservation	Irrigation Water Management	for grass clippings, lawn watering and herbicide and pesticide application.							*Pollution Sensitivity Map (Figure 5)* *Pollution Sensitivity Wells (Figure 7)* *Primary Aquifers by Section (Figure 4)* *DWSMA Map (Figure 10)*						
Protect Groundwater and Drinking Water Quality: Pesticides	Education and Outreach Integrated Pest Management	Promote the adoption and use of MDA's water quality BMPs for agricultural pesticides and insecticides.		X		X	Bevens Belle Plain High Island Le Sueur Middle Branch North Branch South Branch	MDA Pesticide & Fertilizer Division	Focus in areas of pesticide detection in MDA's monitoring wells, along with areas of high pollution sensitivity, and highly vulnerable DWMSAs. *Pollution Sensitivity Map (Figure 5)* *Pollution Sensitivity Wells (Figure 7)* *Primary Aquifers by Section (Figure 4)* *DWSMA Map (Figure 10)*						X
Protect Groundwater and Drinking	Education and Outreach	Promote to farmers and area businesses the Agricultural and Non-Agricultural Waste		X		X	Bevens Belle Plain	MDA Pesticide &	Focus in areas of pesticide detection in MDA's monitoring wells, along with						

Goal	Supporting Strategy	▪ **Recommended Groundwater Actions**	Target Mcleod Co.	Target Nicollet Co.	Target Renville Co.	Target Sibley Co.	HUC-10s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWCF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
Water Quality: Pesticides		Pesticide Collection Program to dispose of unwanted and unusable pesticides.					High Island Le Sueur Middle Branch North Branch South Branch	Fertilizer Division	areas of high pollution sensitivity, and highly vulnerable DWMSAs. *Pollution Sensitivity Map (Figure 5)* *Pollution Sensitivity Wells (Figure 7)* *Primary Aquifers by Section (Figure 4)* *DWSMA Map (Figure 10)*						
Protect Groundwater and Drinking Water Quality: SSTS	SSTS Management	▪ Enforce state and locally adopted SSTS ordinances for the protection of groundwater and drinking water sources. ▪ Evaluate existing SSTS ordinances and identify opportunities to enhance groundwater protection. Activities may include adding a Point of Sale requirement to trigger a SSTS inspection during real estate transactions. ▪ Improve SSTS records by obtaining information on treatment system; age, type and function to understand potential risks to groundwater.		X		X	Bevens Belle Plain High Island Le Sueur Middle Branch North Branch South Branch	MPCA SSTS Field Staff	Focus in areas with high pollution sensitivity, highly vulnerable DWSMAs, and areas with a density of SSTS. You can use the Well Density Map as an imperfect surrogate for SSTS density. *Drinking Water Wells Map (Figure 14)* *Pollution Sensitivity Map (Figure 5)* *Pollution Sensitivity Wells (Figure 7)* *Primary Aquifers by Section (Figure 4)* *DWSMA Map (Figure 10)*						

Goal	Supporting Strategy	▪ **Recommended Groundwater Actions**	Target Mcleod Co.	Target Nicollet Co.	Target Renville Co.	Target Sibley Co.	HUC-10s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWCF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
Protect Groundwater and Drinking Water Quality: SSTS	Education and Outreach SSTS Management	Educate citizens about SSTS including: ▪ The basic principles of how a septic system works ▪ How to operate the system efficiently and effectively ▪ Risks to human health and the environment ▪ Financial options to repair or replace failing or non-compliant system		X		X	Bevens Belle Plain High Island Le Sueur Middle Branch North Branch South Branch	MPCA SSTS Field Staff	Focus in areas with high pollution sensitivity, highly vulnerable DWSMAs, and areas with a density of SSTS. You can use the Well Density Map as an imperfect surrogate for SSTS density. *Drinking Water Wells Map (Figure 14)* *Pollution Sensitivity Map (Figure 5)* *Pollution Sensitivity Wells (Figure 7)* *Primary Aquifers by Section (Figure 4)* *DWSMA Map (Figure 10)*						
Protect Groundwater and Drinking Water Quality: SSTS	Education and Outreach SSTS Management	Host local SSTS training and workshops for area contractors and citizens regarding SSTS technology, compliance, and maintenance.		X		X	Bevens Belle Plain High Island Le Sueur Middle Branch North Branch South Branch	MPCA SSTS Field Staff	Focus in areas with high pollution sensitivity, highly vulnerable DWSMAs, and areas with a density of SSTS. You can use the Well Density Map as an imperfect surrogate for SSTS density. *Drinking Water Wells Map (Figure 14)* *Pollution Sensitivity Map (Figure 5)* *Pollution Sensitivity Wells (Figure 7)* *Primary Aquifers by Section (Figure 4)* *DWSMA Map (Figure 10)*						

Goal	Supporting Strategy	▪ **Recommended Groundwater Actions**	Target Mcleod Co.	Target Nicollet Co.	Target Renville Co.	Target Sibley Co.	HUC-10s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWCF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
Protect Groundwater and Drinking Water Quality: Wellhead Protection (WHP)	Education and Outreach Cropland Management Land Use Planning and Management	Serve on WHP planning teams to assist public water suppliers with planning and implementation activities to address land use planning concerns.		X		X	Bevens High Island Middle Branch North Branch South Branch	MDH SWP Unit	*Wellhead Protection Plan Development Status (Figure 9)* *DWSMA Map (Figure 10)*						
Protect Groundwater and Drinking Water Quality: Wellhead Protection	Land Use Planning and Management	Integrate WHP plan strategies into local plans, such as the 1W1P and land use plans.		X		X	Bevens High Island Middle Branch North Branch South Branch	MDH SWP Unit	*DWSMA Map (Figure 10)*						
Protect Groundwater and Drinking Water: Household Hazardous Waste (HHW)	Education and Outreach Land Use Planning and Management	▪ Educate the public about the risks of improperly disposing of HHW and promote community-supported collection sites. ▪ Make disposal of HHW easy for the public by expanding collection sites through mobile units by stopping in different		X		X	Bevens Belle Plain High Island Le Sueur Middle Branch	MPCA Hazardous Waste Program	Focus on areas with high pollution sensitivity and highly vulnerable DWSMAs. *Pollution Sensitivity Map (Figure 5)* *Pollution Sensitivity Wells (Figure 7)* *Primary Aquifers by Section (Figure 4)*						

Goal	Supporting Strategy	▪ **Recommended Groundwater Actions**	Target Mcleod Co.	Target Nicollet Co.	Target Renville Co.	Target Sibley Co.	HUC-10s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWCF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
		communities throughout the summer for free drop off. ▪ Promote other recycling options of various products at area businesses throughout the year.					North Branch South Branch		*DWSMA Map (Figure 10)*						
Protect Groundwater and Drinking Water: Pharmaceuticals	Education and Outreach	Keep unused/unwanted medications out of drinking water supplies by educating the public about available safe and secure drop box locations at law enforcement facilities and pharmacies.		X		X	Bevens Belle Plain High Island Le Sueur Middle Branch North Branch South Branch	MPCA Hazardous Waste Program	Focus on areas with high pollution sensitivity and highly vulnerable DWSMAs. *Pollution Sensitivity Map (Figure 5)* *Pollution Sensitivity Wells (Figure 7)* *Primary Aquifers by Section (Figure 4)* *DWSMA Map (Figure 10)*						
Protect Groundwater and Drinking Water: Contaminants of Emerging Concern (CEC)	Education and Outreach	Enhance Minnesotans' understanding of CEC's by communicating the health impacts and exposure potential of emerging contaminants in drinking water. Outreach and Education Grants are available through the MDH CEC Initiative. See Outreach and Education Grants (www.health.state.mn.us/divs/eh/risk/guidance/dwec/outreachproj.html) for opportunities.		X		X	Bevens Belle Plain High Island Le Sueur Middle Branch North Branch	MDH CEC Program	Focus on areas with high pollution sensitivity and highly vulnerable DWSMAs. *Pollution Sensitivity Map (Figure 5)* *Pollution Sensitivity Wells (Figure 7)* *Primary Aquifers by Section (Figure 4)* *DWSMA Map (Figure 10)*						

Goal	Supporting Strategy	▪ **Recommended Groundwater Actions**	Target Mcleod Co.	Target Nicollet Co.	Target Renville Co.	Target Sibley Co.	HUC-10s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWCF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
							South Branch								
Protect Groundwater and Drinking Water	Education and Outreach	Educate the public and decision makers about the hydrologic connectivity of groundwater and surface water and how this influences the vulnerability of drinking water resources.		X		X	Bevens Belle Plain High Island Le Sueur Middle Branch North Branch South Branch	DNR Ecological & Water Resources	Focus in areas with high pollution sensitivity. *Pollution Sensitivity Map (Figure 5)* *Pollution Sensitivity Wells (Figure 7)* *Primary Aquifers by Section (Figure 4)*						
Protect Groundwater and Drinking Water Quality Water Sustainability	Education and Outreach	Develop a 'drinking water protection' page on the SWCD or county website or other communication tools that can be used to share information with citizens on what they can do to protect both public and private sources of drinking water. Include information about the connection between surface and groundwater, well sealing and water conservation. Dakota County's webpage Water Quality (https://www.co.dakota.mn.us/Environment/WaterQuality/WellsDrinkingWater/Pages/default.aspx) is a good example.	X	X	X	X	All	MDH Well MGMT & SWP Unit	N/A						

