Minnesota River - Mankato Watershed Restoration and Protection Strategies

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MINNESOTA POLLUTION CONTROL AGENCY

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Glossary

Altered hydrology (USGS 2014b): Changes in the amount of and way that water moves through the landscape. Examples of altered hydrology include changes in: river flow, precipitation, subsurface drainage, impervious surfaces, wetlands, river paths, vegetation, and soil conditions. These changes can be climate- or human-caused.

Animal Units (AU): A term typically used in feedlot regulatory language. One AU is roughly equivalent to 1,000 pounds of animal, but varies depending on the specific animal.

Assessment Unit Identifier (AUID): The unique waterbody identifier for each river reach comprised of the USGS eight-digit HUC plus a three-character code unique within each HUC. The "AUID-3" used to label streams in this report is that three-character code. Also see 'stream reach'

Aquatic consumption impairment: Streams are impaired for impacts to aquatic consumption when the tissue of fishes from the waterbody contains unsafe levels of a human-impacting pollutant. The Minnesota Department of Health provides safe consumption limits.

Aquatic recreation impairment: Streams are considered impaired for impacts to aquatic recreation if fecal bacteria standards are not met. Lakes are considered impaired for impacts to aquatic recreation if total phosphorus, chlorophyll-a, or Secchi disc depth standards are not met.

Biological Impairment (bio-impaired): A biological impairment is an impairment to the aquatic life beneficial use due to a low fish and/or bug IBI score.

Civic Engagement (CE): CE is a subset public participation (IAP2 2007) where decision makers involve, collaborate, or empower citizens in the decision making process. The University of Minnesota Extension (2013) provides information on CE and defines CE as "Making resourceful decisions and taking collective action on public issues through processes that involve public discussion, reflection, and collaboration."

Designated (or Beneficial) Use: Water bodies are assigned a designated use based on how the waterbody is used. Typical beneficial uses include: drinking, swimming, fishing, fish consumption, agricultural uses, and limited uses. Water quality standards for pollutants or other parameters are developed to determine if water bodies are meeting their designated use.

Flow-weighted Mean Concentration (FWMC): The total mass of a pollutant delivered (by water) over a set period of time by the total volume of water over that same period of time. Typical units are: lbs/ac-ft or grams/m^3

Geographic Information Systems (GIS): A GIS or geographical information system (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data. https://en.wikipedia.org/wiki/Geographic_information_system

Hydrologic Unit Code (HUC): Assigned by the USGS for each watershed. HUCs are organized in a nested hierarchy by size. For example, the Minnesota River Basin is assigned a HUC-4 of 0702 and the Minnesota River – Mankato Watershed is assigned a HUC-8 of 07020007.

Impairment: Water bodies are listed as impaired if water quality standards are not met for designated uses including: aquatic life, aquatic recreation, and aquatic consumption.

Index of Biotic integrity (IBI): A numerical value between 0 (lowest quality) to 100 (highest quality) that classifies the aquatic communities.

Nonpoint source pollutants: Pollutants that are from diffuse sources; most of these sources are not regulated. Nonpoint sources include: agricultural field run-off, agricultural drain tile discharge, storm water from smaller cities and roads, bank, bluff, and ravine failures, atmospheric deposition, failing septic systems, animals, and other sources.

Point Source Pollutant: Pollutants that can be directly attributed to one location; generally, these sources are regulated by permit. Point sources include: waste water treatment plants, industrial dischargers, and storm water discharge from larger cities (MS4 permit (MPCA 2014e)), and storm water runoff from construction activity (construction storm water permit).

Pollutant vs Stressor: Generally, these words could be used interchangeably. However, in this report, a pollutant is used to refer to parameters that have a water quality standard and can be tested for directly. Pollutants affect all beneficial uses. A stressor is used to refer to the parameter(s) identified in the stressor identification process, which is only done when a bio-impairment is identified (due to a low fish and/or bug IBI score).

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

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

Source (or Pollutant Source): Actions, locations, or entities that deliver/discharge pollutants.

Stream Class: a classification system for streams to specify the stream's beneficial or designated uses.

> **Stream Class 2B**: The quality of Class 2B surface waters shall be such as to permit the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life and their habitats. These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable.
>
> **Stream Class 2C**: The quality of Class 2C surface waters shall be such as to permit the propagation and maintenance of a healthy community of indigenous fish and associated aquatic life and their habitats. These waters shall be suitable for boating and other forms of aquatic recreation for which the waters may be usable.
>
> **Stream Class 7 waters**: The quality of Class 7 waters of the state shall be such as to protect aesthetic qualities, secondary body contact use, and groundwater for use as a potable water supply.

Stream reach: "Reaches in the network are segments of surface water with similar hydrologic characteristics. Reaches are commonly defined by a length of stream between two confluences, or a lake or pond. Each reach is assigned a unique reach number and a flow direction. The length of the reach, the type of reach, and other important information are assigned as attributes to each reach." USGS 2014

Stressor (or Biological Stressor): A term for the parameters (e.g., altered hydrology, dams preventing fish passage) that were identified as adversely impacting aquatic life in a biologically-impaired stream reach.

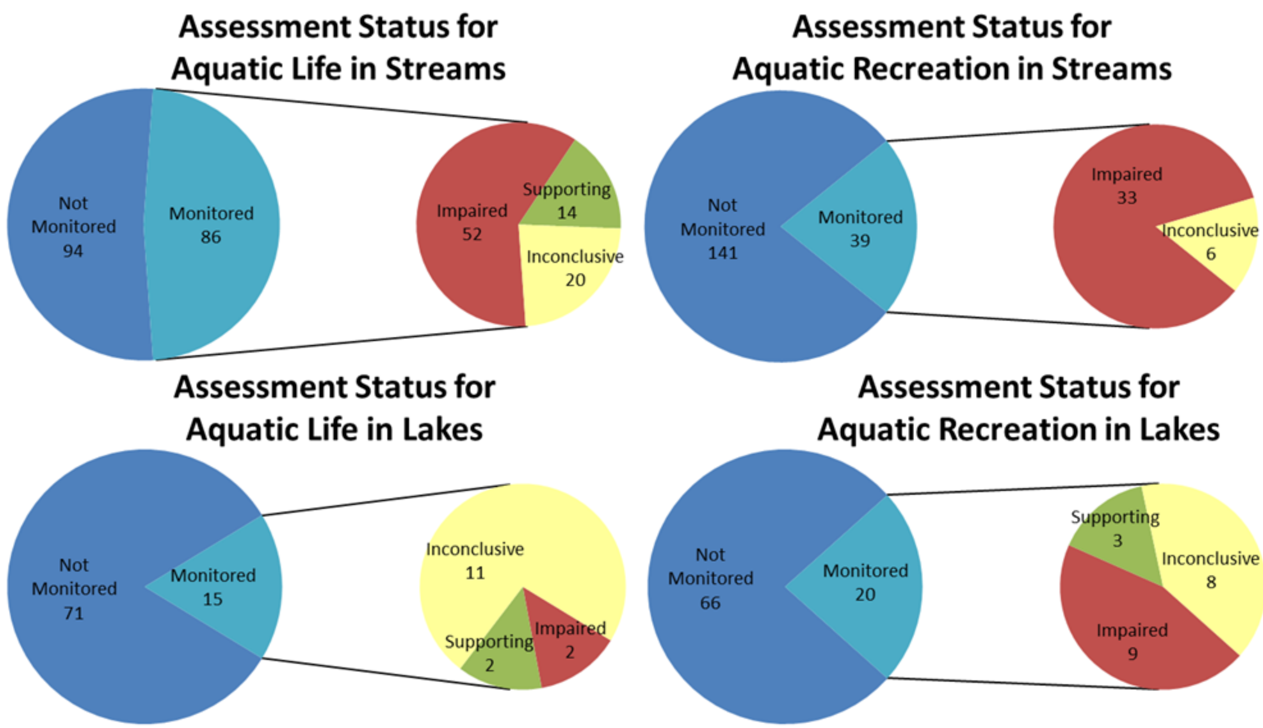
Total Maximum Daily Load (TMDL) is the maximum amount of a pollutant (or load capacity) a waterbody can receive without exceeding the water quality standard. In addition to calculating the load capacity, TMDL studies identify pollutant sources by allocating the load capacity between point sources (or wasteload) and nonpoint sources (or load). Finally, TMDLs calculate the necessary pollutant reductions necessary for a waterbody to meet its standards.

Yield (water, pollutant, crop, etc.): the amount of mass, volume, or depth per unit land area (e.g. lbs/ac, in/ac)

Executive Summary

The State of Minnesota uses a “Watershed Approach” to assess and address the water quality of each of the state’s 80 major watersheds on a 10-year cycle. This report summarizes the findings of Watershed Approach work from the Minnesota River-Mankato Watershed (which is referred to as the Middle Minnesota River Watershed in this report).

Water quality conditions in the Middle Minnesota River Watershed reflect general water quality across Southern and Western Minnesota; the majority of monitored waterbodies are not meeting water quality standards for aquatic life (fishing) and aquatic recreation (swimming), as illustrated in the pie charts below.



Impaired waters should be restored through higher adoption of best management practices (BMPs). However, some localized areas in the Middle Minnesota River Watershed do meet water quality standards, and the land uses and BMPs that enable this clean water should be protected.

The identified pollutants and stressors, the watershed-wide goals, the range of individual stream reach and lakes goals, the 10-year targets, and the estimated years to reach goals are summarized in the following table.

Parameters (Pollutant/ Stressors)	**Watershed-Wide Goal** (Average for Watershed)	**Range of Subwatershed Goals** (Estimated only when TMDL data are available)	**10-year Target** (for 2029)	**Years to Reach Goal** (from 2019)
Altered Hydrology	25% reduction in peak & annual river flow	not estimated (TMDLs not completed on this parameter)	5%	50
	increase dry season river base flow where ID'd in SID by enough to support aquatic life		increase	30
Nitrogen	60% reduction in river concentrations/loads	protect up to a 78% reduction	10%	55
Habitat	25% increase in MSHA habitat score	protect up to a 181% increase	9%	35
Phosphorus	50% reduction in lake and stream concentrations/loads	protect up to a 83% reduction	10%	50
Sediment	50% reduction in restoration areas (1/4 of watershed) No increase in protection areas (3/4 of watershed)	protect up to a 88% reduction	12%	40
Bacteria	60% reduction in river concentrations/loads	10% to 87% reduction	13%	40
Connectivity	Address human-caused issues (dams, culverts) as identified in SID and where practical/feasible	not estimated (TMDLs not completed on this parameter)	9%	45

The report presents Strategies Table A (Table 21), which provides a high-level narrative estimate of the total changes necessary for all waters to be restored and protected, along with Strategies Table B (Table 22), which presents a specific suite of BMPs and numeric adoption rates to meet the 10-year targets. With 80% of the area in cultivated crops, the largest opportunity for water quality improvement is from this land use. However, all land uses should make improvements to help restore and protect waters.

Watershed restoration depends on higher levels of adoption, and adoption focused on key sources, of BMPs, including the following high priority practices: decreased fertilizer use, planting of cover crops, decreased tillage, cropland surface runoff treatment, cropland tile drainage treatment, and improved manure application. Social strategies to accelerate BMP adoption include: education and outreach, networking and relationships, conservation practice targeting, flexible and available funding, and more technical staff time. High priority strategies for protecting waters include maintaining perennial vegetation and BMPs on the landscape, and mitigating future changes to hydrology.

Priority areas for surface water quality restoration and protection are presented throughout the Watershed Restoration and Protection Strategy (WRAPS) report and are summarized in the **Priorities Table** (Table 20). Local partners should further prioritize and target to integrate surface water quality priorities with other local priorities to identify multiple-benefit priority areas.

The farming community has been and continues to be a vital partner to conservation efforts in the Minnesota River Basin. Reducing sediment and nutrient impacts on water resources is important to

Minnesota farmers who innovate new practices to improve the sustainability of their farms. Continued support from the State, local governments, and farm organizations will be critical to finding and implementing solutions that work for individual farmers and help achieve the goal of clean water.

1 Introduction and Background

1.1 Watershed Approach and WRAPS

The State of Minnesota uses a "*Watershed Approach*" (MPCA 2015a) to assess and address the water quality of each of the state's 80 major watersheds on a 10-year cycle. In each cycle of the Watershed Approach, rivers, lakes and wetlands across the watershed are monitored and assessed, waterbody restoration and protection strategies and local plans are developed, and conservation practices are implemented. Watershed Approach assessment work started in the Minnesota River-Mankato major watershed (referred to in this report as the Middle Minnesota River Watershed) in 2013 (Figure 1).

Much of the information presented in this report was produced in earlier Watershed Approach work, prior to the development of the WRAPS report. However, the WRAPS report presents additional data and analyses. To ensure the WRAPS strategies and other analyses appropriately represent the Middle Minnesota River Watershed, local county, SWCD staff, and state natural resource and conservation professionals (referred to as the WRAPS Feedback Group) were convened to inform the report and advise technical analyses.

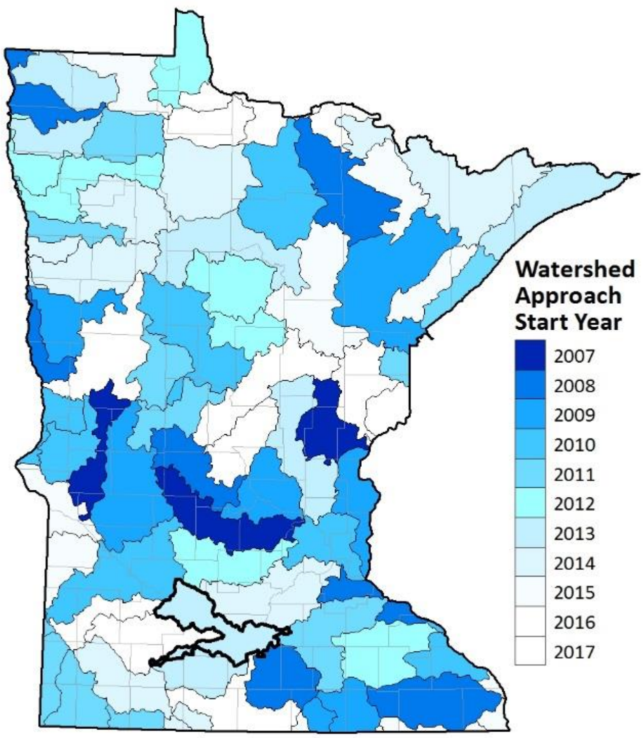


Figure 1: "Watershed Approach" work started in 2013 in the Middle Minnesota River Watershed (in bold). Watershed Approach work starts in approximately 8 major watersheds each year.

Two key products of this WRAPS report are the strategies table and the priorities table, each developed with the WRAPS Feedback Group. The strategies table outlines high-level strategies and estimated adoption rates necessary to restore and protect water bodies in the Watershed, including social strategies that are key to achieving the physical strategies. The priorities table presents criteria to identify priority areas for water quality improvement, including specific examples of water bodies and areas that meet the prioritizing criteria. Additional tools and data layers that can be used to refine priority areas and target strategies within those priority areas are listed in Appendix 4.3.

In summary, the ***purpose*** of the WRAPS report is to summarize work done in this first cycle of the Watershed Approach in the Middle Minnesota River Watershed, which started in 2013. The ***scope*** of the report is surface water bodies and their aquatic life and aquatic recreation beneficial uses for tributaries and land in the Middle Minnesota River Watershed (the Minnesota River as a whole is addressed in a separate report). The primary ***audience*** for the WRAPS report is local planners, decision makers, and conservation practice implementers; watershed residents, neighboring downstream states, agricultural business, governmental agencies, and other stakeholders are the secondary audience.