Goal	Supporting Strategy	▪ **Recommended Groundwater Actions**	Target Mcleod Co.	Target Nicollet Co.	Target Renville Co.	Target Sibley Co.	HUC-10s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWCF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
Protect Groundwater and Drinking Water Quality Water Sustainability	Land Use Planning and Management	Develop ordinances, overlay districts, performance standards, etc. to further protect drinking water and groundwater connected features from future land use impacts for their long-term sustainability and use.	X	X	X	X	All	MN Assoc. of Counties	Focus in areas with high pollution sensitivity, highly vulnerable DWSMAs and groundwater connected natural features *Pollution Sensitivity Map (Figure 5)* *Pollution Sensitivity Wells (Figure 7)* *Primary Aquifers by Section (Figure 4)* *DWSMA Map (Figure 10)* *GWC Plants, Animals, Native Plant Communities Map (Figure 32)* *Mapped Native Plant Communities (Figure 31)*		X				
Protect Groundwater and Drinking Water Quality Water Sustainability	Land Use Planning and Management	Incorporate basic groundwater and drinking water information into local comprehensive plans and ordinances including: ▪ Local geology and aquifer information ▪ The sources of drinking water and the pollution sensitivity of public and private wells ▪ Maps of state approved WHP areas ▪ Groundwater dependent natural features ▪ Contaminant areas of concern	X	X	X	X	All	MDH SWP Unit	*Pollution Sensitivity Map (Figure 5)* *Pollution Sensitivity Wells (Figure 7)* *Primary Aquifers by Section (Figure 4)* *DWSMA Map (Figure 10)* *GWC Plants, Animals, Native Plant Communities Map (Figure 32)* *Mapped Native Plant Communities (Figure 31)* *Tank & Leak Site Map* (Figure 16)						

Goal	Supporting Strategy	▪ **Recommended Groundwater Actions**	Target Mcleod Co.	Target Nicollet Co.	Target Renville Co.	Target Sibley Co.	HUC-10s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWCF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
		▪ Other local information needed to consider and protect groundwater and drinking water resources in local land use planning decisions													
Protect Groundwater and Drinking Water Quality	Land Use Planning and Management	Conduct a survey of property owners within the flood plain to identify unused/unsealed wells. Seal those wells identified to prevent contamination of the aquifer.	X		X	X	Belle Plain High Island Le Sueur Middle Branch	MDH Well MGMT	Prioritize areas of greatest risk to flooding: *Drinking Water Wells and Flood Risk (Figure 12)*						
Protect Groundwater and Drinking Water Quality	Land Use Planning and Management	Request flooded well test kits from MDH Well Management to distribute to private well owners after a flood event.	X		X	X	Belle Plain High Island Le Sueur Middle Branch	MDH Well MGMT	*Prioritize areas impacted by recent flooding that may be at risk to contamination:* *Drinking Water Wells and Flood Risk (Figure 12)*						
Protect Groundwater and Drinking Water Quality **Water Sustainability:** Recharge	Conservation Easements	Enroll private lands in land acquisition programs or conservation easements. Programs may include: Continuous CRP, RIM Reserve for wellhead protection, and CREP.	X	X	X	X	All	BWSR	Prioritize areas of high pollution sensitivity and highly vulnerable DWSMAs. Target areas of high water use, known groundwater connected natural features. Examine areas where you can expand on existing easements and protected lands to increase protections.	X	X	X	X	X	X

Goal	Supporting Strategy	▪ **Recommended Groundwater Actions**	Target Mcleod Co.	Target Nicollet Co.	Target Renville Co.	Target Sibley Co.	HUC-10s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWCF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
									Pollution Sensitivity Map (Figure 5) *Pollution Sensitivity Wells (Figure 7)* *DWSMA Map (Figure 10)* *Monitoring Wells/Pumping (Figure 23)* *GWC Plants, Animals, Native Plant Communities Map (Figure 32)* *Mapped Native Plant Communities (Figure 31)* *RIM Easements Map (Figure 35)*						
Protect Groundwater and Drinking Water Quality **Water Sustainability:** Recharge	Conservation Easements	Maintain and expand set-aside acres in sensitive areas, including areas in publicly supported conservation programs like CRP, from being converted to high intensity uses, such as corn and soybeans.	X	X	X	X	All	FSA	Prioritize private lands with existing CRP contracts, along with state and federal easement, such as RIM and DNR and USFW habitat easements. Target areas of known groundwater dependent features, areas of high pollution sensitivity, and highly vulnerable DWSMAs. *RIM Easements Map (Figure 35)* *GWC Plants, Animals, Native Plant Communities Map (Figure 32)* *Mapped Native Plant Communities (Figure 31)*	X	X	X	X	X	X

Goal	Supporting Strategy	▪ **Recommended Groundwater Actions**	Target Mcleod Co.	Target Nicollet Co.	Target Renville Co.	Target Sibley Co.	HUC-10s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWCF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
									Pollution Sensitivity Map (Figure 5) *DWSMA Map (Figure 10)*						
Protect Groundwater and Drinking Water Quality: Stormwater Management **Water Sustainability:** Recharge	Land Use Planning and Management Education and Outreach	Manage stormwater runoff to minimize adverse impacts to groundwater. Refer to the Minnesota Stormwater Manual for infiltration guidance on project sites located in wellhead protection areas.				X	Belle Plain Le Sueur	MPCA MS4 Program	Prioritize MS4 communities, target highly sensitive areas and highly vulnerable DWSMAs. *Pollution Sensitivity Map (Figure 5)* *DWSMA Map (Figure 10)*	X	X		X		X
Groundwater Sustainability: Water Conservation	Education and Outreach	Provide education on water conservation practices that can be adopted in people's homes and businesses. Use the Met Council's Water Conservation Toolbox.	X	X	X	X	All	DNR Ecological & Water Resources	N/A		X				
Groundwater Sustainability: Water Conservation	Land Use Planning and Management	Assist communities serving over 1,000 people with water conservation measures outlined in their DNR municipal water supply plans.				X	High Island Middle Branch North Branch	DNR Ecological & Water Resources	N/A		X				
Water Sustainability: Recharge	Land Use Planning and Management	Promote and increase the adoption of recharge BMPs including wetland construction/restoration, perennial	X	X	X	X	All	DNR Ecological &	Target areas near sensitive features and groundwater fed lakes.	X	X	X	X	X	X

Goal	Supporting Strategy	▪ **Recommended Groundwater Actions**	Target Mcleod Co.	Target Nicollet Co.	Target Renville Co.	Target Sibley Co.	HUC-10s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWCF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
Water Sustainability: Rare or Declining Habitats		establishment, riparian buffers, and conservation easements.						Water Resources	*GWC Plants, Animals, Native Plant Communities Map (Figure 32)* *Mapped Native Plant Communities (Figure 31)* Groundwater Dominated Lakes Map *(Figure 33)*						

Descriptions of Supporting Strategies

Conservation Easements

Conservation easements are a legal agreement between a landowner and a land trust or government agency that permanently limits uses of the land in order to protect its conservation values. Easements allow landowners to continue to own and use their land. They can also sell it or pass it on to heirs. Maintaining and expanding set-aside acres, including areas in publicly supported conservation programs (like CRP) from being converted to high intensity land uses, such as row crop agriculture, will help protect groundwater quantity and quality.

Existing Programs and Resources

- BWSR **Conservation Reserve Program** (https://bwsr.state.mn.us/conservation-reserve-program): A voluntary program designed to help farmers restore and protect environmentally sensitive land.
- BWSR **Conservation Reserve Enhancement Program - CREP** (https://bwsr.state.mn.us/mn-crep-landowners): This project is a federal, state and local partnership and will voluntarily retire environmentally sensitive land using the nationally-recognized Reinvest in Minnesota (RIM) Reserve. Figure 35 shows where RIM easements are in the watershed.