This WRAPS is not a regulatory document but is legislatively required per the Clean Water Legacy legislation on WRAPS (ROS 2016). This report has been designed to meet these requirements, including an opportunity for public comment, which was provided via a public notice in the State Register from July 22, 2019 to September 20, 2019. The WRAPS report concisely summarizes an extensive amount of information. The reader may want to review the supplementary information provided (links and references in document) to fully understand the summaries and recommendations made within this document.

1.2 Watershed Description

The Middle Minnesota River Watershed (HUC-8: 07020007 [USGS 2014a]) drains approximately 862,000 acres through 1,564 miles of streams into the Minnesota River (Figure 2). The watershed is bisected by the Minnesota River and its substantial valley, which was created by the Glacial River Warren.

Portions of nine counties comprise the watershed: Nicollet (24%), Brown (22%), Renville (18%), Blue Earth (13%), Redwood (11%), Le Sueur (7%), Cottonwood (3%), Sibley (3%), and Watonwan (<0.1%). Larger cities in the watershed include Mankato, New Ulm, St. Peter, Lake Crystal, Fairfax, and portions of Redwood Falls. A total of roughly 95,000 people reside in the Middle Minnesota River Watershed, a density of about 115 people per 1,000 acres.

Topography through the upland portions of the watershed is relatively flat and well drained through an extensive network of constructed ditches (Figure 4). The Minnesota River valley, carved by the enormous Glacial River Warren, lies hundreds of feet below the upland areas. In the transition between the upland and Minnesota River valley is an active “nick zone” with steep stream slopes that cut down to reach the much lower elevation of the Minnesota River. This nick zone results in steep, eroding banks, bluffs, and ravines, incising channels that limit floodplain connectivity, and waterfalls in areas where the stream cuts down to bedrock.

Current land use in the Middle Minnesota River Watershed is similar to other regions in Southern and Western Minnesota: land use is dominated by warm-season, annual, cultivated, row crops (Figure 5).

More description information on the Middle Minnesota River Watershed can be found at:

Middle Minnesota River Rapid Watershed Assessment (NRCS 2017)

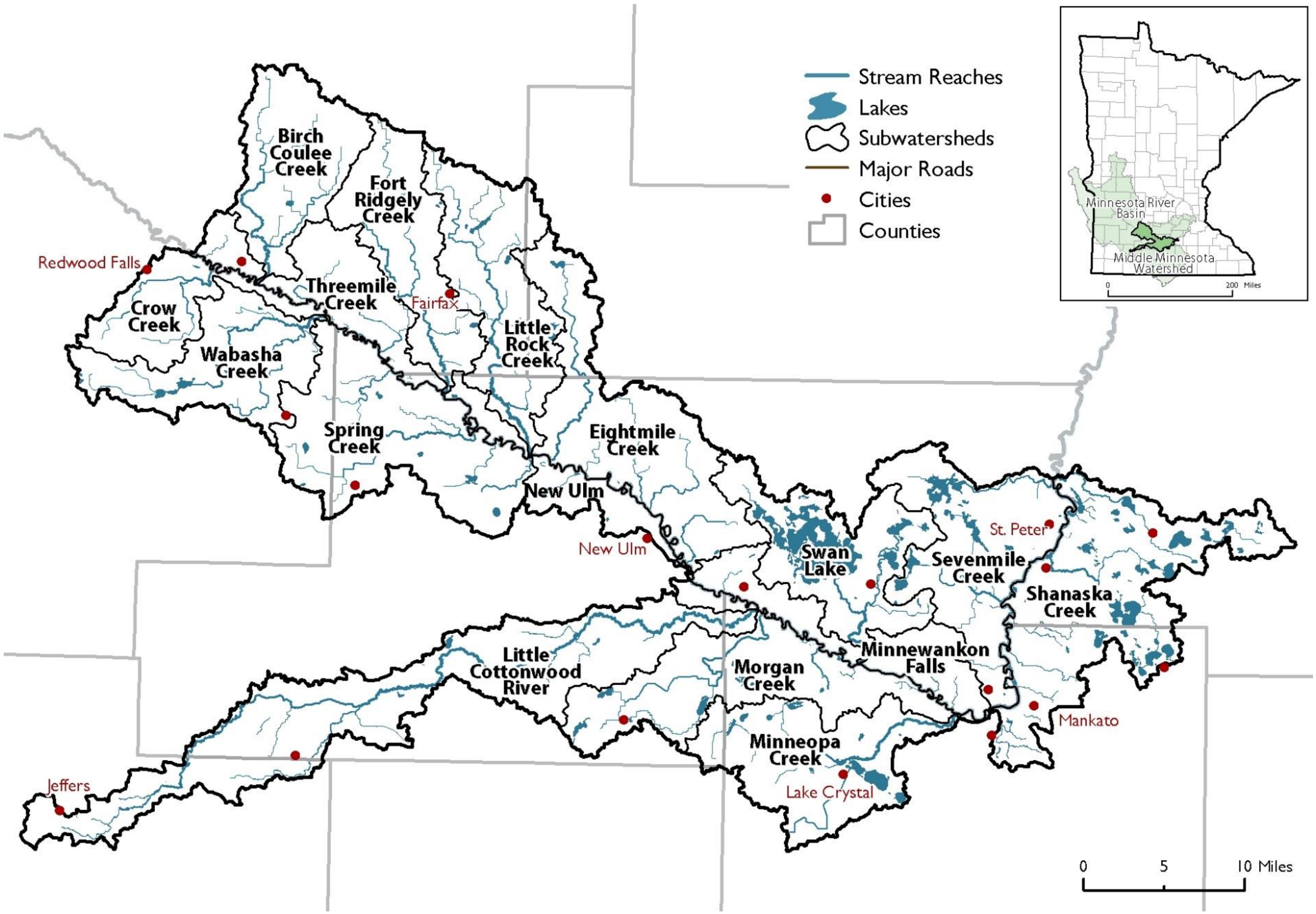


Figure 2: The Middle Minnesota River Watershed drains 826,000 acres from nine counties in south central Minnesota through dozens of tributaries into the Minnesota River.

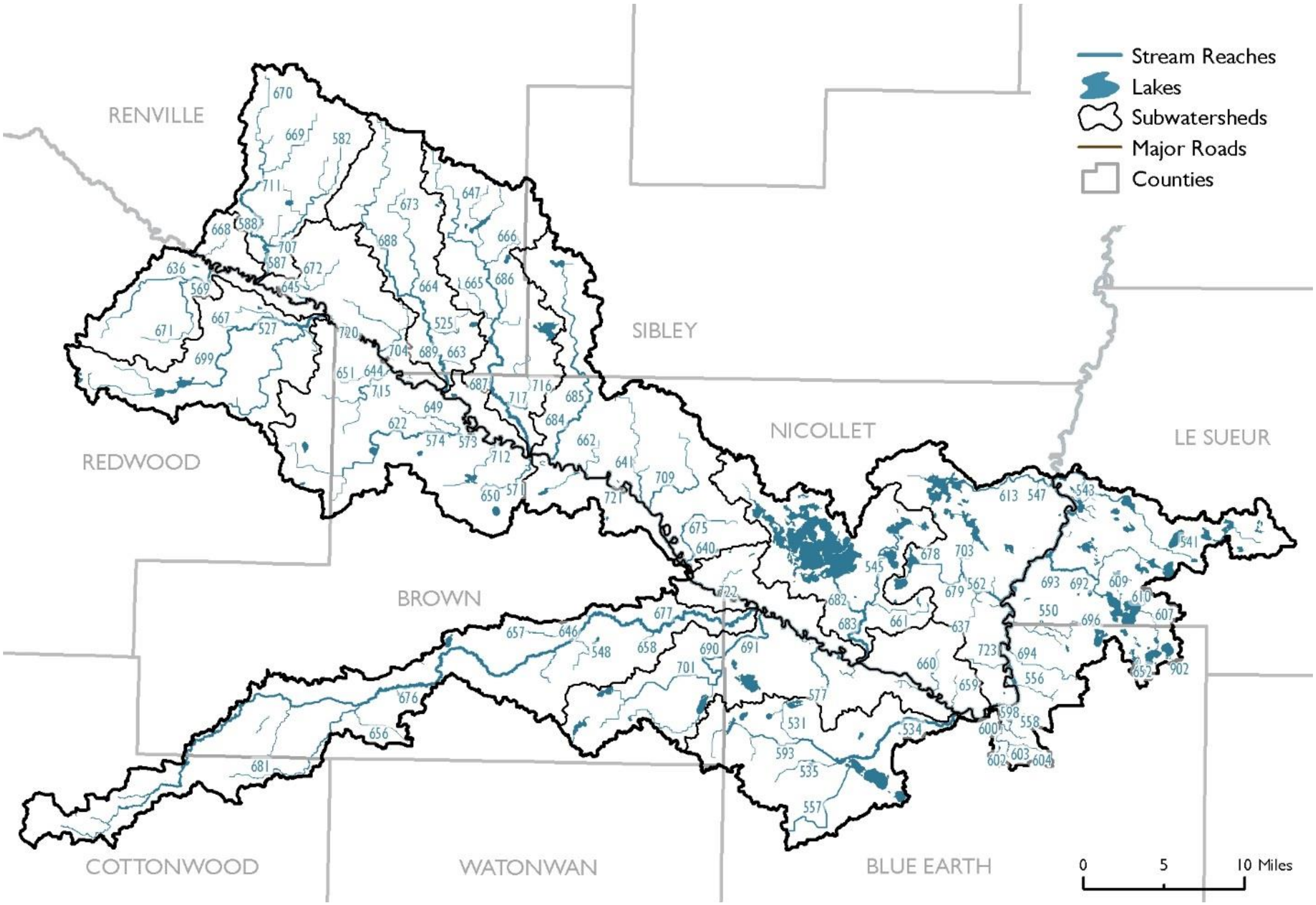


Figure 3: Map of streams and lakes in the Middle Minnesota River Watershed. The stream line size is used to indicate the estimated average stream flow, and stream reaches are labeled by the last three digits of the AUID.

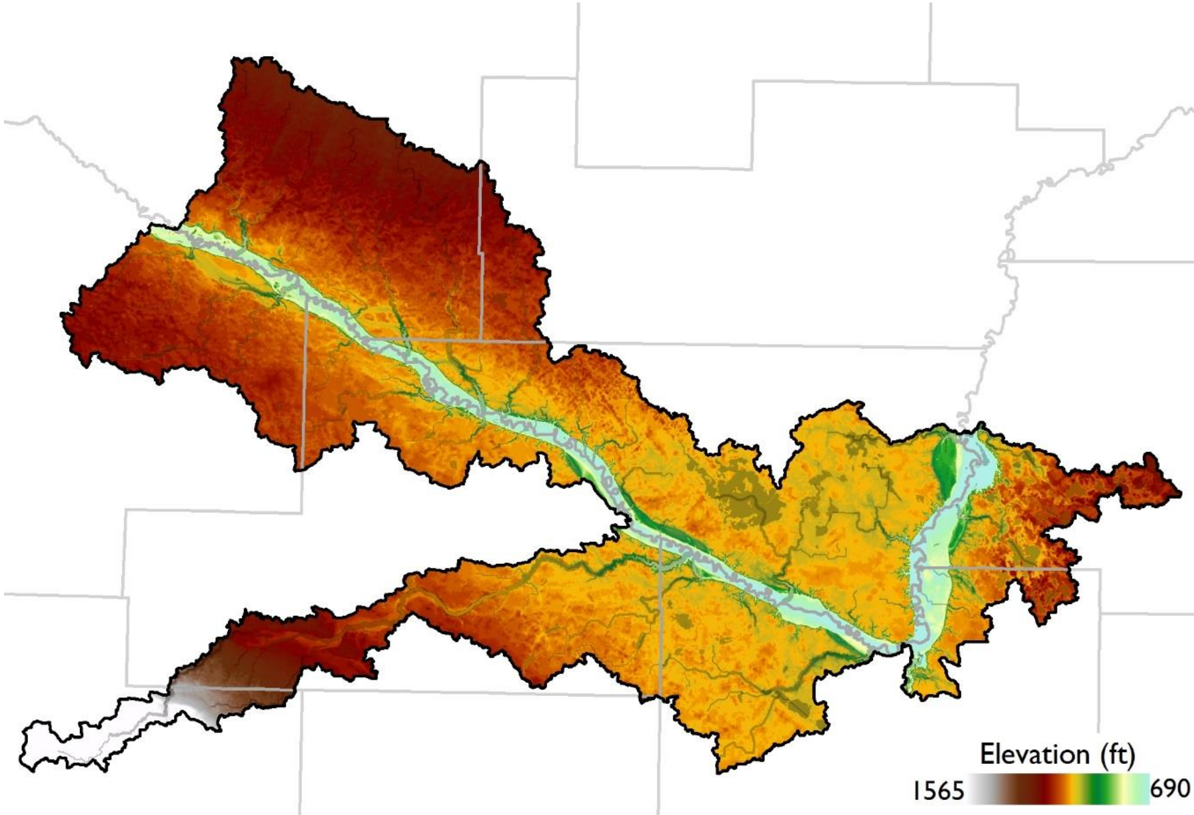


Figure 4: The Middle Minnesota River Watershed has 875 feet of fall from the upland areas to the river valley below. Large areas of similar color illustrate flatter areas of the watershed. The drastic change in color near the Minnesota River Valley illustrates the significant drop in elevation from the uplands to the Minnesota River.

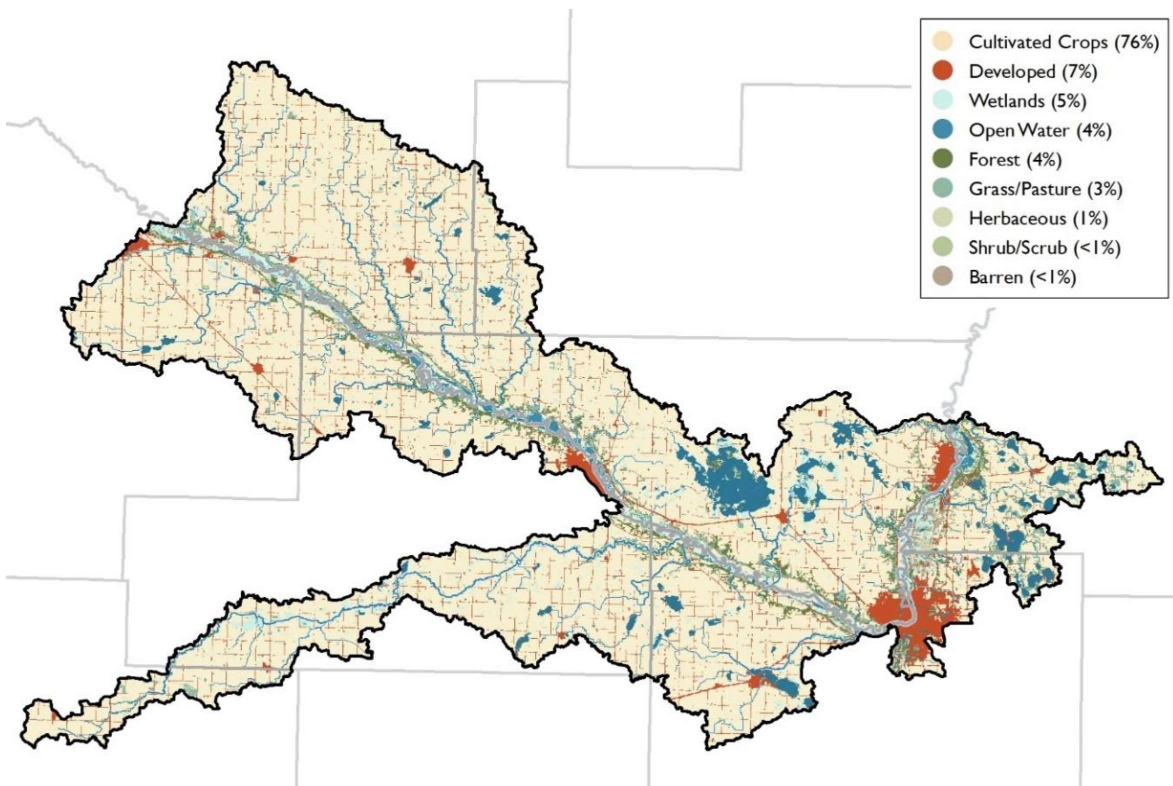


Figure 5: Land use in the Middle Minnesota River Watershed is dominated by cultivated crops. Breakdowns of land uses are shown in the figure key.

1.3 Assessing Water Quality

Assessing water quality is a complex process with many steps including: developing water quality standards, monitoring the water, ensuring the monitoring data set is comprehensive and accurately represents the water, and local professional review. A summary of process steps is included below.

Water Quality Standards

Water quality is not expected to be as clean as it would under undisturbed, "natural background" conditions. However, water bodies are expected to support designated uses (also known as beneficial uses) including: fishing (aquatic life), swimming (aquatic recreation), and eating fish (aquatic consumption). Water quality standards (MPCA 2015b; also referred to as "standards") are set after extensive review of data about the pollutant concentrations that support different beneficial uses and include natural background conditions.

Water Quality Assessment

To determine if water quality is supporting its designated use, data on the waterbody are compared to relevant standards. When pollutants/parameters in a waterbody do not meet the water quality standard, the waterbody is considered impaired (MPCA 2011a). When pollutants/parameters in a waterbody meet the standard (e.g. when the monitored water quality is cleaner than the water quality standard), the waterbody is considered supporting. If the monitoring data sample size is not robust enough to ensure that the data adequately represent the waterbody, or if monitoring results seem unclear regarding the condition of the waterbody, an assessment is delayed until further data are collected in the assessment cycle; this is referred to as inconclusive or insufficient findings.

Monitoring Plan

Data from three water quality monitoring programs enable water quality assessment and create a long-term data set to track progress towards water quality goals. These programs will continue to collect and analyze data in the Middle Minnesota River Watershed as part of *Minnesota's Water Quality Monitoring Strategy* (MPCA 2011b). Data needs are considered by each program and additional monitoring is implemented when deemed necessary and feasible. Combined, these programs collect data at dozens of locations around the watersheds (Figure 6). The parameters collected at each monitoring site can vary. Local partners collect additional data to supplement Minnesota Pollution Control Agency (MPCA) programs. These monitoring programs are summarized below:

Intensive Watershed Monitoring (IWM; MPCA 2012a) data provide a periodic but intensive "snapshot" of water quality conditions throughout the watershed. This program collects water chemistry and aquatic life (fish and aquatic macroinvertebrates, referred to simply as bugs for the remainder of the report) community data. Monitoring sites are generally selected to provide comprehensive coverage of watersheds at numerous stream and lake monitoring stations in one to two years, every ten years including citizen monitoring and pour point sites of HUC-10 watersheds. This work is scheduled to start its second iteration in the Middle Minnesota River Watershed in 2023.

Watershed Pollutant Load Monitoring Network (WPLMN; MPCA 2015c) data provide a continuous and long-term record of water quality conditions at the major watershed and subwatershed scale. This program collects pollutant samples and flow data to calculate continuous daily flow, sediment, and nutrient loads. In the Middle Minnesota River Watershed, there is one subwatershed site on the Little Cottonwood River and one subwatershed site on Seven Mile Creek.

[Citizen Stream and Lake Monitoring Program](#) (MPCA 2015d) data provide a continuous record of waterbody transparency. This program relies on a network of volunteers who make about monthly lake and river measurements. About a dozen volunteer-monitored locations exist in the Middle Minnesota River Watershed.

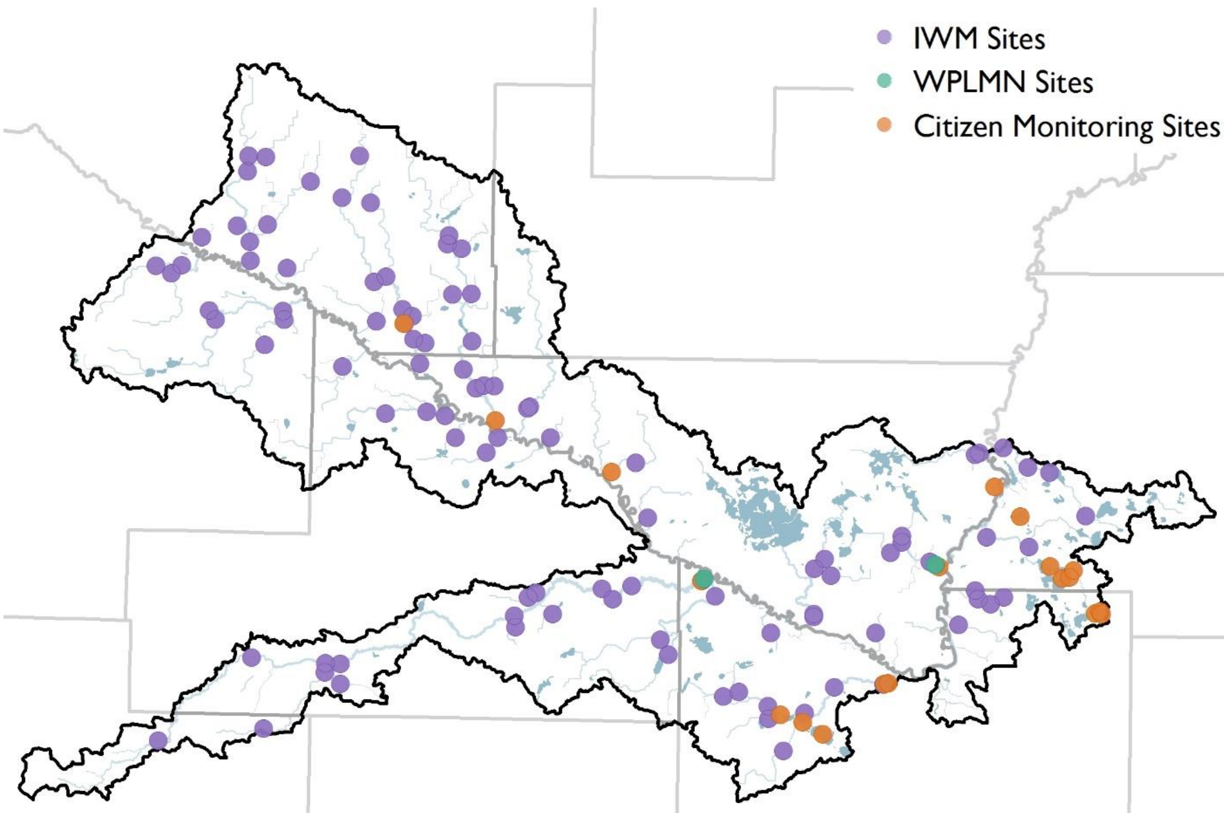


Figure 6: Many water chemistry and aquatic life monitoring sites are within the Middle Minnesota Watershed. The data collected by three different water quality monitoring programs are used to assess and track area-wide conditions.

Computer Modeling

With the Watershed Approach, monitoring for pollutants and stressors is generally extensive, but not every stream or lake can be monitored due to financial and logistical constraints. Computer modeling can extrapolate the known conditions of the watershed to areas with less monitoring data. Computer models, such as Hydrological Simulation Program – FORTRAN (HSPF [USGS 2014c]), represent complex natural phenomena with numeric estimates and equations of natural features and processes.

HSPF incorporates data including: stream pollutant monitoring, land use, weather, soil type, etc. to estimate flow, sediment, and nutrient conditions within the watershed. *Building a Picture of a Watershed* (MPCA 2014b) explains the model's uses and development. Information on the HSPF development, calibration, and validation in the Middle Minnesota River Watershed are available: *Middle Minnesota River HPSF Summary* (MPCA 2017a), *Model Resegmentation and Extension for Minnesota*

River Watershed Model (RESPEC 2014a), and "*Minnesota River Basin HSPF Model Hydrology Recalibration*" (Tetra Tech 2015).

HSPF model outputs provide a reasonable estimate of pollutant concentrations across watersheds and can be used for total maximum daily load (TMDL) calculations, prioritizing and targeting, and other efforts. However, these outputs are not used for impairment assessments since monitoring data are required for assessments. Modeled pollutant and stressor yields are presented in Appendix 4.3 and modeled landscape and practice changes (referred to as scenarios) are discussed in Section 3.1 and summarized in Appendix 4.4.

2 Water Quality Conditions

This section summarizes condition information including water quality data and the associated assessment (supporting, impaired, or inconclusive) of beneficial uses and parameters. Section 2 is broken into two subsections. The first part, Section 2.1, summarizes conditions/assessment by beneficial use, any identified water quality trends, an overview of pollutant/stressor sources, and a summary table of the goals and 10-year targets for the parameters affecting water quality. The second part, Section 2.2, looks at the individual parameters in more detail, including the status, sources, and goals for each parameter.

Refer to Appendix 4.1 for a table of all impairments, pollutants, and stressors by stream reach. More information on individual streams and lakes, including water quality data and trends, can be reviewed on the Environmental Data Application (MPCA 2015e).

This report covers only the tributaries to the Minnesota River in this watershed and only the beneficial uses of aquatic recreation and aquatic life. While the Minnesota River bisects the watershed, this large river is addressed in its entirety in a separate report The Minnesota River: Evaluating its health (MPCA 2017b) through the Large River Monitoring program (MPCA 2019a).

More information on the conditions of the Middle Minnesota River Watershed can be found at:

Minnesota River-Mankato Watershed Monitoring and Assessment Report (MPCA 2016b)

Minnesota River- Mankato Watershed Stressor ID Report (MPCA 2018d)

Minnesota River- Mankato Watershed Characterization Report (DNR 2016)

Watershed Health Assessment Framework (DNR 2013)

State-wide Mercury TMDL (MPCA 2015f)

Fish Consumption Advice (MDH 2013)

2.1 Conditions Overview

This section provides a general overview of watershed conditions and basic information to orient the reader to Section 2.2, where the status, sources, and goals are presented for each of the identified pollutants and stressors.

Status Overview

A breakdown of the total number of water bodies (monitored-dark blue and not monitored-light blue) and the assessment results (impaired-red, supporting-green, or inconclusive-yellow) by designated use (aquatic life and aquatic recreation) are presented in Figure 7.

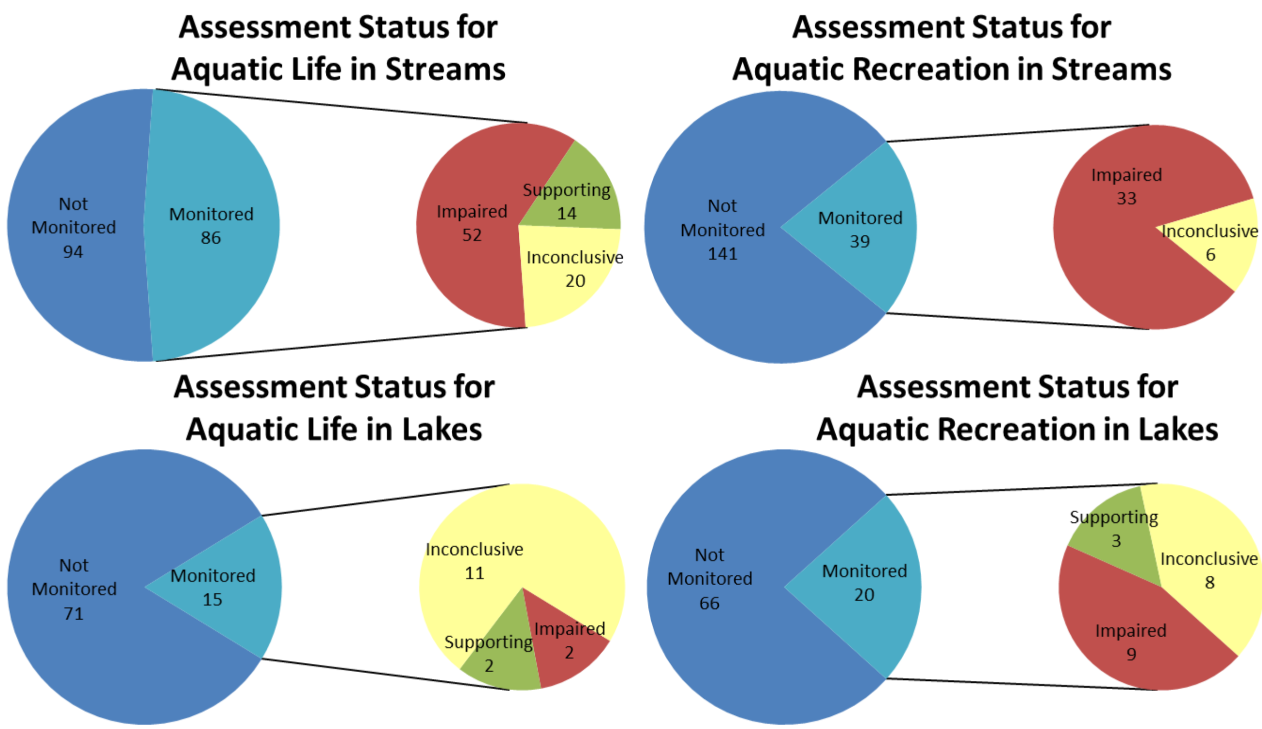


Figure 7: Beneficial Use Assessments for Streams and Lakes in the Middle Minnesota River Watershed

Many of the monitored stream reaches and lakes are impaired for aquatic recreation (swimming) and/or aquatic life (fish and bugs) as illustrated in Figure 8 (red). Fourteen assessed stream reaches fully support aquatic life, and no assessed stream reaches support aquatic recreation. Three assessed lakes support aquatic recreation (Figure 8, green) and two assessed lakes support aquatic life. Several stream reaches and lakes need more data to make a scientifically-conclusive finding (Figure 8, yellow). The specific parameters that are causing the impairments are identified in Section 2.2.