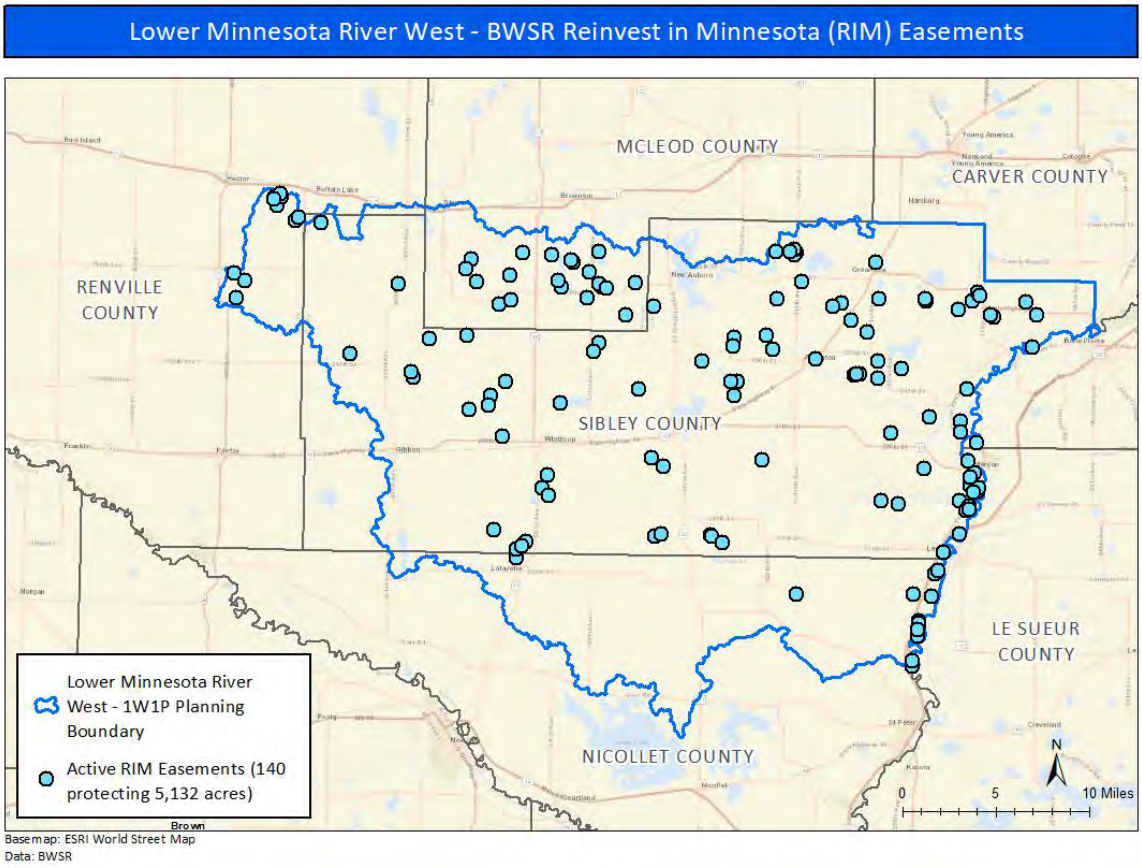

Figure 35: Lower Minnesota River West Watershed – BWSR RIM easements

Contaminant Planning and Management

Protect groundwater and drinking water supplies from contaminant releases in the environment through land use planning, ordinances, and collaboration with state regulatory agencies.

Existing Programs and Resources

- MDA **What's in My Neighborhood? Agricultural Interactive Mapping** (www.mda.state.mn.us/chemicals/spills/incidentresponse/neighborhood.aspx): A tool that tracks and maps spills of agricultural chemicals and sites contaminated with agricultural chemicals.
- MPCA **Manure Management** (https://www.pca.state.mn.us/quick-links/feedlot-nutrient-and-manure-management): Resources such as fact sheets, guidelines, computer tools and forms for feedlot nutrient and manure management.
- MPCA **Tank Compliance and Assistance Program--Storage Tanks** (https://www.pca.state.mn.us/waste/storage-tanks): A program that provides information and assistance to tank owners and others regarding technical standards required of all regulated underground storage tanks and aboveground storage tank systems.
- MPCA **Closed Landfill Program** (https://www.pca.state.mn.us/waste/closed-landfill-program): A voluntary program to properly close, monitor, and maintain Minnesota's closed municipal sanitary landfills.
- MPCA **Feedlots** (https://www.pca.state.mn.us/quick-links/feedlot-program): Information about feedlot rules, permits, and management.
- MPCA **What's in My Neighborhood** (https://www.pca.state.mn.us/data/whats-my-neighborhood)**:** An online tool for searching information about contaminated sites and facilities all around Minnesota.
- UMN Extension **Manure Management in Minnesota** (https://extension.umn.edu/animals-and-livestock#manure-management): Information about manure characteristics, application, and economics.
- MDH **Contaminants of Emerging Concern** (www.health.state.mn.us/cec): A program that investigates and communicates the health and exposure potential of contaminants of emerging concern (CECs) in drinking water.

Cropland Management

Voluntary practices to manage resource concerns while minimizing environmental loss. Practices may include conservation tillage, cover crops, soil health and other agricultural BMPs.

Existing Programs and Resources

- MDA **The Agricultural BMP Handbook for Minnesota** (https://www.mda.state.mn.us/protecting/cleanwaterfund/research/handbookupdate): A literature review of empirical research on the effectiveness of 30 conservation practices.
- NRCS **Conservation Stewardship Program** (www.nrcs.usda.gov/wps/portal/nrcs/main/mn/programs/financial/csp/): A voluntary conservation program that encourages producers to address resource concerns in a comprehensive manner.
- NRCS **Environmental Quality Incentives Program** (https://www.nrcs.usda.gov/wps/portal/nrcs/main/mn/programs/financial/eqip/): A program that provides financial and technical assistance to agricultural producers so they can implement

structural and management conservation practices that optimize environmental benefits on working agricultural land.

- NRCS **Cover Crops** (www.nrcs.usda.gov/wps/portal/nrcs/detail/mn/technical/?cid=nrcs142p2_023671): Provides information, fact sheets, and tools about cover crops.
- NRCS **Soil Health** (https://www.nrcs.usda.gov/wps/portal/nrcs/main/mn/soils/health/): Provides information about the basics and benefits of soil health.
- **Midwest Cover Crop Council** (mccc.msu.edu/statesprovince/minnesota/): Provides resources to help with technical support and answer questions from a local perspective at no cost.
- MDA **Minnesota Agricultural Water Quality Certification Program** ()https://www.mda.state.mn.us/environment-sustainability/minnesota-agricultural-water-quality-certification-program A voluntary program for farmers to implement conservation practices to protect water quality.

Education and Outreach

Educate landowners, private well users, and other stakeholders about how their actions impact groundwater quality and quantity. Provide information about potential health risks related to groundwater quality. Identify actions individuals, households, and partner agencies can take to sustain groundwater and protect or improve drinking water quality. Some ideas include managing household hazardous waste, maintaining household septic systems, and household water conservation measures.

For educational materials and programs related to a specific topic, go to the strategy about that topic. For example, go to 'nutrient management' to learn more about potential education opportunities regarding reducing nitrogen use. The list below provides some additional tools that may be helpful.

Existing Programs and Resources

- Metropolitan Council **Water Conservation Toolbox** (https://metrocouncil.org/Wastewater-Water/Planning/Water-Supply-Planning/Guidance-Planning-Tools/Water-Conservation/Toolbox.aspx): Information about how residents and businesses, suppliers, learners, and communities can conserve water.
- Minnesota Rural Water Association **Source Water Protection Resources** (www.mrwa.com/sourcewater.html): Resources to help public water suppliers develop plans to use local community resources to protect drinking water quality.
- MPCA **Waste** (https://www.pca.state.mn.us/waste): Information about managing waste, recycling, composting, and preventing waste and pollution.
- MPCA **Manual for Turfgrass Maintenance with Reduced Environmental Impacts** (https://www.pca.state.mn.us/sites/default/files/p-tr1-04.pdf): Practical advice for those who manage turfgrass (golf courses and athletic fields excluded).
- MDH **Wells Laws and Rules** (www.health.state.mn.us/divs/eh/wells/rules/index.html): Minnesota State Well Code (MR 4725.0050 – 4725.7605).
- MDH **Wells and Borings—Well Management Program** (www.health.state.mn.us/divs/eh/wells/index.html): Information about proper well construction, maintenance, testing, and sealing.
- MDH **Wellowner's Handbook** (www.health.state.mn.us/divs/eh/wells/construction/handbook.pdf): A consumer's guide to water wells in Minnesota.
- MDH **Arsenic in Minnesota's Well Water** (www.health.state.mn.us/divs/eh/wells/waterquality/arsenic.html): Information about arsenic in Minnesota.

- MDH **Water Treatment Units for Arsenic Reduction** (http://www.health.state.mn.us/divs/eh/wells/waterquality/arsenictreat.pdf)
- MDA **Waste Pesticide Collection Program** (https://www.mda.state.mn.us/chemicals/spills/wastepesticides.aspx): Information about the safe disposal of unwanted and unusable pesticides from farms and area businesses.
- MPCA **Managing Unwanted Medications** (https://www.pca.state.mn.us/living-green/managing-unwanted-medications)**:** Information about the safe disposal of unwanted or unused medications from households.

Integrated Pest Management

Integrated Pest Management (IPM) is a balanced approach to pest management which incorporates the many aspects of plant health care/crop protection in ways that mitigate harmful environmental impacts and protect human health. Some of the IPM program activities include generating and distributing IPM information for growers, producers, land managers, schools, and the general public. Information should help them make alternative choices in their pest management decisions.

Existing Programs and Resources

- MDA **Integrated Pest Management Program** (www.mda.state.mn.us/pesticide-fertilizer/pesticide-best-management-practices): A program that develops and implements statewide strategies for the increased use of IPM on private and state managed lands.
- MDA **Groundwater and Surface Water Protection from Agricultural Chemicals** (www.mda.state.mn.us/protecting/bmps/herbicidebmps.aspx): Information to address pesticide use and water resource protection.

Irrigation Water Management

The process of determining and controlling the volume, frequency, and application rate of irrigation water in a planned, efficient manner (NRCS Codes 442 & 449).

Existing Programs and Resources

- MDA **Irrigation Management** (https://www.mda.state.mn.us/irrigation-outreach-farm-nitrogen-management-central-minnesota): Provides information about irrigation management, similar practices, guidance from NRCS, and links to additional resources.
- DNR **Minnesota Water Use Data** (www.dnr.state.mn.us/waters/watermgmt_section/appropriations/wateruse.html)**:** Data gathered from permit holders who report the volume of water used each year.

Land Use Planning and Management

This broad strategy encompasses many different concepts including regulations, ordinances, BMP implementation, conservation measures, and education to protect groundwater levels, quality, and contributions to groundwater-dependent features.

Land use planning focuses on the application of city or county government planning and regulations to restore and protect groundwater and groundwater levels. Local planning and regulations can help restrict land uses in groundwater sensitive areas, areas of high aquifer sensitivity, or regions of limited water supply to prevent conflict.

Land management implements voluntary practices that manage resource concerns while minimizing environmental loss. This may include the efficient use of groundwater through conservation measures and use of emerging technology to increase water conservation at the field or local level.

Existing Programs and Resources

- Association of Minnesota Counties (www.mncounties.org/): A voluntary, non-partisan statewide organization that helps provide effective county governance to Minnesotans. The Association works closely with the legislative and administrative branches of government in seeing that legislation and policies favorable to counties are enacted.
- DNR Water Supply Plans (www.dnr.state.mn.us/waters/watermgmt_section/appropriations/eandc_plan.html)**:** Provides information about Minnesota public water supply plans.
- DNR MPARS (MNDNR Permitting and Reporting System) (www.dnr.state.mn.us/mpars/index.html): DNR is the permitting authority for high capacity water use.
- DNR Water Conservation (www.dnr.state.mn.us/waters/watermgmt_section/appropriations/conservation.html): Provides tips and tools for promoting water conservation at home, public water supply systems, and other environments.
- League of Minnesota Cities (https://www.lmc.org): Promotes excellence in local government through effective advocacy, expert analysis, and trusted guidance for all Minnesota cities.
- MPCA Condition Groundwater Monitoring (https://www.pca.state.mn.us/water/condition-groundwater-monitoring).
- MPCA Stormwater and Wellhead Protection (stormwater.pca.state.mn.us/index.php/Stormwater_and_wellhead_protection): Guidance and recommendations for determining the appropriateness of infiltrating stormwater in a Drinking Water Supply Management Area.
- MPCA Minnesota Stormwater Manual (stormwater.pca.state.mn.us/index.php/Main_Page): A manual to help the everyday user better manage stormwater.
- MPCA Enhancing Stormwater Management in Minnesota (https://www.pca.state.mn.us/water/enhancing-stormwater-management-minnesota): Information about standards and tools for minimal impact designs for stormwater management.
- MPCA Stormwater (https://www.pca.state.mn.us/water/stormwater): MPCA regulates the discharge of stormwater and snowmelt runoff from municipal separate storm sewer systems, construction activities, and industrial facilities.
- MDH Source Water Protection (www.health.state.mn.us/divs/eh/water/swp/): MDH works with communities to protect the source(s) of their drinking water.
- DNR and Minnesota Geological Survey County Geologic Atlas Program (www.dnr.state.mn.us/waters/groundwater_section/mapping/index.html): Provides additional information on the groundwater resources and hydrogeology of the watershed through maps and reports of geology, groundwater, pollution sensitivity, and special studies.
- MPCA Household Hazardous Waste (www.pca.state.mn.us/waste/household-hazardous-waste-managers-and-operators): Resources for HHW managers and operators, education resources, searchable by county HHW facilities.

Nutrient Management

This strategy addresses both nutrient and manure management.

Nutrient management concepts are centered on applying crop fertilizer or manure using the right source, right rate, right time, and right place (NRCS Codes 327, 340, 345, 393, 590, 656).

Manure management targets the collection, transportation, storage, processing, and disposal of animal manure.

Existing Programs and Resources

- MDA **Fertilizer** (https://www.mda.state.mn.us/pesticide-fertilizer/fertilizers). MDA is the lead state agency for all aspects of pesticide and fertilizer environmental and regulatory functions. This page provides information on nutrient management programs, reports, publications, factsheets, and related external sources.
- MDA **Nutrient Management Initiative Program in Minnesota** (www.mda.state.mn.us/protecting/cleanwaterfund/onfarmprojects/nmi): The program assists farmers and crop advisers in evaluating alternative nutrient management practices for their fields.
- MDA **Township Testing Program** (www.mda.state.mn.us/township-testing-program): The program tests private wells for nitrate and pesticides in areas of the state with the greatest potential for nitrate and pesticide contamination.
- MDA **Nitrogen Fertilizer Best Management Practices** (www.mda.state.mn.us/pesticide-fertilizer/nitrogen-fertilizer-best-management-practices-agricultural-lands)): Provides nitrogen BMPs for various areas within Minnesota.
- MDA **Minnesota Nitrogen Fertilizer Management Plan** (www.mda.state.mn.us/pesticide-fertilizer/minnesota-nitrogen-fertilizer-management-plan): The state's blueprint for preventing or minimizing impacts of nitrogen fertilizer on groundwater.
- MDA Monitoring & Assessment for Agricultural Chemicals in the Environment (www.mda.state.mn.us/node/2696): Information about agricultural chemical monitoring and assessment programs and additional resources.
- UMN Extension **Nutrient Management** (https://extension.umn.edu/crop-production#nutrient-management): The page focuses on helping farmers and agriculture professionals optimize crop production using appropriate nutrient inputs while minimizing effects on the environment.
- UMN Extension **Nitrogen Application with Irrigation Water: Chemigation** (https://extension.umn.edu/irrigation/applying-nitrogen-irrigation-water-chemigation): Information about risks, benefits, and methods.
- MDA **The Agricultural BMP Handbook for Minnesota** (https://www.mda.state.mn.us/protecting/cleanwaterfund/research/handbookupdate): A literature review of empirical research on the effectiveness of 30 conservation practices.
- Nutrient Stewardship **What are the 4Rs** (www.nutrientstewardship.com/4rs): Information about the 4Rs of Nutrient Stewardship.
- MPCA **Manure Management** (https://www.pca.state.mn.us/quick-links/feedlot-nutrient-and-manure-management): Resources such as fact sheets, guidelines, computer tools, and forms for feedlot nutrient and manure management.
- UMN Extension **Manure Management in Minnesota** (https://extension.umn.edu/animals-and-livestock#manure-management): Information about manure characteristics, application, and economics.

SSTS Management

Monitoring, maintenance, and/or upgrading of individual septic treatment systems to maintain proper operation and treatment of septage by the system. In some areas, the intensity of use may require upgrading to a sanitary sewer to eliminate risks to the environment.

Existing Programs and Resources

- MPCA **Subsurface Sewage Treatment Systems** (https://www.pca.state.mn.us/water/subsurface-sewage-treatment-systems). This program protects public health and the environment through adequate dispersal and treatment of domestic sewage from dwellings or other establishments generating volumes less than 10,000 gallons per day.
- UMN Extension **Septic System Owner's Guide** (https://septic.umn.edu/septic-system-owners): Provides information about the basic principles of how a septic systems works and how to operate and maintain the system.

Making Sense of the Regulatory Environment

State agencies and programs play a variety of roles in restoring and protecting groundwater. Understanding the groundwater-related authorities and resources available at the state level and leveraging strengths of local water resource professionals are key to implementing effective groundwater protection strategies. Figure 36 provides a very basic introduction into the roles Minnesota state agencies have for groundwater.

- MDA works with groundwater that is or could be affected by pesticides and/or fertilizers.
- MDH focuses on proper well construction, assessing health risks related to groundwater, and protecting drinking water supplies.
- MPCA works with groundwater that is or could be affected by chemical releases and/or industrial pollutants.
- DNR focuses on assuring the availability of groundwater and protecting groundwater dependent features.