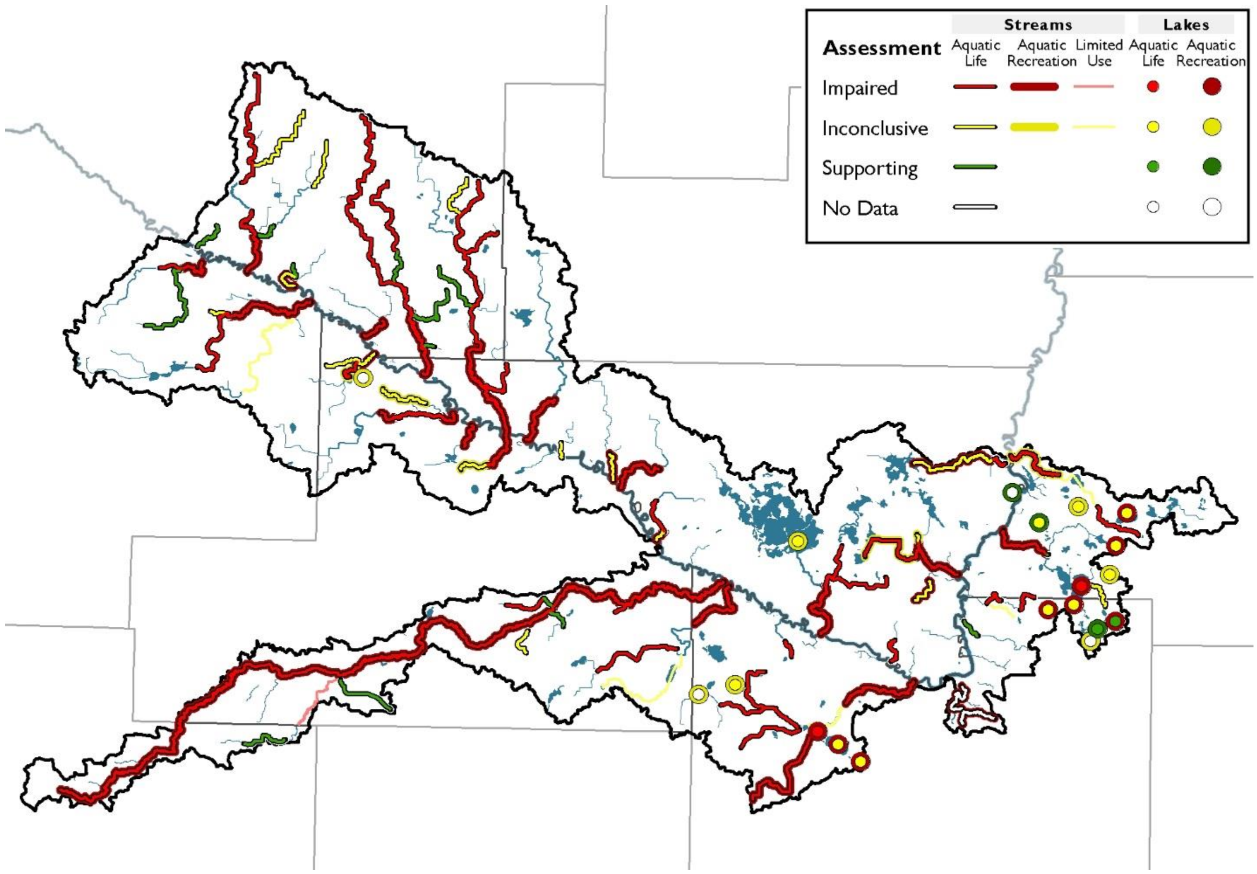


Figure 8: Impairments (shades of red) of aquatic life and aquatic recreation beneficial uses dominate the monitored streams across the Middle Minnesota River Watershed. Just a handful of stream reaches are supporting (shades of green) these beneficial uses. Similarly, many of the monitored lakes in the watershed are impaired (shades of red), but many lakes need more data to make an assessment. In this image, the inside line color indicates the aquatic life assessment and the outside line color indicates the aquatic recreation assessment. Lake assessment results are indicated by circles, where the inside circle color indicates aquatic life assessment and the outside circle color indicates the aquatic recreation assessment.

Several stream reaches with an aquatic life impairment were impaired due to low or imbalanced fish or bug populations, which are referred to as "bio-impaired". The causes, or "stressors", of these bio-impairments were identified in the Stressor Identification (SID) report. Pollutants and bio-impairments are identified in the monitoring and assessment report. The reader should reference those reports for additional details. The identified stressors were: high phosphorus causing eutrophication, high nitrates, lack of habitat, low dissolved oxygen (DO), high turbidity, lack of connectivity, high temperature, and altered hydrology. Each of these stressors along with the identified pollutants are discussed in Section 2.2.

Trends Overview

A substantial amount of land use and practice change has occurred (farming practices, human populations, etc.) that has caused changes in water quality over time. Trends observed in the Minnesota River Basin are discussed in the *Minnesota River Basin Trends Report* (MSU 2009).

Statistical trends in stream and lake water quality can be difficult to identify because substantial data sets are required for trend analysis. Furthermore, year-to-year climatic variability can obscure gradual trends. Even with these challenges, statistical trends in pollutant concentrations were identified in Seven Mile Creek. Data were analyzed for trends in Seven Mile Creek and Little Cottonwood River using the Seasonal Kendall test (Table 1). The Little Cottonwood River showed no long trend in stream flow, total phosphorus (TP), nitrite/nitrate (NO_2/NO_3), and total suspended solids (TSS). Seven Mile Creek showed no trend in stream flow and increasing trends in TP, nitrite/nitrate (NO_2/NO_3), and TSS.

Table 1: Stream pollutant trends in the Middle Minnesota River Watershed show mixed results for the Little Cottonwood River and Seven Mile Creek. Loading and stream flow for the Little Cottonwood River shows no trend. Seven Mile Creek shows no trend in stream flow, but increasing trends in loading of TSS, TP and NO_2/NO_3.

Stream	Years with Data	Trend in Data			
		Flow	TSS	TP	NO_2/NO_3
Little Cottonwood River	1974-2016	No Trend	No Trend	No Trend	No Trend
Seven Mile Creek	2007-2016	No Trend	Degrading	Degrading	Degrading

Transparency trends were calculated for several lakes in the watershed (Table 2). The statistical analysis method used provides a minimum, median, maximum likely trend in feet per decade based on the years with data. Ballantyne, Crystal, Emily, and Washington Lakes have improving trends while Duck, Hallett, and Scotch Lakes showed a declining trend. Lakes not listed in the table did not have sufficient data to calculate a trend.

Table 2: Lake transparency trends in the Middle Minnesota River Watershed (of lakes with adequate data to assess trends) show mixed results; four lakes show improving trends, and three lakes show declining trends.

Lake	Years with data	Transparency Trend (ft/decade)		
		Minimun	Median	Maximum
Ballantyne	1985-2001, 2013-2016	0	0.21	0.73
Crystal	2006-2016	-0.01	0.19	0.72
Duck	1988-2016	-0.25	-0.49	-0.76
Emily	1995-2016	0	0.27	0.62
Hallett	1998-2016	-2.11	-3.56	-5.44
Scotch	2000-2014	-0.08	-1.61	-4.9
Washington	1985-2016	0.05	0.27	0.51

Sources Overview

This section orients readers to the array of sources of pollutants and stressors in the Middle Minnesota River Watershed. Sources of pollutants and stressors can be grouped into either point sources (NOAA 2008), which discharge directly from a discrete point, and nonpoint sources (EPA 2018), which is runoff and drainage from diffuse areas. Examples of point sources are wastewater plants and industries, and examples of nonpoint sources are farm drainage and some city runoff. Generally, point sources are regulated to ensure any discharge supports water quality standards, while nonpoint sources are generally not- or minimally regulated.

Within Section 2.2 a detailed source assessment will be presented for each pollutant and stressor. These source assessments were developed after analyzing multiple lines of evidence (see Appendix 4.2). These lines of evidence include state and basin-level reports, model studies, TMDLs, and field-scale and watershed data. The WRAPS Local Work Group was asked to review and use this information, applying their professional judgement and local knowledge, to ensure source assessments reflected recent conditions in the Middle Minnesota River Watershed. The Watershed Approach starts a new iteration every 10 years, each time striving for more refined and widespread analysis. Therefore, source assessments will be revisited and revised with each iteration to ensure that new data and science are incorporated.

Point Sources

Point sources that discharge are regulated through National Pollutant Discharge Elimination System (NPDES; EPA 2014a). Depending on the type of point source, regulatory requirements vary. Some point sources are not allowed to discharge; some are allowed to discharge but must treat wastewater and measure levels of discharged pollutants; and some are allowed to discharge under special circumstances, or required to use BMPs to reduce pollutants.

Municipal and Industrial Wastewater

Municipal and industrial wastewater point sources have discharge and monitoring requirements specified in the facility permits to ensure pollutant levels in their discharge support water quality goals. Facilities within the Middle Minnesota River Watershed are listed in Table 3 and Table 4. Because these systems often require monitoring, their total contributions can be calculated. The estimated contributions of these facilities to the watershed's total pollutant loads between 2011 and 2015 are: 2% of nitrogen, 4% of phosphorus, and <0.1% of sediment (see data and calculations in Appendix 4.2).

Table 3: Sixteen municipal wastewater treatment plants (WWTPs) have NPDES permits to discharge into the Middle Minnesota River Watershed.

Municipal Facilities	County
Lake Crystal WWTP	Blue Earth
Mankato Water RRF	Blue Earth
Comfrey WWTP	Brown
Evan WWTP	Brown
Hanska WWTP	Brown
New Ulm WWTP	Brown
Searles WWTP	Brown
Jeffers WWTP	Cottonwood

Municipal Facilities	County
Cleveland WWTP	Le Sueur
Nicollet WWTP	Nicollet
Saint George DSS	Nicollet
Saint Peter	Nicollet
Morgan WWTP	Redwood
Fairfax WWTP	Renville
Franklin WWTP	Renville
Morton WWTP	Renville

Table 4: Twenty-nine industries have NPDES permits to discharge into the Middle Minnesota River Watershed.

Industrial Facilities	County
ADM - Mankato	Blue Earth
Cemstone Products Co	Blue Earth
Hoffman Construction - Cambria Pit	Blue Earth
Jordan Sands LLC	Blue Earth
Minnesota Quarries dba Mankato Kasota Stone	Blue Earth
POET Biorefining - Lake Crystal LLC	Blue Earth
WW Blacktopping Inc	Blue Earth
Xcel Energy - Key City/Wilmarth	Blue Earth
OMG Midwest Inc/Southern MN Construction Co Inc	Blue Earth, Brown, Cottonwood
Blue Earth County Highway Department	Blue Earth, LeSueur
Vetter Stone Co	Blue Earth, LeSueur
Rehnelt Excavating LLC	Blue Earth, Nicollet
Firmenich Inc	Brown
Northern Con-Agg LLP - Frohrip Kaolin Mine	Brown

Industrial Facilities	County
Mathiowetz Construction Co	Brown, Nicollet
MR Paving/Valley Asphalt Products	Brown, Nicollet
Unimin Corp - Kasota Mining Project	Le Sueur
Unimin Corp - Ottawa Plant	Le Sueur
Courtland WTP	Nicollet
Geldner Brothers Sand & Gravel LLC	Nicollet
Ground Zero Services LLC	Nicollet
Hancock Concrete Products LLC	Nicollet
Jansen-Hard Rock Quarries Inc	Nicollet
Old Castle Materials/New Ulm Quartzite Quarry	Nicollet
Shafer Contracting Co Inc	Nicollet
Duininck Inc	Redwood
Northern Con-Agg LLP - Redwood Falls	Redwood
Cold Spring Granite Co	Renville
Gordy Serbus & Sons Gravel LLC	Renville

While the impact of these point sources on the total pollutant loads are minimal, they can be substantial sources at times of low flow. Refer to the TMDLs (links provided in Goals & Targets Overview section) for more information on the impact of point sources on impaired reaches. Four other facilities have NPDES permits but are not allowed to discharge to surface waters and are listed in Appendix 4.2.

Urban, Construction, and Industrial Stormwater

Large urban areas are regulated under the Municipal Separate Storm Sewer System (MS4; MPCA 2014e) program, which requires the use of BMPs to reduce pollutants. 3.7% of the Middle Minnesota River Watershed is an MS4, including areas in and adjacent to the cities of Mankato, St. Peter, New Ulm, and Redwood Falls.

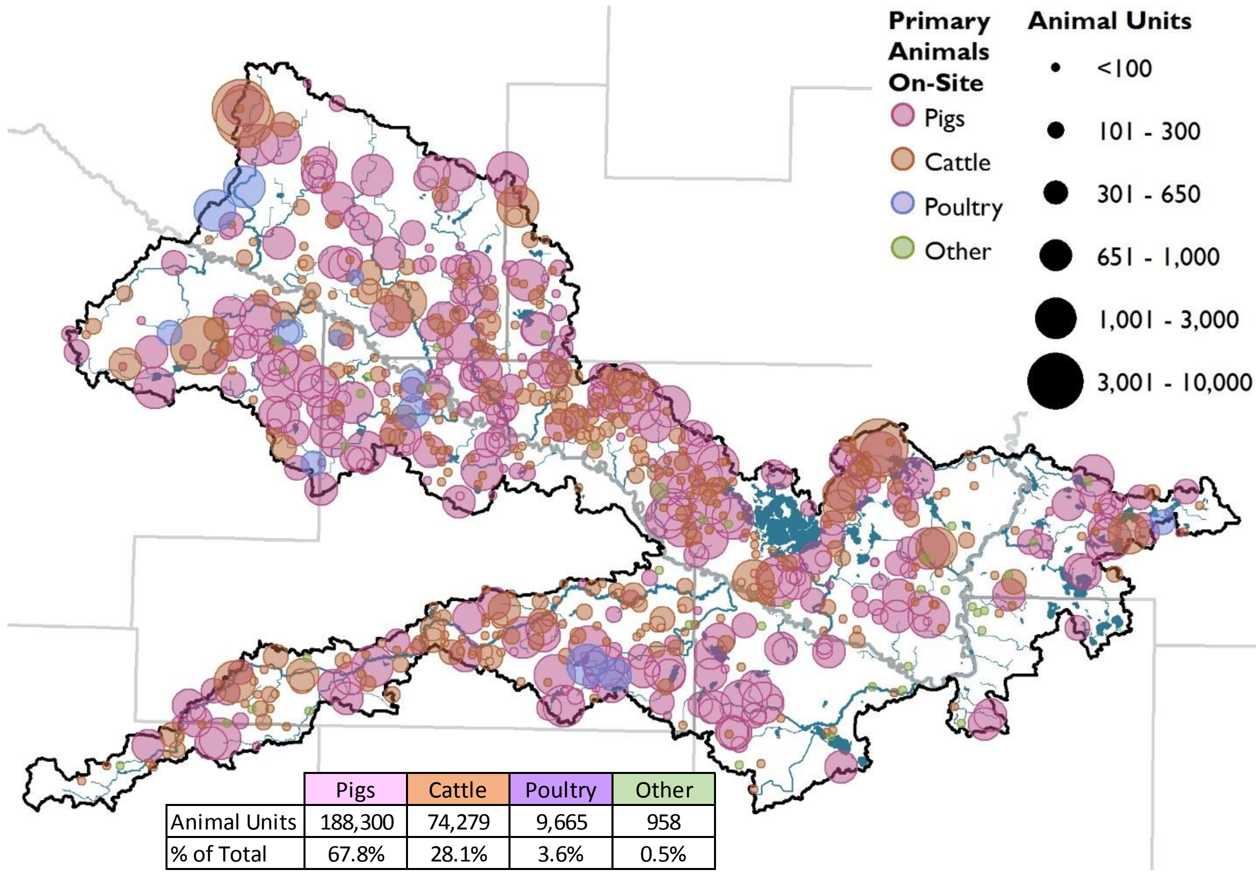
Construction projects disturbing more than one acre require an NPDES permit. These projects are required to use BMPs to reduce pollutant runoff. County estimates for construction stormwater areas indicate less than 1% of the Middle Minnesota River Watershed land area is impacted by construction projects at any given time.

Similar to large urban areas and large construction projects, industrial stormwater (MPCA 2019c) is regulated through the NPDES program. Industrial facilities must have either no discharge or manage discharge with sufficient BMPs to protect water quality.