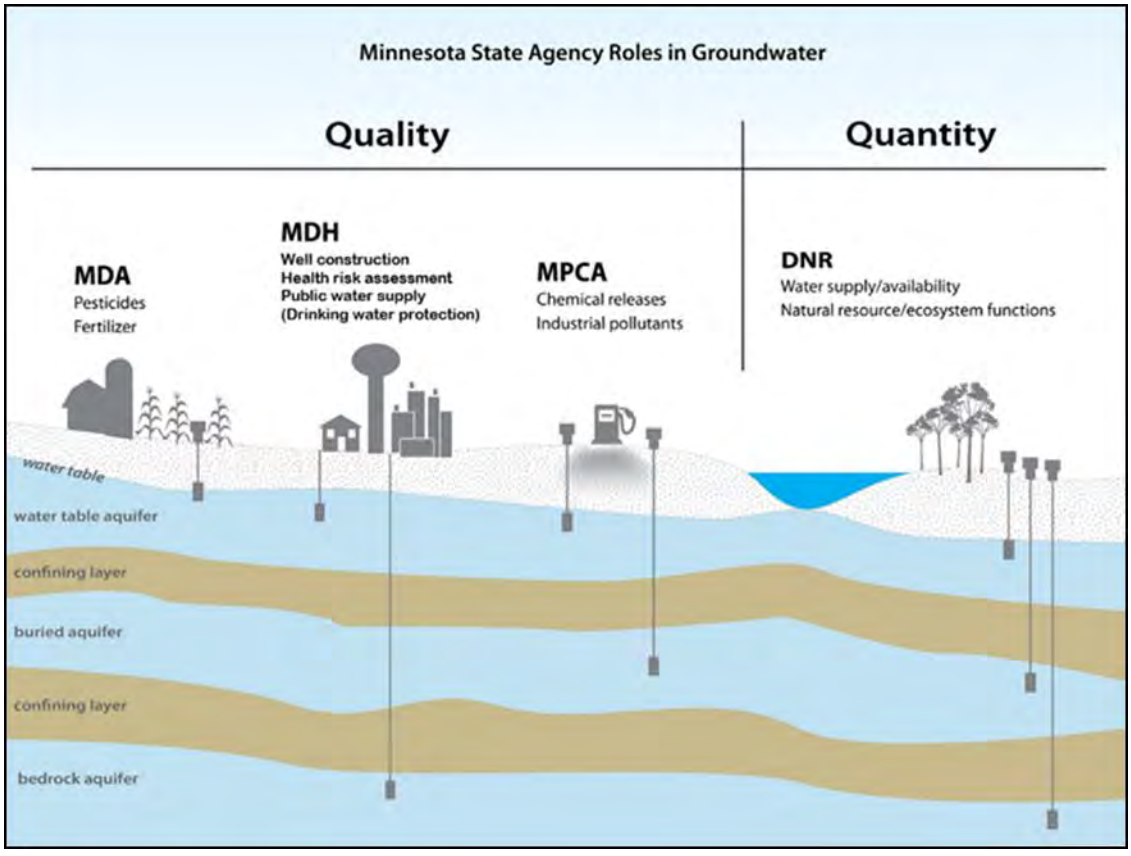

Figure 36: Minnesota State Agency Roles in Groundwater

Each of the state agencies listed above has a variety of programs to help meet their role in groundwater restoration and protection. Programs each of the agencies manage are referenced in the Descriptions of Supporting Strategies Section. Programs are listed under the restoration or protection strategy they mostly closely correspond to.

Figure 37 provides a more detailed overview of the different roles agencies play within Minnesota's Water Management Framework. Principal water resource management agencies are DNR, MPCA, MDA, BWSR, and MDH. These agencies are responsible for state or federal programs, including:

- the Clean Water Act for MPCA,
- the Safe Drinking Water Act for MDH, and
- Appropriation Permitting for the DNR.

The strength of these programs is that they provide technical assistance and regulatory oversight (including enforcement) to safeguard public health, natural resources, ecological needs, and the environment. These programs are generally effective at managing most types of point sources of contamination in the state and at managing quantity issues at the local and regional level. In addition, these programs often set standards for performance that can be used to drive action.

Two weaknesses of state or federal programs are that they (with few exceptions) are ineffective against non-point sources of contamination and lack authority relative to managing general land use practices. Non-point source management is a difficult issue for water resource managers at all levels. With few regulatory options available, the most common approaches involve the use of financial incentives, technical assistance, and education and communication about sound land and water stewardship. Seldom are representatives from state agencies able to spend the necessary time in the local community to build trust among landowners. As a result, these approaches benefit greatly from the perspectives and relationships that local water resource professionals can forge by working locally.

	Ongoing Implementation	Monitoring and Assessment	Watershed Characterization & Problem Investigation	Restoration and Protection Strategy Development	Comprehensive Watershed Management Plan
BWSR	Funding and technical assistance for locally implemented watershed restoration and protection projects	Monitor progress of local implementation goals	Conservation targeting tools (e.g., Environmental Benefits Index) BMP guidance (e.g., drainage water management)	Participate on interagency watershed teams developing WRAPS (with all agencies)	Comprehensive Watershed Management Planning (One Watershed, One Plan) Local water and watershed plans
MNDNR	Appropriations and Public Waters Permitting Shoreland and floodplain management Technical assistance for projects	Stream flow Fish and plants (lakes) Mercury in fish tissue Aquifer levels (with Met Council)	Stream hydrology and geomorphology (support MPCA) Small scale watershed modeling and groundwater level modeling County Geologic Atlas	Advise on conservation actions based on holistic view of watershed health (hydrology, geomorphology, connectivity, biology, water quality)	Input on local conservation actions informed by statewide plans for prairies, forests, etc. Water supply planning and groundwater management areas (with Met Council)
MDH	Funding for source water protection, contaminants of emerging concern Well sealing cost share	Source water and finished drinking water Bacteria monitoring on Lake Superior beaches	Guidance for contaminants of emerging concern Data analysis and modeling to support WHPA delineation and vulnerability assessments for public water supplies	Source water protection planning (identification of problems, issues, and opportunities) Well construction management	Guidance for infiltration in DWSMAs Source water protection planning (local measures and strategies)
PFA	Loans and grants for water infrastructure projects based on priorities set by MDH and PCA				
MPCA	NPDES permit programs, SSTS compliance Grants for Clean Water Partnership, Great Lakes Restoration, stormwater and wastewater treatment (PFA)	Water chemistry (surface and groundwater) Fish and macroinvertebrates (streams) Surface water assessment grants	Stressor identification for biological impairments Watershed Modeling (8-HUC) TMDLs Civic engagement	Stakeholder agreement on broad watershed restoration and protection strategies (WRAPS) WRAPS report – includes implementation table TMDLs to EPA	Provide WRAPS for incorporation into local plans Input on management strategies informed by statewide nutrient plan
MDA	Ag BMP loans MN Agricultural Water Quality Certification Program Implement Pesticide and Nitrogen Fertilizer Management Plans	Pesticides in surface and groundwater Nitrate in groundwater	Research/evaluation on ag sources, practices and solutions Technical assistance on ag sources and practices, BMP demonstration/evaluation sites Stressor ID for pesticides	Ag practices and management options, nitrogen fertilizer and pesticide use Participate on interagency teams developing WRAPS Vegetative cover	Input on management strategies informed by pesticide and nitrogen fertilizer management plans
Metropolitan Council	Technical assistance and demonstration projects	Lake, stream, river monitoring: flow, chemistry, biology Effluent monitoring (WWTPs) Impervious surface and land cover assessments	Modeling and trend assessments (surface water) Pollutant load calculations Groundwater mapping and characterization	Participate in WRAPS and local water planning teams Master water supply plan Groundwater management areas (with DNR)	Participate in review of local water and watershed plans (metro area); local water supply plans; and comprehensive land use plans (metro area)

Figure 37: Roles agencies play within the Minnesota Water Management Framework

Appendices

List of Acronyms

BMP	Best Management Practices
BWSR	Board of Soil and Water Resources
CAFO	Concentrated Animal Feeding Operation
CRP	Conservation Reserve Program
DWSMA	Drinking Water Supply Management Area
EPA	United States Environmental Protection Agency
GRAPS	Groundwater Restoration and Protection Strategies
HUC	Hydrologic Unit Code
IPM	Integrated Pest Management
MCL	Maximum Contaminant Level
MDA	Minnesota Department of Agriculture
MDH	Minnesota Department of Health
DNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer Systems
MWI	Minnesota Well Index
NRCS	United States Department of Agriculture Natural Resources Conservation Service
NLCD	National Land Cover Database
NPDES	National Pollutant Discharge Elimination System
PFA	Public Facilities Authority
QBAA	Quaternary Buried Artesian Aquifer
QWTA	Quaternary Water Table Aquifer
RIM	Reinvest in Minnesota Program
SSTS	Subsurface Sewage Treatment System
SDWA	Safe Drinking Water Act
SWCD	Soil and Water Conservation District
TTP	MDA Township Testing Program
UMN	University of Minnesota Extension
USDA	United States Department of Agriculture
USGS	United States Geological Survey

WIMN	What's in My Neighborhood
WHP	Wellhead Protection
WHPAS	Wellhead Protection Areas
WRAPS	Watershed Restoration and Protection Strategy

Glossary of Key Terms

Aquifer

An aquifer is an underground layer of water-bearing permeable rock, rock fractures or unconsolidated materials (gravel, sand, or silt) from which groundwater can be extracted using a water well.

Aquifer Vulnerability

Defined as the ease with which recharge and contaminants from the ground surface can be transmitted into the subsurface aquifer. MDH uses the terminology 'vulnerability'; whereas the MNDNR references 'sensitivity'. Both terms cite the risk to groundwater degradation.

Community Public Water Supply System

A public water supply system that serves at least 25 persons or 15 service connections year-round, which includes municipalities (cities), manufactured mobile home parks, nursing homes, etc.

Drinking Water Supply Management Area (DWSMA)

The surface and subsurface area surrounding a public water supply well, including the wellhead protection area that must be managed by the entity identified in a wellhead protection plan. The boundaries of the DWSMA are roads, public land survey and fractions thereof, property lines, political boundaries, etc. (See MN WHP Rules 4720.5100, Subp. 13.)

Groundwater recharge

The process through which water moves downward from surface water to groundwater. Groundwater recharge is the main way water enters an aquifer.

Hydrologic Unit Code (HUC)

HUCs are assigned by the USGS for each watershed. HUCs are organized in a nested hierarchy by size. For example, the St. Croix River Basin is assigned a HUC-4 of 0703 and the Sunrise River Watershed is assigned a HUC-8 of 07030005.

Maximum Contaminant Level (MCL)

The highest level of a contaminant that EPA allows in drinking water. MCLs ensure that drinking water does not pose either a short-term or long-term health risk. EPA sets MCLs at levels that are economically and technologically feasible.

Protection

This term is used to characterize actions taken in watersheds to maintain conditions and beneficial uses of waters not known to be impaired.

Pollution Sensitivity

The ease with which recharge and contaminants from the ground surface can be transmitted into the subsurface.

Public Water System

A water system with 15 or more service connections or regularly serves at least 25 people for 60 or more days a year. A system that serves water 60 or mores day a year is considered to 'regularly serve' water. Public water systems can be publicly or privately owned. Public water systems are subdivided into two categories: community and noncommunity water systems. This division is based on the type of consumer served and the frequency the consumer uses the water.

Restoration

This term is used to characterize actions taken in watersheds to improve conditions to eventually meet water quality standards and achieve beneficial uses of impaired waters.

Source (or Pollutant Source)

Actions, places, or entities that deliver/discharge pollutants (e.g., sediment, phosphorus, nitrogen, pathogens).

Source Water Protection

Protecting sources of water used for drinking, such as streams, rivers, lakes, or underground aquifers.

Transient Noncommunity System

A public water system that serves at least 25 people at least 60 days of the year but does not serve the same 25 people over 6 months of the year (places such as restaurants, campgrounds, hotels, and churches).

Water Budget

An accounting of all the water that flows into and out of a particular area. This area can be a watershed, wetland, lake, or any other point of interest.

Water Table

The boundary between the water filled rock and sediment of an aquifer and the dry rock and sediment above it. The depth to the water table is highly variable. It can range from zero when it is at land surface, such as at a lake or wetland, to hundreds or even thousands of feet deep. In Minnesota, the water table is generally close to the land surface, typically within a few tens of feet in much of the state.

Wellhead Protection (WHP)

A method of preventing well contamination by effectively managing potential contaminant sources in all or a portion of a well's recharge area. This recharge area is known as the wellhead protection area.

Wellhead Protection Area (WHPA)

The surface and subsurface area surrounding a well or well field that supplies a public water system, through which contaminants are likely to move toward and reach the well or well field. This definition is the same for

the federal Safe Drinking Water Act (40 Code of Federal Regulations, Section 1428) and the Minnesota Groundwater Protection Act (Minnesota Statute 103I).

Dataset Sources

- Adams, R., (2016), *Pollution sensitivity of near-surface materials* [electronic file], Minnesota Department of Natural Resources, St. Paul, Minn., Minnesota Hydrogeology Atlas Series HG-02, 15 p., 1 plate, scale 1:1,000,000. Available via Minnesota Department of Natural Resources: Minnesota Hydrogeology Atlas (MHA) (www.dnr.state.mn.us/waters/programs/gw_section/mapping/platesum/mha_ps-ns.html). [August 8, 2016].
- Jirsa, M.A., Boerboom, T.J., Chandler, V.W., Mossler, J.H., Runkel, A.C., and Setterholm, D.R. (2011), *Geologic Map of Minnesota-Bedrock Geology* [electronic file], Minnesota Geological Survey, St. Paul, Minn., State Map Series S-21, 1 plate, scale 1:500,000. Available via University of Minnesota Digital Conservancy: S-21 Geologic Map of Minnesota-Bedrock Geology (http://hdl.handle.net/11299/101466). [August 9, 2011].
- Minnesota Board of Water and Soil Resources (2018), *State Funded Conservation Easement (RIM Reserve)* [electronic file], St. Paul, Minn.
- Minnesota Department of Health (2017), *Minnesota Drinking Water Information System* [electronic file], St. Paul, Minn.
- Minnesota Department of Health (2017), *Water Chemistry Database* [electronic file], St. Paul, Minn.
- Minnesota Department of Health (2017), *Well Management Section Data System* [electronic file], St. Paul, Minn.
- Minnesota Department of Natural Resources (2017), *MNDNR Permitting and Reporting System 1988-2016* [electronic file], St. Paul, Minn. Available via Minnesota Department of Natural Resources: Minnesota Water Use Data (dnr.state.mn.us/waters/watermgmt_section/appropriations/wateruse.html). [August 7, 2017].
- Minnesota Geological Survey and Minnesota Department of Health (2017), *Minnesota County Well Index* [electronic file], Minnesota Department of Health, St. Paul, Minn. Available via Minnesota Geological Survey: Index of /pub2/cwi4/ (ftp://mgssun6.mngs.umn.edu/pub2/cwi4/). [2016-2017].
- Minnesota Pollution Control Agency (2017), *Closed Landfill Program Facilities* [electronic file], St. Paul, Minn. Available via Minnesota Geospatial Commons: MPCA Closed Landfill Facilities (https://gisdata.mn.gov/dataset/env-closed-landfill). [June 15, 2017].
- Minnesota Pollution Control Agency (2016), *What's In My Neighborhood* [electronic file], St. Paul, Minn. Available via Minnesota Pollution Control Agency: What's in My Neighborhood (https://www.pca.state.mn.us/data/whats-my-neighborhood). [December 19, 2016].
- Multi-Resolution Land Characteristics Consortium (2011), *National Land Cover Database 2011* [electronic file], U.S. Geological Survey, Reston, Va. Available via USDA-NRCS Geospatial Data Gateway: 1-Where (http://datagateway.nrcs.usda.gov/GDGOrder.aspx/). [August 25, 2014].

Additional Resources

The following resources may be helpful for gathering data and learning more about groundwater in the watershed. The resources are listed alphabetically by the topic they address.

Type of Information	Where you can get more information
Aquifer Vulnerability	For information on aquifer vulnerability ratings DWSMA, please contact MDH or the public water supplier in question. ▪ Protecting Drinking Water Sources (www.health.state.mn.us/communities/environment/water/swp/about.htm) ▪ 651-201-4700
Groundwater Quality Data	Find water-related monitoring data on Minnesota streams, lakes, wells, Superfund Program, closed landfills, other remediation sites, open landfills, data from MDA, MPCA, and USGS. ▪ Environmental Quality Information System (EQuIS) (https://www.pca.state.mn.us/quick-links/environmental-quality-information-system-equis) ▪ Environmental data (https://www.pca.state.mn.us/environmental-data) ▪ Groundwater (www.pca.state.mn.us/water/state-groundwater)
Drinking Water Annual Reports	MDH has issued a report regarding the state of drinking water in Minnesota each year since 1995. These reports provide test results, an overview on the role of the Department's drinking water program in monitoring and protecting drinking water, and an examination emerging issues. ▪ Drinking Water Protection Annual Reports (www.health.state.mn.us/communities/environment/water/dwar.html)
DWSMA maps and Shapefiles	PDF maps and shape files of the DWSMAs can be downloaded from the MDH website. ▪ Source Water Assessments (www.health.state.mn.us/communities/environment/water/swp/swa.html) ▪ Maps and Geospatial Data (www.health.state.mn.us/communities/environment/water/swp/maps/index.htm)
Point Source Pollution	Visit the following sites for more information on point source pollution: ▪ Nonpoint Source Pollution (oceanservice.noaa.gov/education/kits/pollution/03pointsource.html) ▪ Point Source Pollution (www.mncenter.org/point-source-pollution.html) ▪ Water Permits and Forms (https://www.pca.state.mn.us/water/water-permits-and-forms)
Well Construction and Use Data	Most of the construction and use data pertaining to wells in the state is housed in the Minnesota Well Index (MWI), an online database. All of the key data in the MWI is also available in spatial datasets, designed for use in geographic information systems (GIS). The Minnesota Geological Survey and MDH work together to maintain and update the