CAFO Feedlots

Feedlots (MPCA 2017c) are animal operations (either open lots or buildings) used in intensive animal farming where manure accumulates and vegetative cover cannot be maintained. Manure contains high levels of bacteria and nutrients, and therefore, feedlot and manure management have a potential to impact water quality. Large feedlots are regulated as point sources and discussed here. Other animal operations and land-applied feedlot manure are considered nonpoint sources and discussed in the nonpoint source section below.

In total, 273,000 animal units (AUs; see feedlots link above for conversions of animal types to AUs) in 596 feedlots are located within the Middle Minnesota River Watershed (Figure 9). On average, this translates to roughly 330 AUs per 1,000 acres. 146,000 (53%) AUs reside in 106 CAFOs, which are regulated as point sources (list available in the Minnesota River- Mankato Watershed TMDL).



	Pigs	Cattle	Poultry	Other
Animal Units	188,300	74,279	9,665	958
% of Total	67.8%	28.1%	3.6%	0.5%

Figure 9: About 273,000 AUs are registered within the Middle Minnesota River watershed in 793 feedlots. Swine (pigs) make up more than two-thirds of the total registered AUs in the watershed.

NPDES permits are required for facilities that meet the definition of a Large CAFO (EPA 2015a) and have discharged. Either a State Disposal System (SDS) or NPDES permit is required by state rule for feedlots with 1,000 AUs or more. Having and complying with an NPDES permit allows some enforcement protection if a facility discharges due to a 25-year, 24 hour precipitation event (approximately 5.3" in 24 hours) and the discharge does not contribute to a water quality impairment. Large CAFOs permitted with an SDS permit or those not covered by a permit must contain all runoff, regardless of the precipitation event. Therefore, many Large CAFOs in Minnesota have chosen to have an NPDES permit, even if discharges have not occurred in the past at the facility.

Nonpoint Sources

Nonpoint sources of pollutants/stressors are products of land use and how well human impacts are managed/mitigated with BMPs. Nonpoint sources of pollutants/stressors typically travel from the land into the waterbody in response to precipitation. Once the area where precipitation falls cannot hold more water, water and the pollutants/stressors it carries will move via surface runoff, artificial drainage networks, or groundwater pathways to streams and lakes. The pollutants/stressors can be of natural origin (like tree leaves breaking down), human-accelerated natural origin (like excessive streambank erosion from altered hydrology), or of human origin (like fertilizer and manure applied on fields and lawns).

Farm and City Runoff

Typically, highly manipulated land uses contribute higher levels of pollutants/stressors compared to more naturalized areas. Grasslands and forests tend to have lower contributions of pollutants/stressors, while highly-manipulated, not-adequately-managed/mitigated areas such as some cultivated crops, urban developments, and over-grazed pastures tend to have higher contributions of pollutants/stressors. One example of this was tested and documented by the MDA (2016), who found much larger exports of nutrients, sediment, and water runoff on a corn plot compared to a prairie plot. Furthermore, when land uses such as cultivated crops do not adhere to conservation recommendations (for instance the over application of fertilizer/manure as documented in the *Commercial Nitrogen and Manure Fertilizer… Management Practices* [MDA 2014]), contributions of pollutants and stressors can be further accelerated. The Middle Minnesota River Watershed is dominated by cultivated crop production (refer to land use back in background section), which has a large potential impact on water quality.

While highly-manipulated (urban and agricultural) land often does contribute higher levels of pollutants/stressors, the impacts can be reduced by adequately managing/mitigating with sufficient BMPs. For instance, a farm that incorporates nutrient management practices, conservation tillage, cover crops, grassed waterways, and buffers will contribute substantially less pollutants/stressors than if those BMPs were not used. Likewise, a city stormwater system can be designed and built to contain a substantial amount of runoff (up to the design event, like a 1.25 inch rainfall event).

While some agricultural and urban runoff has been reduced using sufficient BMPs, substantial additional BMPs need to be adopted to achieve clean water. The new MPCA Healthier Watersheds Accountability Report (MPCA 2018a) shows that 1,616 BMPs have been installed in the Middle Minnesota River Watershed since 2004. The Agricultural Water Quality Certification Program (MDA 2019) has certified 13 producers on 6,236 acres (<1%). These farms are certified by MDA that impacts to water quality are adequately managed/mitigated. While these producers and others have incorporated sufficient BMPs to protect water quality, much of the cultivated crops, pastures, urban development, and residential landscape are not adequately managed/mitigated with BMPs.

Subsurface Drainage

Surface runoff is not the only pathway that transports pollutants/stressors to water bodies. Subsurface tile drainage systems, which are typically designed to drain water from fields within a couple days of a precipitation event, also have the potential to carry and deliver pollutants and stressors to surface waters. With recent crop and yield changes, the application and density of subsurface drainage tile has grown. Based on a Geographic Information System (GIS) analysis, between 28% to 63% of the Middle Minnesota River Watershed's area is tile drained (Figure 10).

Tile drainage has been identified as a primary cause of stream flow changes in heavily-tiled landscapes. Several research papers found that roughly 60% or more of increases in stream flow between mid and late-20th century in heavily-tiled areas of the Midwest and Southern Minnesota are due to agricultural drainage changes: *Twentieth Century Agricultural Drainage Creates More Erosive Rivers* (Schottler et al. 2013), Temporal Changes in Stream Flow and Attribution of Changes… (Gyawali, Greb, and Block 2015), and Quantifying the Relative Contribution of the Climate and Direct Human Impacts… (Wang and Hejazi 2011). The rest of the increase in stream flow is attributed to crop and climate changes.

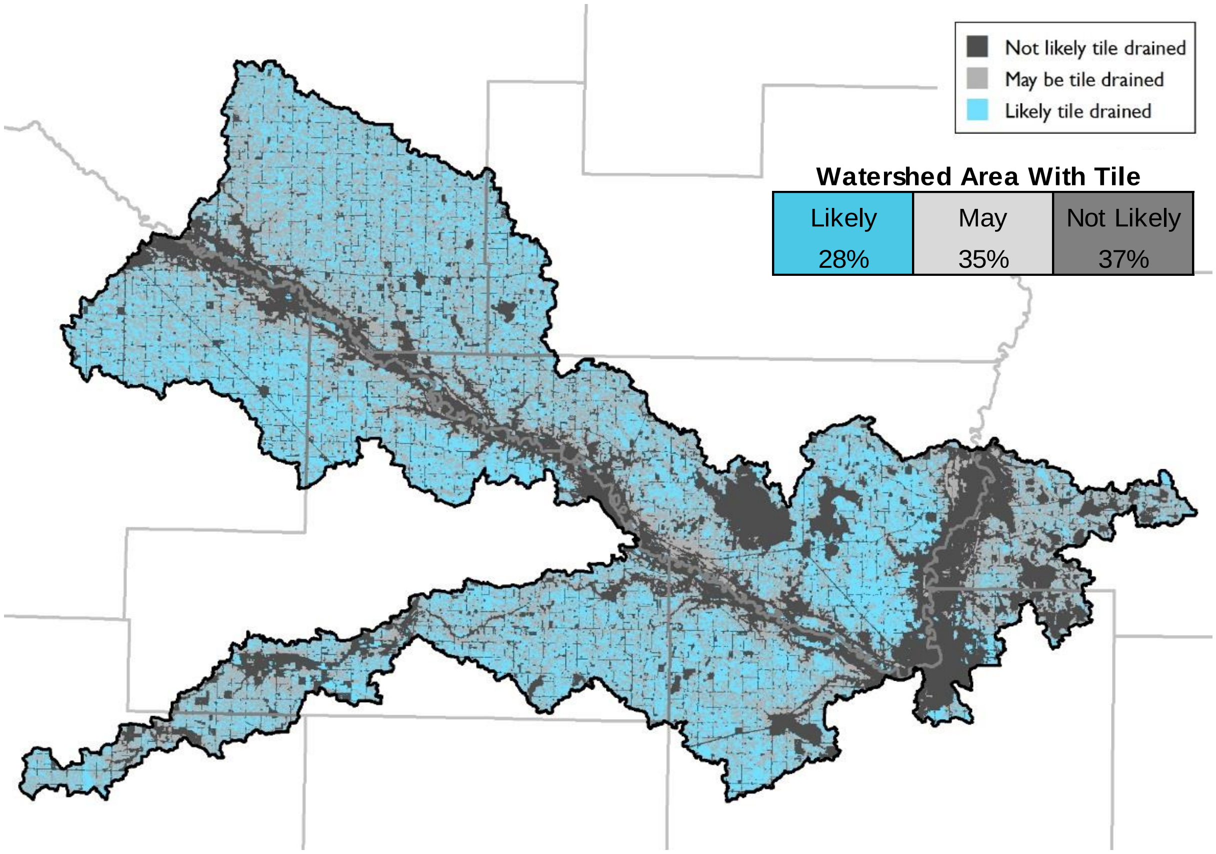


Figure 10: A large portion of agricultural lands within the Middle Minnesota Watershed is tile drained. This analysis focused on cultivated land and was not designed to identify tile drainage within urban and non-cultivated areas.

While agricultural and urban drainage can negatively impact water resources, the historical perspective and agricultural and infrastructural benefits of drainage are important to recognize. European settlers drained wetlands to settle and farm lands. For decades, the government further encouraged drainage to reduce pests, increase farmable lands, and clear lands for roads and infrastructure. Today, drainage is still encouraged by some agricultural interests to increase crop production. Overall, drainage is sometimes necessary for crop production and other land uses including urban development; however, drainage impacts can be better managed/mitigated to reduce impacts to water bodies.

Other Feedlots, Manure Application, and Pastures

Only the largest feedlots are regulated as point sources (discussed in section above). 128,000 (47%) AUs in 490 feedlots are not regulated as point sources (feedlots not meeting Large CAFO criteria). However, these facilities are still regulated and may only have discharge/runoff that meets a maximum pollutant concentration (using a designated estimation tool). Small animal operations (<10 AUs in shoreland or <50 AUs elsewhere) are not considered feedlots and are not regulated. AU counts associated with the non-regulated operations are not available but can be presumed to be relatively small.

Feedlots within close proximity to water bodies (referred to as shoreland) may pose a disproportionately high risk to water quality if runoff is not prevented or treated. In the Middle Minnesota River

Watershed, 11,000 (4%) AUs in 83 feedlots are near shoreland, none of which are CAFOs. Of these, 5,800 AUs (2%) in 67 feedlots have access to open lots, where manure can run off without adequate runoff controls.

Because most feedlots are regulated to have minimal runoff, the largest water quality risk associated with feedlots is from the land-applied manure. Like other types of fertilizer application, the location, method, rate, and timing of manure application are important considerations to estimate the impact and likelihood of runoff. Most feedlots are required to keep manure application records. CAFOs are required to submit their manure records annually, but records are infrequently requested from smaller feedlots. However, some inferences can be made based on the animal statistics as discussed below. Additional interpretation is offered in Appendix 4.2.

Manure that is injected versus surface-applied is generally considered less likely to produce runoff. Manure from roughly 66% of the AUs in the watershed is likely injected and incorporated manure (swine manure for facilities with more than 300 AUs - roughly 66% of the AUs in the Middle Minnesota River Watershed). 31% of the AUs in the watershed are cattle and poultry. This manure is generally handled as solid manure and may not be immediately incorporated.

While the percent of land in grass and pasture is only 3%, often, pastures are located directly adjacent to water bodies and therefore can disproportionately impact water bodies if not properly managed. Perennial vegetation, like that of pasture, typically provides an overall benefit to water quality compared to inadequately managed/mitigated urban and cultivated cropland uses. However, when pasture is overgrazed (indicated by too little vegetation), especially adjacent to a waterbody, these areas can be sources of pollutants/stressors. Furthermore, when cattle access streams, the delicate streambank habitat is trampled, the stream geomorphology (DNR 2017) is negatively impacted, and streambank erosion is accelerated.

Septic Systems and Unsewered Communities

Well-functioning individual and small community wastewater treatment systems generally pose little risk to waters. When these systems fail or do not offer ample treatment, these systems can pose a risk to water quality.

Based on the estimates provided by counties, there are between one and five failing septic systems (subsurface treatment systems, SSTS) per 1,000 acres in the Middle Minnesota River Watershed (Figure 11). At this concentration, failing septic systems are unlikely to contribute substantial amounts of pollutants/stressors to the total annual load. However, the impacts of failing SSTS on water quality may be pronounced in areas with high concentrations of failing SSTS or at times of low precipitation and/or flow. In the

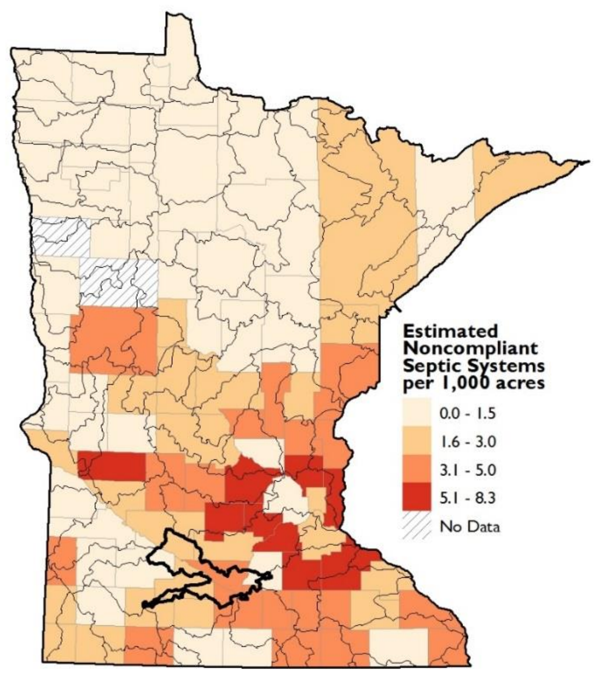


Figure 11: The Middle Minnesota River Watershed has an estimated average of one to five failing septic systems per 1,000 acres.

Middle Minnesota River Watershed, most of the lakes with a high density of shoreland development are now served by a sewer district, eliminating the risk of failing systems to those lakes.

Unsewered or undersewered communities (MPCA 2019d) are clusters of five or more homes or businesses on small lots where individual or small community systems do not provide sufficient sewage treatment (including straight pipes). Many of these have been upgraded, but a handful of unsewered or undersewered areas still exist in the Middle Minnesota River Watershed.

High Risk Areas

While some highly manipulated land uses can adequately manage pollutant contributions by adopting sufficient BMPs, some areas within a landscape are particularly sensitive from a water quality perspective. For instance, the area or buffer around water bodies is particularly sensitive. Crops or lawn turf directly adjacent to a stream or lake can cause more pollutants/stressors to enter water bodies, accelerate erosion, and destroy sensitive habitat. On the contrary, a high quality, naturalized vegetative buffer adjacent to a waterbody can help capture pollutants/stressors, stabilize the streambank, and provide habitat to sensitive aquatic species.

Historical Changes

Understanding landscape conditions prior and subsequent to European settlement provides context for today's water quality conditions and pollutant sources. The landscape in the Middle Minnesota River Watershed has been highly manipulated since European settlement. Figure 12 compares the estimated streams, lakes, and wetlands of pre-European settlement to those of today. In 1855, the Middle Minnesota River Watershed was predominately covered by prairie and speckled with prairie potholes (EPA 2015b). These potholes and the rich, healthy, prairie soils provided water storage, nutrient recycling, and superior erosion protection across the landscape.