Type of Information	Where you can get more information
	data in the Index. MWI provides basic information, such as location, depth, geology, construction and static water level, for many wells and borings drilled in Minnesota. It by no means contains information for all the wells and borings and the absence of information about a well on a property does not mean there is no well on that property. ▪ Minnesota Well Index (MWI) (www.health.state.mn.us/communities/environment/water/mwi/index.html)
Wellhead Protection Plans	These plans can be obtained directly from the communities or from MDH with permission from the communities. Water chemistry data collected from these systems can be provided by request to MDH. ▪ Protecting Drinking Water Sources (www.health.state.mn.us/communities/environment/water/swp/about.htm) ▪ 651-201-4700

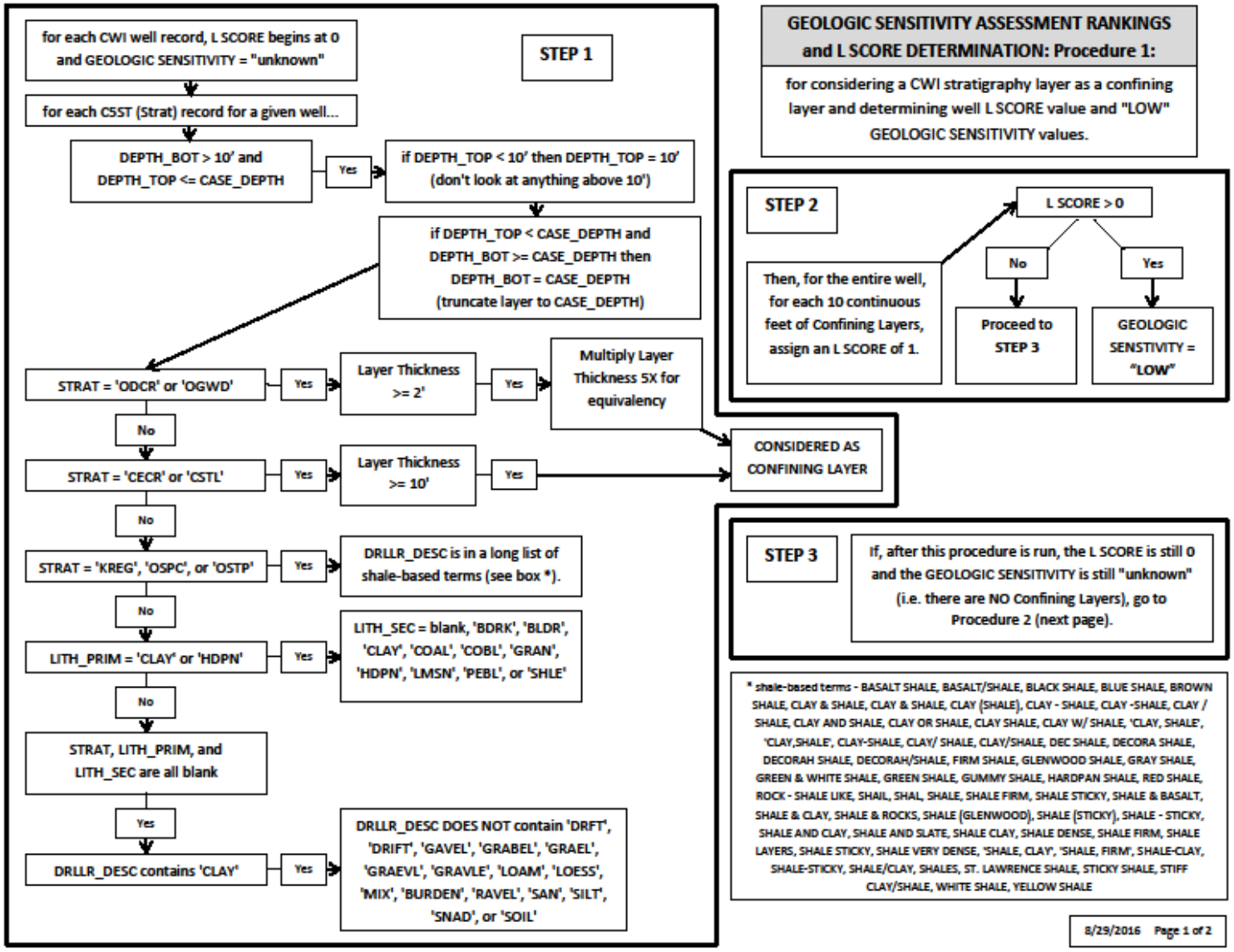

Figure 38: Sensitivity Assessment and Calculation for Pollution Sensitivity of Wells (Figure 9)

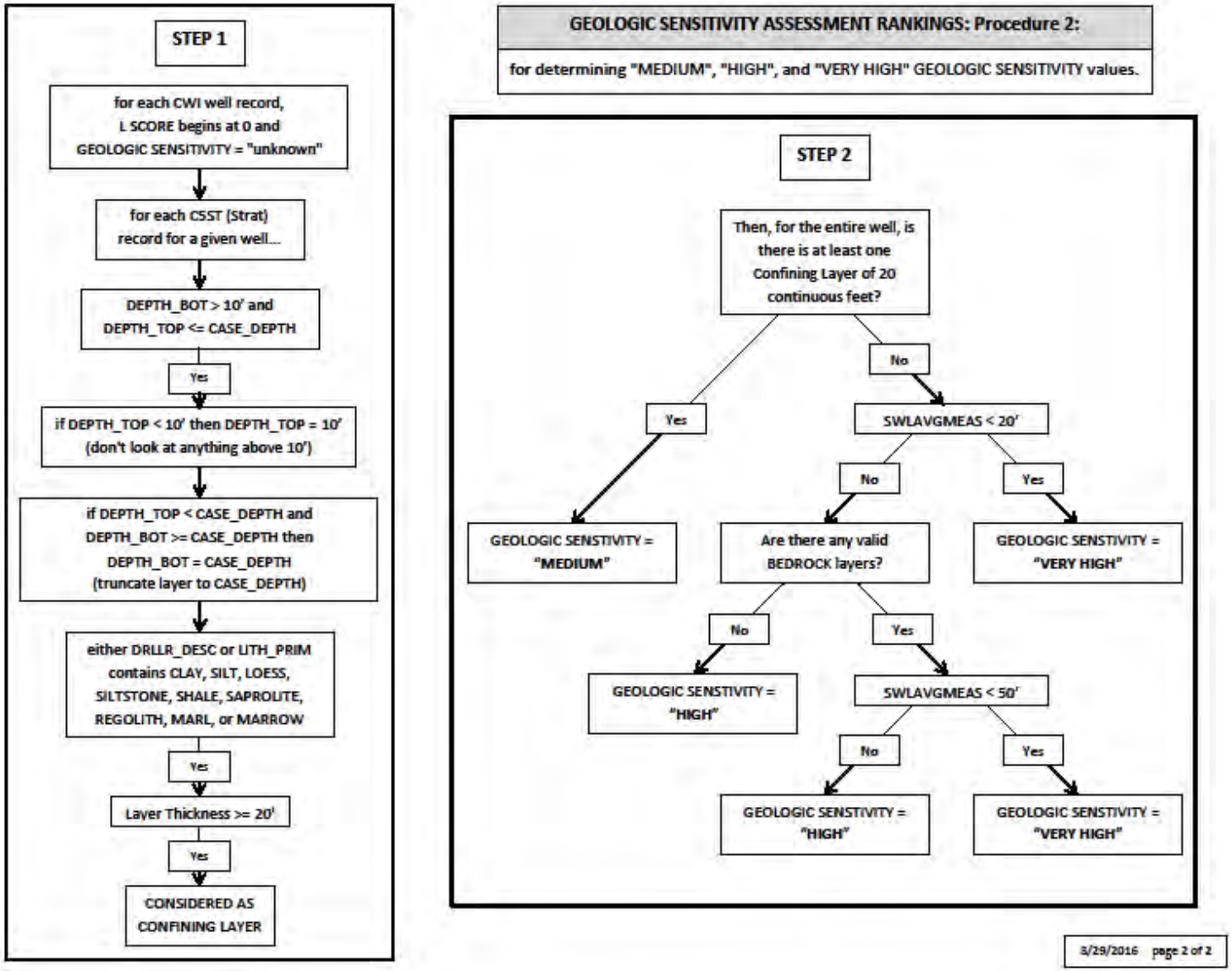

Figure 39: Sensitivity Assessment and Calculation for Pollution Sensitivity of Wells (Figure 9) continued

Table 10: Rare Species Connected with Groundwater in the Lower Minnesota River West Watershed[14]