Grasslands and wetlands provided water storage and kept most precipitation on the landscape to be evapotranspirated or to recharge groundwater and resulted in relatively fewer streams. Today, most of the grasslands have been converted to crops and cities, streams have been ditched or straightened, ditches have been added to the landscape, and prairie potholes have been drained or highly altered. The drainage networks that replaced prairies and wetlands have created a "short-circuit" in hydrologic conditions and accelerated the delivery of pollutants to water bodies.

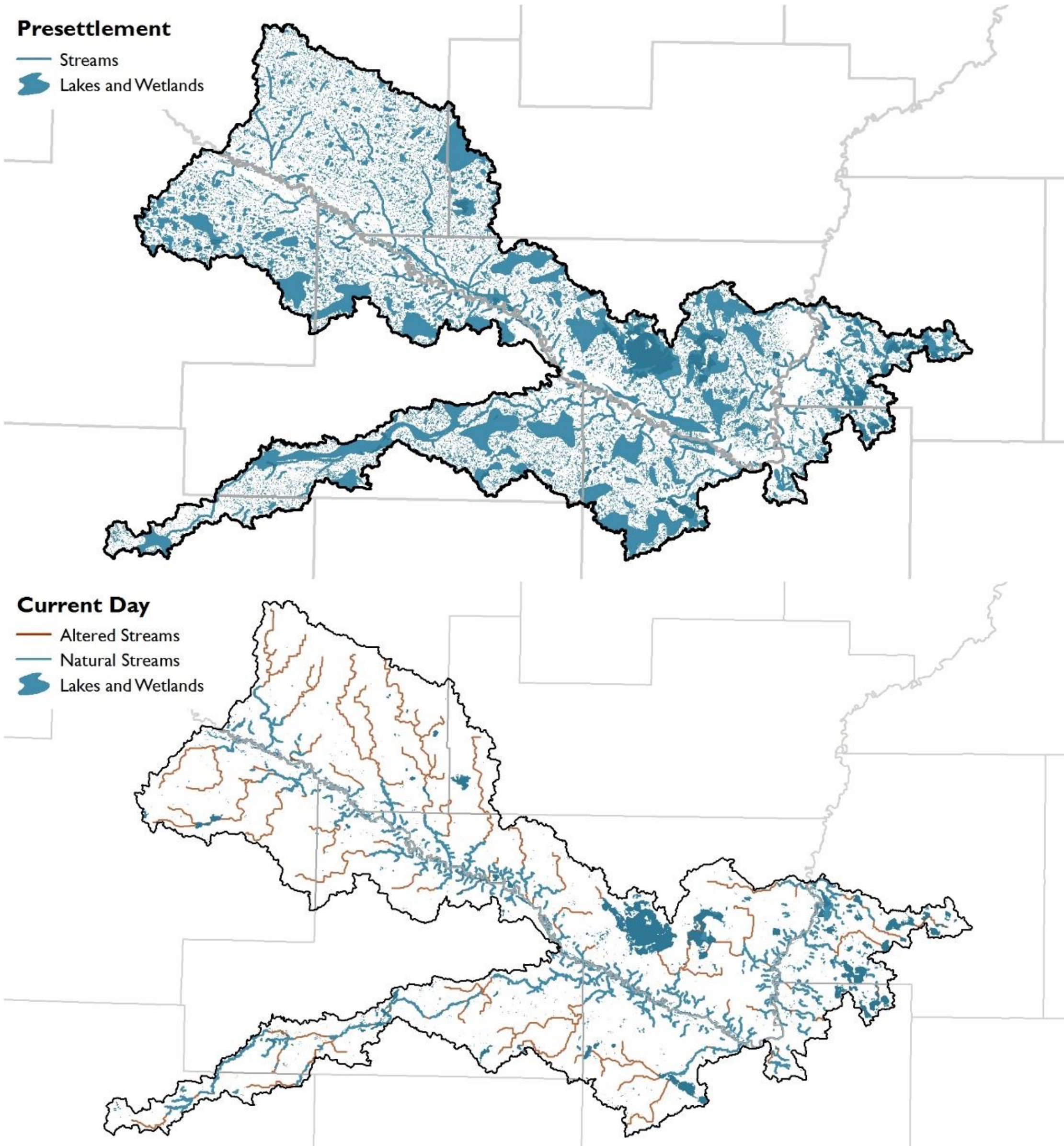


Figure 12: The areas covered by wetlands, lakes, and streams have changed substantially between the mid-19th century and today. The Middle Minnesota River Watershed likely had substantial amounts of wetlands to hold, infiltrate, and evapotranspirate water. Today, roughly 65% of the total stream miles in the Middle Minnesota River Watershed have been straightened (ditched) or otherwise altered. This image is for illustrative purposes only. See Appendix 4.2 for data sources.

Since European settlement, the diversity of vegetation and crops on the landscape has continued to decline. Grasslands were replaced by diverse crops and cities. Then during the mid- to late-20th century, the diverse crops - including substantial amounts of small grains and hay - were replaced by a dominance of corn and soybeans (Figure 13). The changes in land use and crops have resulted in impacts to hydrology: less evapotranspiration (ET) in spring and more ET in mid-summer (Figure 14), resulting in more precipitation entering rivers in spring and less entering in mid-summer.

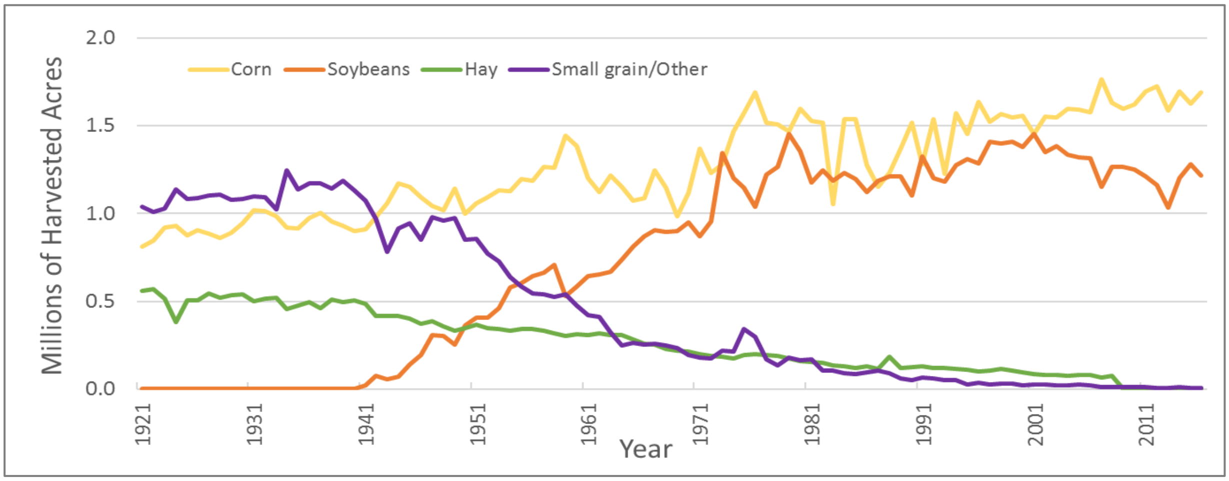


Figure 13: The harvested acres of corn, soybeans, hay, and small grains in the South Central agricultural region of Minnesota illustrate how small grains and hay were replaced through time by soybeans and corn in the Middle Minnesota River Watershed.

Goals & Targets Overview

Water quality goals for the Middle Minnesota River Watershed (Table 5) are intended to help both waterbodies within and downstream of the watershed meet water quality standards and other goals (e.g. Gulf Hypoxia and Lake Pepin goals). These goals were set after analyzing TMDL studies, state-wide reduction goals, WPLMN data, and HSPF model output. The TMDL studies include: the Middle Minnesota River Watershed TMDL produced as part of the Watershed Approach (produced concurrently

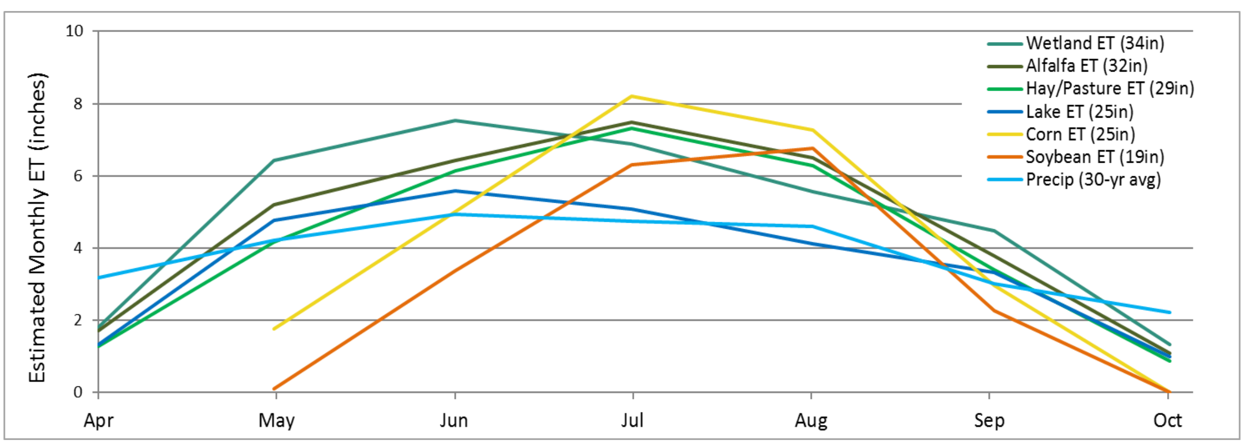


Figure 14: Since European settlement, prairies and wetlands were replaced first by diverse crops and then by corn and soybeans. The total annual ET rates (indicated in the figure legend) of these replacement crops are smaller and the timing of ET through the year has shifted. These changes affect the hydrology of the watershed. See Appendix 4.1 for data sources and calculations.

with this WRAPS report; see the MPCA Middle Minnesota River Watershed webpage [MPCA 2019b]), *Crystal Lake TMDL Study Excess Nutrients* (MPCA 2008) and *Minnesota River and Greater Blue Earth River Basin Total Suspended Solids Total Maximum Daily Load Study* (published concurrently with this WRAPS report; see Minnesota River and Greater Blue Earth River Basin TMDL for TSS website [MPCA 2018e]).

The specific goal for every lake and stream reach is to meet water quality standards for all relevant parameters and to support downstream water quality goals. However, in order to more understandably communicate water quality goals and to make the identification of strategies and adoption rates more straight-forward, the multiple levels of goals were integrated into one average or “surrogate” watershed-wide goal for the major watershed. Likewise, because water quality standards do not include a specific method to calculate a reduction, surrogate goals for individual streams and lakes were calculated from TMDL data. A summary of the WRAPS report calculation methods and results is in Appendix 4.3.

For parameters that are the effect of other pollutants/stressors (Fish-Index of Biotic Integrity (IBI), Macroinvertebrate IBI, DO, eutrophication, and temperature), a numeric goal for the identified pollutants/stressors was estimated. For instance, in the case of bio-impaired streams (where the aquatic life impairment was due to a low fish or bug IBI score), the goal is to have the fish and/or bug populations meet thresholds. However, there is not a tool or model available to estimate the magnitude or change needed to meet this threshold. Therefore, numeric goals for the stressors causing the bio-impairments (altered hydrology, sediment, nitrogen, etc.) are the surrogate goal.

Within Section 2.2, goals for each pollutant and stressor are illustrated in a “goals map”. The subwatershed area of each waterbody is colored according to its goal: the darker the gray shading, the larger the reduction goal. White indicates areas in need of protection. Stream reaches supporting healthy fish and bugs communities are illustrated in lime green, and the associated subwatersheds are indicated by hash marks. The watershed-wide goal underlays subwatershed goals. The watershed-wide goal is also the default goal for any area that does not have sufficient data to calculate an individual subwatershed goal.

Interim water quality “10-year targets” were selected via average consensus by the WRAPS Feedback Group, and allow opportunities to adaptively manage implementation efforts.

With each iteration of the Watershed Approach, progress will be measured, goals will be reassessed, and new 10-year targets will be set. Future efforts should consider changes in waterbody conditions reflected by new data or due to changes in standards, state-wide goals, and calculation methods.

Table 5: Watershed-wide and subwatershed goals were selected after analyzing water quality data within the watershed. The "10-year Target" and "Years to Reach Goal" were set using an averaging consensus of WRAPS Feedback Group proposals. Refer to the narrative above and to the Goal & 10-year Target subsections in the following report sections for more information.

Parameters (Pollutant/ Stressors)	**Watershed-Wide Goal** (Average for Watershed)	**Range of Subwatershed Goals** (Estimated only when TMDL data are available)	**10-year Target** (for 2029)	**Years to Reach Goal** (from 2019)
Altered Hydrology	25% reduction in peak & annual river flow	not estimated (TMDLs not completed on this parameter)	5%	50
	increase dry season river base flow where ID'd in SID by enough to support aquatic life		increase	30
Nitrogen	60% reduction in river concentrations/loads	protect up to a 78% reduction	10%	55
Habitat	25% increase in MSHA habitat score	protect up to a 181% increase	9%	35
Phosphorus	50% reduction in lake and stream concentrations/loads	protect up to a 83% reduction	10%	50
Sediment	50% reduction in restoration areas (1/4 of watershed) No increase in protection areas (3/4 of watershed)	protect up to a 88% reduction	12%	40
Bacteria	60% reduction in river concentrations/loads	10% to 87% reduction	13%	40
Connectivity	Address human-caused issues (dams, culverts) as identified in SID and where practical/feasible	not estimated (TMDLs not completed on this parameter)	9%	45
Parameters that are impacted/addressed by the above pollutants and stressors				
F-IBI & M-IBI	Each paramter's goal is to meet the water quality standard and support downstream goals. Because these parameters are a response to (caused by) the above pollutants/stressors, the above watershed-wide and subwatershed goals are indirect goals for these parameters and are more usable for selecting strategies than direct goals for these parameters.	not estimated (TMDLs not completed on these parameters)	meet other 10-year targets	45
Eutrophication				50
DO				45
Temperature				45

2.2 Identified Pollutants and Stressors

This section looks at each of the identified pollutants and stressors in detail, describing and illustrating:

- the streams and lakes known to be impaired or stressed by the pollutant/stressor
- a detailed source assessment
- estimated reductions necessary to meet water quality goals in and downstream of the Middle Minnesota River Watershed
- priority areas based on estimated reductions, areas of protection, and model output

The difference between a pollutant and a stressor and a brief summary of how pollutants and stressors are identified is illustrated in Figure 15. Refer to Section 1.3, the Monitoring and Assessment Report, and Stressor ID Reports for more information.