Scientific Name	Common Name	Species Class	Listing Status[15]	AQUATIC (Y OR N)	WETLAND (Y OR N)	GROUND-WATER DEPENDENT (Y OR N)	General Habitat Type
Rare Plant: *Asclepias sullivantii*	Sullivant's Milkweed	Terrestrial Plant	THR	N	N	Sometimes	Mesic tallgrass prairies
Rare Plant: *Berula erecta*	Stream parsnip	Vascular Plant	THR	N	Y	Y	Calcareous fens; alkaline springs; usually occurs in active seepage areas
Rare Plant: *Cypripedium candidum*	Small White Lady's-slipper	Terrestrial Plant	SPC	N	Y	Sometimes	Calcareous seeps, wet prairie
Rare Animal: *Necturus maculosus*	Mudpuppy	Amphibian	SPC; SGCN	Y	N	Sometimes	Freshwater lakes, rivers, streams, and ponds
Rare Bird: *Antigone canadensis*	Sandhill Crane	Bird	NL	N	Y	Sometimes	Breeding and foraging: Open prairies, grasslands, and wetlands; Outside of the breeding season: often roost in deeper water of ponds or lakes
Rare Bird: *Chlidonias niger*	Black Tern	Bird	NL, SGCN	Y	Y	Sometimes	Marshes/ wetlands
Rare Bird: *Xanthocephalus xanthocephalus (Colonial Waterbird Nesting Area)*	Yellow-headed Blackbird	Bird (grouping of a variety of nesting bird species)	NL; SGCN	Y	Y (Sometimes)	Sometimes	Breeding: Prairie wetlands, shallow marshes, ponds, and rivers

[14] Last Updated 06/03/2020

[15] END =State Endangered; THR = State Threatened; SPC = State Special Concern; Watch list = Species the DNR is tracking because they are in suspected decline SGCN= Species of Greatest Conservation Need

Rare Mussels: *Actinonaias ligamentina*	Mucket	Mussel	THR, SGCN	Y	N	Y	Medium to large rivers with sand and gravel substrates
Rare Mussels: *Alasmidonta marginata*	Elktoe	Mussel	THR, SGCN	Y	N	Y	Medium to large rivers with sand and gravel substrates
Rare Reptiles: *Apalone mutica*	Smooth Softshell	Reptile	SPC; SGCN	Y	N	Possibly	Large, unpolluted rivers with sandy substrates
Rare Reptiles: *Emydoidea blandingii*	Blanding's Turtle	Reptile	THR, SGCN	Y	Y	Possibly	Wetland complexes, small streams, and adjacent uplands, typically, but not always mapped as sandy soils

Tables 11-13[16] show the documented wetland native plant communities connected to groundwater in the Lower Minnesota River West Watershed.

Table 11: Lower Minnesota River West Watershed documented wetland native plant communities dependent on sustained groundwater discharge

Native Plant Community Code	Native Plant Community Name	Conservation Status Rank
Fens and Seepage Wetlands	-	
OPp93c	Calcareous Fen (Southeastern)	S1
WMs83a	Seepage Meadow/Carr	S3

Table 12: Lower Minnesota River West Watershed documented wetland native plant communities dependent on groundwater associated with consistently high water tables

Native Plant Community Code	Native Plant Community Name	Conservation Status Rank
Wetland Prairies		
WPs54b	Wet Prairie (Southern)	S2=Imperiled
Marshes		
MRn83a	Cattail - Sedge Marsh (Northern)	S2
MRn93a	Bulrush Marsh (Northern)	S3=Vulnerable to Extirpation
MRp83b	Cattail Marsh (Prairie)	S1=Critically imperiled

[16] Updated 06/20/2020

Table 13: Lower Minnesota River West Watershed documented wetland native plant communities dependent on groundwater associated with water table that are high for some portion of the growing season

Native Plant Community Code	**Native Plant Community Name**	**Conservation Status Rank**
Forested Wetlands		
FFs68	Southern Floodplain Forest	S3
FFs68a	Silver Maple - (Virginia Creeper) Floodplain Forest	S3
Wet Meadow/Shrub Carr Wetlands		
WMn82a	Willow - Dogwood Shrub Swamp	S5=secure
WMn82b	Sedge Meadow	S4= Apparently secure or S5

References

Adams, R., 2016, Pollution sensitivity of near-surface materials: St. Paul, Minnesota Department of Natural Resources, Minnesota Hydrogeology Atlas Series HG-02, report and plate, accessible at https://www.dnr.state.mn.us/waters/programs/gw_section/mapping/platesum/mha_ps-ns.html.

Adams, Roberta; Barry, John; and Green, Jeff (2016). Minnesota Regions Prone to Surface Karst Feature Development (PDF) (files.dnr.state.mn.us/waters/groundwater_section/mapping/gw/gw01_report.pdf). Series GW-01.

Baratta, V.M. and Petersen, T.A., 2016, Geologic atlas of Nicollet County, Minnesota (Part B): Minnesota Department of Natural Resources, County Atlas Series C-25, report and pls. 7–8, http://www.dnr.state.mn.us/waters/programs/gw_section/mapping/platesum/nicocga.html.

Baratta, V.M., and Petersen, T.A., 2017, Geologic atlas of Sibley County, Minnesota (Part B): Minnesota Department of Natural Resources, County Atlas Series C-24, report and pls. 7–8, http://www.dnr.state.mn.us/waters/programs/gw_section/mapping/platesum/siblcga.html.

Geologic Sensitivity Project Workgroup (1991), *Criteria and guidelines for assessing pollution sensitivity of ground water resources in Minnesota,* Minnesota Department of Natural Resources, Division of Waters, St. Paul, Minn., 122 p.

Gergel, S.E., Turner, M.G, and Kratz, T.K., 1999, Dissolved Organic Carbon as an Indicator of the Scale of Watershed Influence on Lakes and Rivers: Ecological Applications, v. 9, No. 4, p.1377-1390.

Kroening, S. and Ferrey, M. (2013), The Condition of Minnesota's Groundwater, 2007-2011. Document number: wq-am1-06

Lusardi, B.A.. (2009). C-20 Geologic atlas of Mcleod County, Minnesota [Part A]. Minnesota Geological Survey. Retrieved from the University of Minnesota Digital Conservancy, https://hdl.handle.net/11299/58781.

Lusardi, B.A.; Runkel, A.C.; Meyer, G.N.. (2011). C-24 Geologic Atlas of Sibley County, Minnesota [Part A]. Minnesota Geological Survey. Retrieved from the University of Minnesota Digital Conservancy, https://hdl.handle.net/11299/116056.

Meyer, G.N.; Runkel, A.C.; Lusardi, B.A.. (2012). C-25 Geologic Atlas of Nicollet County, Minnesota [Part A]. Minnesota Geological Survey. Retrieved from the University of Minnesota Digital Conservancy, https://hdl.handle.net/11299/116090.

Minnesota State Agency Workgroup under the direction of the U.S. EPA *(1998), Guidance or Mapping Nitrate in Minnesota Groundwater*, p 7.

M.L. Erickson and R.J. Barnes, 'Arsenic in Groundwater: Recent Research and Implications for Minnesota,' CURA Reporter 34,2 (2004): 1–7; and M.L. Erickson and R.J. Barnes, 'Glacial Sediment Causing Regional-Scale Elevated Arsenic in Drinking Water,' Ground Water 43 (2005): 796–805.

Minnesota Department of Agriculture (2014), 2014 Water Quality Monitoring Report.

Minnesota Department of Agriculture (2015), 2015 Nitrogen Fertilizer Management Plan.

Minnesota Department of Natural Resource, MGS, UMD (1997), *Geomorphology of Minnesota, Scale 1:100,000.*

Morey, G.B.; Meints, J.P.. (2000). S-20 Geologic map of Minnesota, bedrock geology. Minnesota Geological Survey. Retrieved from the University of Minnesota Digital Conservancy, S-20 Geologic map of Minnesota, bedrock geology (http://hdl.handle.net/11299/60086).

Mueller, D.K., and Helsel, D.R., 1996, Nutrients in the Nation's water--Too much of a good thing?: U.S. Geological Survey Circular 1136, 24 p.

Petersen, T.P. and Solstad, J.A., 2007, Interaction of Lakes and Ground Water in Geologic atlas of Crow Wing County, Minnesota: Minnesota Department of Natural Resources, County Atlas Series C-16, Part B, pl. 10.

USGS. 2017. National Land Cover Database (NLCD) Land Cover Collection. Available at NLCD Land Cover Collection (https://catalog.data.gov/dataset/national-land-cover-database-nlcd-land-cover-collection).

Warner, K.L. and Arnold, T.L., 2010, Relations that affect the probability and prediction of nitrate concentration in private wells in the glacial aquifer system in the United States (https://pubs.usgs.gov/sir/2010/5100/): U.S. Geological Survey Scientific Investigations Report 2010-5100, 73 p.