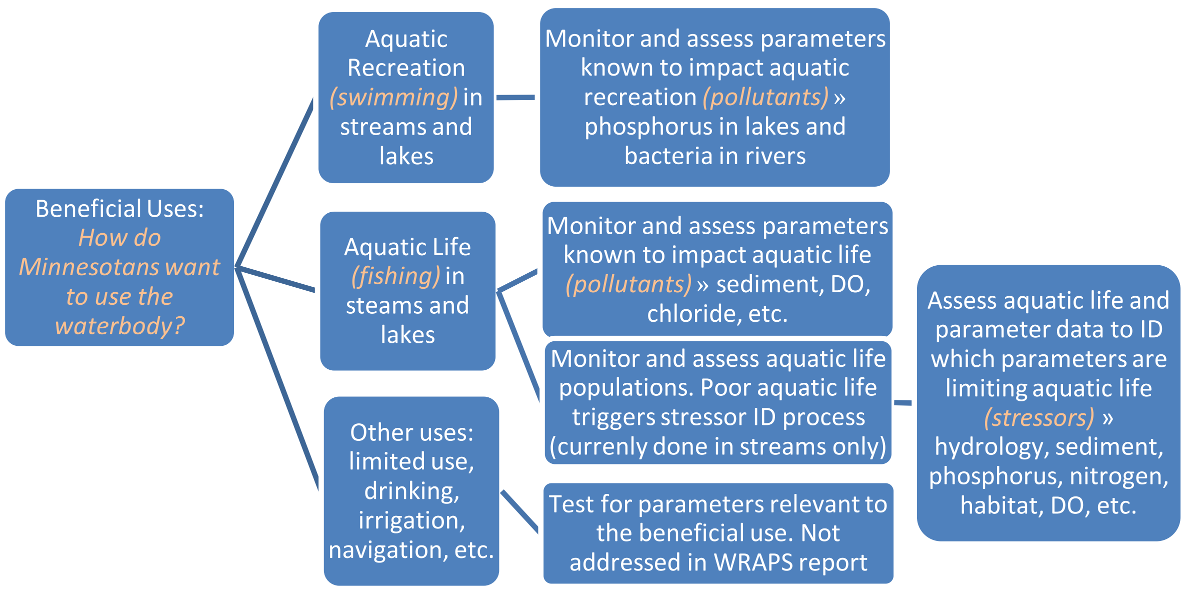


Figure 15: Pollutants and stressors are identified through different processes. Pollutants are parameters that are tested for directly, and the level of the parameter can be compared directly to a pre-developed numeric water quality standard. Stressors are parameters that are assessed only when aquatic life populations are monitored and assessed and found to be low or imbalanced (using the IBI score). Then, the stressor identification process is triggered to determine which parameters are impacting the aquatic life populations. Both pollutants and stressors must be addressed to restore and protect water quality beneficial uses like swimming and fishing.

Often times, pollutants and stressors can be complex and interconnected. Furthermore, an identified stressor can be more of an effect than a cause, and will therefore have additional stressors and/or sources driving the problem. A brief explanation of the inter-connectedness is discussed throughout this section, but a more thorough description of these interconnections is presented in the Stressor ID Report.

Altered Hydrology

Altered hydrology (USGS 2014b) in general refers to changes in hydrologic parameters including: stream flow, precipitation, drainage, impervious surfaces, wetlands, stream paths, vegetation, soil conditions, etc. Altered hydrology as an identified stressor more specifically refers to changes in the amount and timing of stream flow. Both too much and too little stream flow directly harm aquatic life by creating excessive speeds in the water or reducing the amount of water. Altered hydrology also indirectly harms aquatic life because it increases the transport or exacerbates the conditions of other pollutants and stressors including sediment from streambank erosion, nitrogen, and connectivity issues.

Status

Altered hydrology was the most commonly identified stressor in the Middle Minnesota River Watershed. Of the 52 bio-impaired stream reaches, all 52 were found to be stressed by altered hydrology. No stream reaches were found to be inconclusive, and no stream reaches were found not to be stressed by altered hydrology.

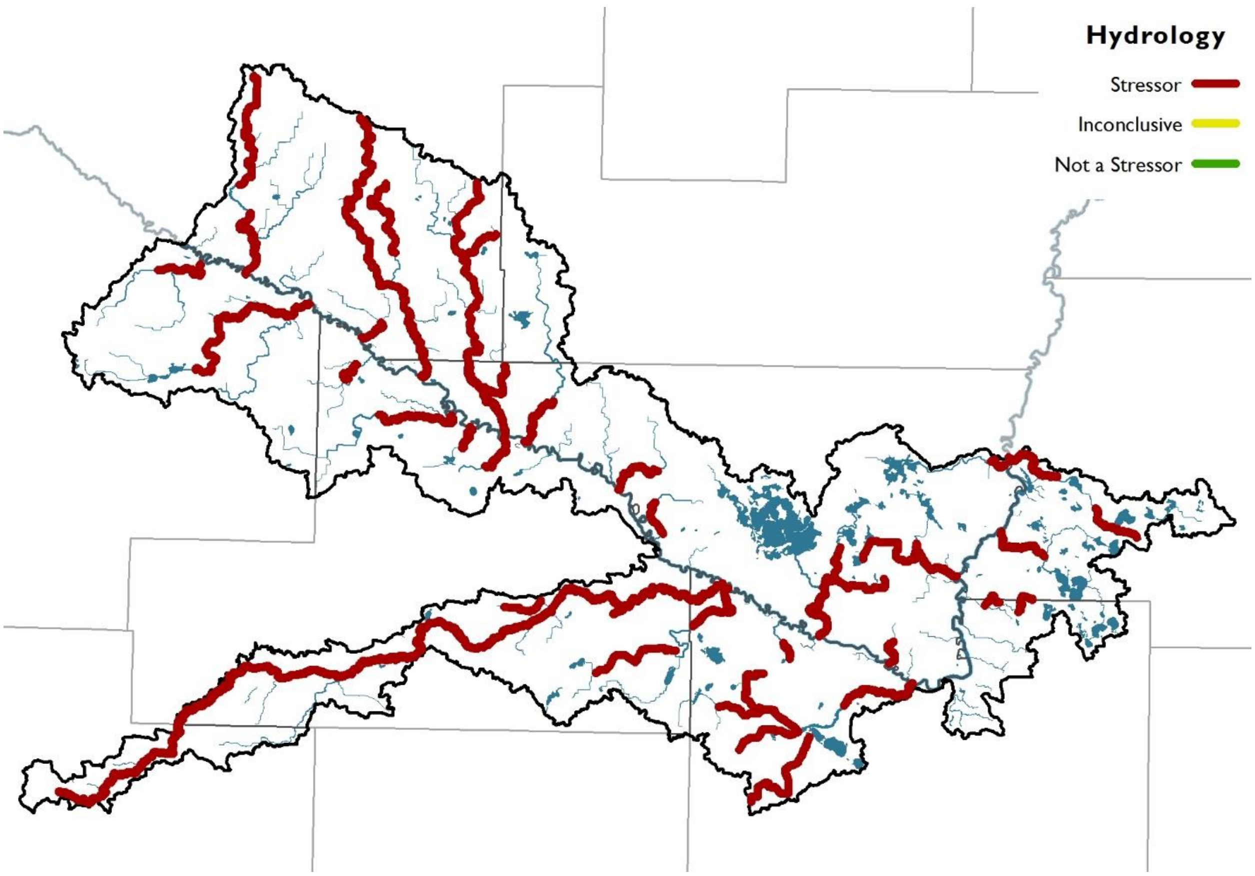


Figure 16: Assessment results show that altered hydrology is stressing aquatic life throughout the Middle Minnesota River Watershed. Red indicates a stressor (altered hydrology is problematic in that reach).

Table 6: Assessment results for altered hydrology as a stressor for stream reaches in the Middle Minnesota River Watershed.

Stream Name	Reach AUID-3	Hydrology
Birch Coulee Creek	587	X
Birch Coulee Creek	588	X
Cherry Creek	541	X
Cherry Creek	543	X
County Ditch 10 (John's Creek)	571	X
County Ditch 106A (Fort Ridgely Creek)	688	X
County Ditch 11	657	X
County Ditch 11	661	X
County Ditch 115	673	X
County Ditch 124	670	X
County Ditch 124	711	X
County Ditch 13	712	X
County Ditch 27	535	X
County Ditch 3	660	X
County Ditch 4/County Ditch 39	545	X
County Ditch 46A	678	X
County Ditch 46A	679	X
County Ditch 52	636	X
County Ditch 56 (Lake Crystal Inlet)	557	X
County Ditch 67	658	X
Crow Creek	569	X
Eightmile Creek	684	X
Fort Ridgely Creek	689	X
Fritsche Creek (County Ditch 77)	709	X
Heyman's Creek	675	X
Judicial Ditch 10	701	X

Stream Name	Reach AUID-3	Hydrology
Judicial Ditch 13	716	X
Judicial Ditch 13	717	X
Judicial Ditch 48	593	X
Judicial Ditch 8	666	X
Little Cottonwood River	676	X
Little Cottonwood River	677	X
Little Rock Creek (Judicial Ditch 31)	686	X
Little Rock Creek (Judicial Ditch 31)	687	X
Minneopa Creek	531	X
Minneopa Creek	534	X
Morgan Creek	691	X
Rogers Creek	547	X
Sevenmile Creek	562	X
Sevenmile Creek	703	X
Shanaska Creek	693	X
Spring Creek	573	X
Spring Creek (Hindeman Creek)	574	X
Spring Creek (Judicial Ditch 29)	622	X
Swan Lake Outlet (Nicollet Creek)	683	X
Threemile Creek	704	X
Unnamed creek	550	X
Unnamed creek	577	X
Unnamed creek	696	X
Unnamed creek	715	X
Wabasha Creek	527	X
Wabasha Creek	699	X

x = stressor

Sources

Sources of altered hydrology are common throughout the Middle Minnesota River Watershed, ranging from landscape and climate changes, to crop and vegetative changes, to soil and drainage changes. Hydrology is interconnected in the landscape; when changes are made to one hydrologic parameter, there are responses in other hydrologic parameters. For instance, tile drainage quickly removes water from the soil profile, increasing the total volume and timing of water inputs to water bodies. Likewise, altered and channelized (straightened) streams have less total volume and create higher flow speeds than unaltered streams.

Two of the most substantial aspects of altered hydrology in the Middle Minnesota River Watershed are altered streams and tile drainage. As illustrated in the Sources Overview section, 28% of the landscape is likely and up to 63% of the landscape may be tile drained (Figure 10), and 65% of stream miles are altered (Figure 12). In particular, the headwater portion of streams tend to be extensively altered, causing direct and indirect impacts to the immediate and downstream reaches. Without extensive mitigation of these altered hydrologic parameters, stream flow is negatively altered.

Rather than attempting to numerically estimate the magnitude of change in river flow from the varied forms of altered hydrology, source assessment work focused on the land use and pathway that water travels after being received as precipitation. While most precipitation is returned to the atmosphere by ET, the remaining water travels to water bodies via different pathways. These pathways include: surface runoff, groundwater flow, or artificial subsurface drainage such as drainage tile or storm sewer networks. Numeric estimates of the Middle Minnesota River Watershed's land uses' contributions of water to waterbodies (Figure 17) were estimated using a water portioning calculator (Appendix 4.2) and vetted using additional lines of evidence and local professional judgement.

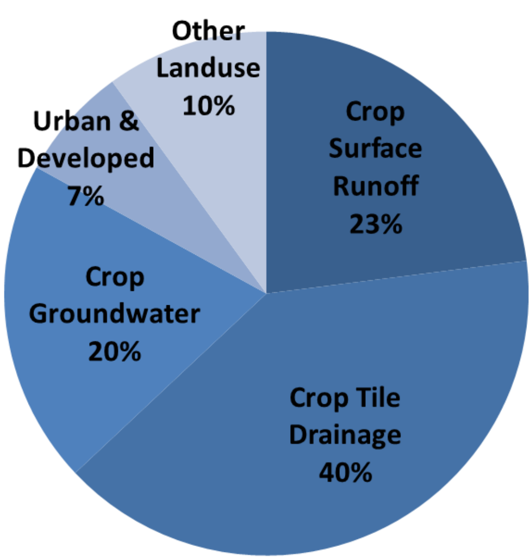


Figure 17: Source assessment for water details the land use and pathway that water travels from the landscape and into water bodies in the Middle Minnesota River Watershed. Cultivated cropland use in the Watershed contributes most water to waterbodies through three different pathways: surface runoff, tile drainage, and groundwater.

Areas of the watershed with higher levels of hydrologic alteration were estimated using GIS (Figure 18). By combining the following individual analyses, an overall estimate of the relative amount of hydrologic alteration per subwatershed was estimated. Hydrologic factors considered in the presented analysis include: 1) the estimated percentage of land area that is tile drained, 2) the percentage of stream length that is channelized/artificially straightened, 3) the percentage of wetlands that were drained, 4) the percentage of land in non-perennial vegetation, 5) the percentage of land covered in impervious surfaces, and 6) the number of road crossings per stream length. See Appendix 4.1 for maps of the individual hydrologic factors.

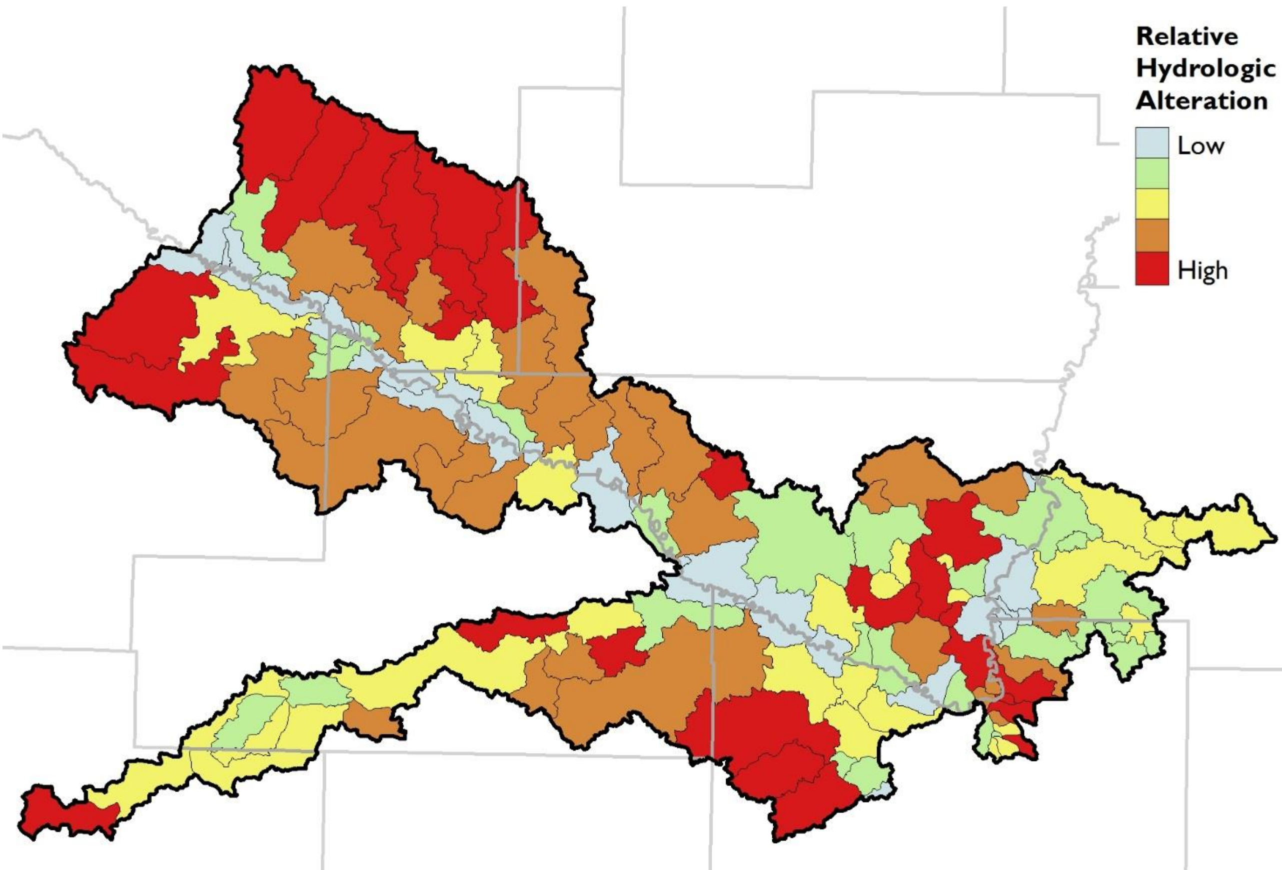


Figure 18: GIS analysis of the watersheds estimates where more changes to the natural hydrology of the watershed have occurred. Refer to Appendix 4.1 for more information on this analysis and maps of the individual hydrologic parameters used.

Additional information regarding the suspected sources and issues related to altered hydrology were compiled for bio-impaired stream reaches in the Stressor ID report and are summarized in Appendix 4.2.

Goal & 10-year Target

The watershed-wide goals for the altered hydrology are a 25% reduction of total and peak flow, and an increase in dry season base flow where Stressor ID identified low flow as a stressor (Figure 19). Typically, altered hydrology goals are set after considering long-term flow datasets of the outlets of major watersheds. The Middle Minnesota River Watershed is comprised of multiple small tributaries that drain directly to the Minnesota River rather than a primary stream, and limited flow records are available for only two of these tributaries (Little Cottonwood River and Seven Mile Creek). This lack of watershed-wide flow data makes adequately representing flow conditions at the major watershed scale more difficult. However, Stressor ID found that altered hydrology was the most prevalent stressor in the watershed. Therefore, setting a goal for this critical stressor is necessary.

With the lack of a long-term flow record that represents the major watershed, additional lines of evidence were used to develop a flow goal for the watershed. The goal considered the Sediment Reduction Strategy for the Minnesota River Basin (MPCA 2015h) which identifies the need for flow reduction across the Basin. Data and goals for altered hydrology from other southwestern Minnesota watersheds were also considered. This goal is revisable and will be revisited in the next iteration of the Watershed Approach, but allows for consideration of this critical stressor.

Decreases in the total annual flow should focus on decreasing peak flows, increasing base flow, and maintaining the dynamic properties of the natural hydrograph, which are important for channel geomorphology, vegetation, and aquatic life. Strategies to accomplish these tasks must increase ET, and store and infiltrate water on the landscape to increase ground water contributions (base flow) to streams during dry periods. Strategies and methods to prioritize regions to address altered hydrology are summarized in Section 3.

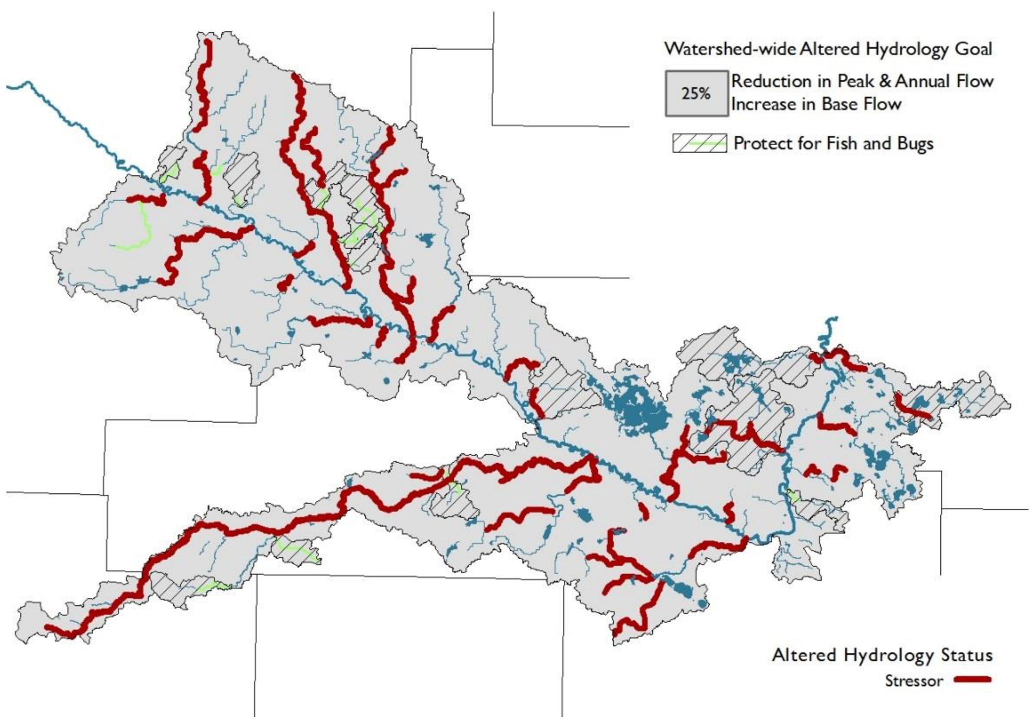


Figure 19: The watershed-wide altered hydrology goal is a 25% decrease in peak and annual flow and increase base flow in reaches identified by Stressor ID. Areas where fish and bugs are meeting the standard should be protected.

Nitrogen

Nitrogen can be present in water bodies in several forms including ammonia, nitrite, and nitrate. The process in which nitrogen changes from one form to another is called the nitrogen cycle (Britannica 2019). Most nitrogen in waters starts as ammonia; ammonia is converted to nitrite, and then nitrite is converted to nitrate. Since these forms are intricately connected, and all forms pose risks, the different nitrogen forms are addressed together in this report as the sum of the forms, or the total nitrogen (TN).

Excessive nitrogen can be toxic to fish and bugs and even at small concentrations can limit sensitive species. The eutrophication causing the Gulf Hypoxic Zone (NOAA 2015) is due to excessive nitrogen contributions from the Mississippi River Basin. Nitrogen is also a major human health concern, as excessive nitrogen consumption via drinking water causes blue baby syndrome (Washington State DOH 2016). Due to this health risk, excessive nitrogen in drinking water can necessitate expensive treatments.

Status

Nitrogen was the second most commonly identified stressor, behind altered hydrology. Nitrogen as a stressor and/or pollutant was identified in 33 stream reaches, ruled out in 2, and was inconclusive in 17. Figure 20 illustrates the stream aquatic life impaired reaches that were assessed for nitrogen, and Table 7 tabulates those results. Nitrogen as a pollutant is currently assessed only for cold-water streams, which are classified as secondary drinking water sources.

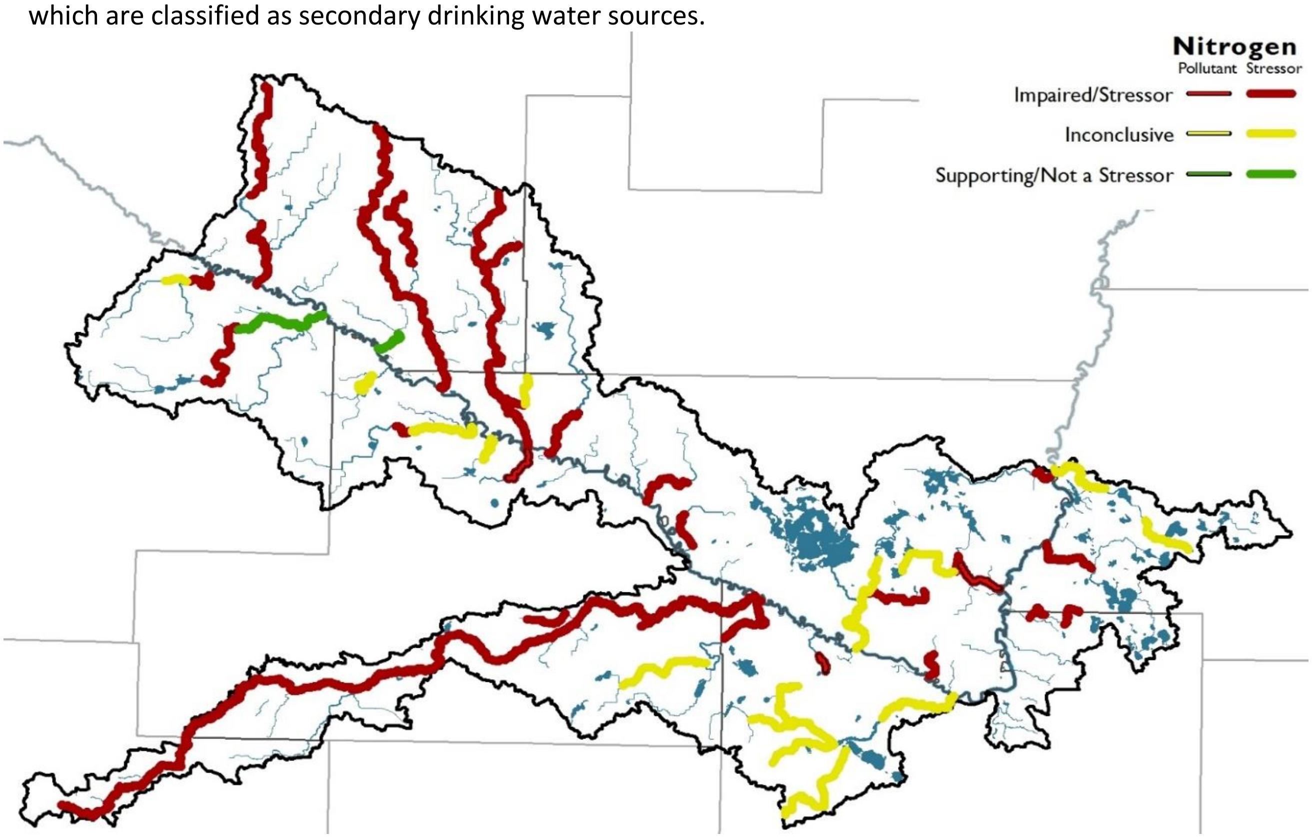


Figure 20: Assessment results show that nitrogen is stressing aquatic life in a majority of the Middle Minnesota River Watershed stream reaches where it was assessed. Nitrogen was also identified as a pollutant in three stream reaches. Red indicates nitrogen was identified as a stressor/pollutant (nitrogen is problematic in that reach), green indicates nitrogen is not a stressor/pollutant (nitrogen is not problematic in that reach), and yellow indicates that more data are needed to assess nitrogen.

Table 7: Assessment results for nitrogen as a stressor and pollutant for stream reaches in the Middle Minnesota River Watershed.

Stream Name	Reach AUID-3	Nitrogen Stressor Assessment	Nitrogen Pollutant Assessment
Birch Coulee Creek	587	X	
Birch Coulee Creek	588	X	
Cherry Creek	541	?	
Cherry Creek	543	?	
County Ditch 10 (John's Creek)	571	X	X
County Ditch 106A (Fort Ridgely Creek)	688	X	
County Ditch 11	657	X	
County Ditch 11	661	X	
County Ditch 115	673	X	
County Ditch 124	670	X	
County Ditch 124	711	X	
County Ditch 13	712	?	
County Ditch 27	535	?	
County Ditch 3	660	X	
County Ditch 4/County Ditch 39	545	?	
County Ditch 46A	678	?	
County Ditch 46A	679	X	
County Ditch 52	636	?	
County Ditch 56 (Lake Crystal Inlet)	557	?	
County Ditch 67	658	X	
Crow Creek	569	X	
Eightmile Creek	684	X	
Fort Ridgely Creek	689	X	
Fritsche Creek (County Ditch 77)	709	X	
Heyman's Creek	675	X	
Judicial Ditch 10	701	?	

Stream Name	Reach AUID-3	Nitrogen Stressor Assessment	Nitrogen Pollutant Assessment
Judicial Ditch 13	716	?	
Judicial Ditch 13	717	X	
Judicial Ditch 48	593	?	
Judicial Ditch 8	666	X	
Little Cottonwood River	676	X	
Little Cottonwood River	677	X	
Little Rock Creek (Judicial Ditch 31)	686	X	
Little Rock Creek (Judicial Ditch 31)	687	X	
Minneopa Creek	531	?	
Minneopa Creek	534	?	
Morgan Creek	691	X	
Rogers Creek	547	X	
Sevenmile Creek	562	X	X
Sevenmile Creek	703	X	
Shanaska Creek	693	X	
Spring Creek	573	?	
Spring Creek (Hindeman Creek)	574	?	
Spring Creek (Judicial Ditch 29)	622	X	
Swan Lake Outlet (Nicollet Creek)	683	?	
Threemile Creek	704	+	
Unnamed creek	550	X	
Unnamed creek	577	X	X
Unnamed creek	696	X	
Unnamed creek	715	?	
Wabasha Creek	527	+	
Wabasha Creek	699	X	

+ = supporting/not a stressor
? = inconclusive (need more data)
x = impaired/stressor

In addition to impacting surface water, nitrogen concentrations have reached concerning levels in both the Mankato Ranney wells and the St. Peter well. Mankato operates two Ranney wells, which extract water from an aquifer with direct connections to surface water; one well is influenced by the Minnesota River and another well is located where the Minnesota River and Blue Earth River meet. The city of St. Peter has several wells that draw from the Jordan Sandstone Aquifer. This aquifer is relatively shallow and is quickly recharged through surface water. A portion of the surface water is derived from tile-drained cropland on the western edge of the Drinking Water Supply Management Area (DWSMAs). The tile drainage discharges into ditches and then flows towards the wells where it encounters sandy soils near the western city limits where higher infiltration rates occurs. Thorough groundwater analysis is outside the scope of the WRAPS. However, additional information on nitrogen in drinking water is in the Nitrogen in Groundwater section of Appendix 4.1 and is provided by the Minnesota Department of Health.

From a statewide perspective, the subwatersheds in the Middle Minnesota River Watershed have a high yield and FWMC of nitrogen (Figure 21).

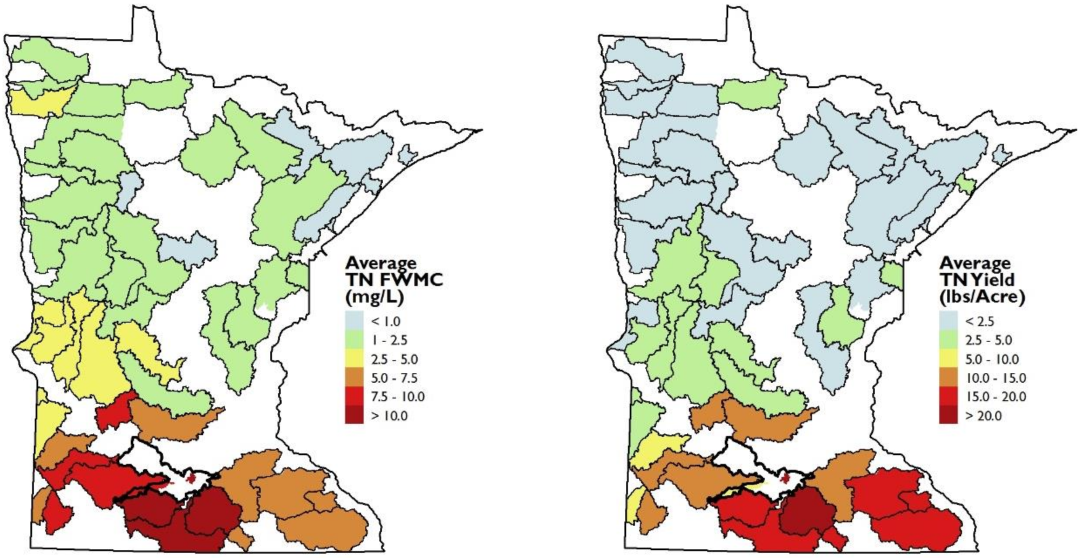


Figure 21: The Middle Minnesota River Watershed nitrogen loads represented by the Little Cottonwood River (monitored 2014 through 2016) has FWMC of 9.90 mg/L and yield of 19.27 lbs/acre. Seven Mile Creek (monitored 2007 through 2016) nitrogen has FWMC of 21.73 mg/L and yield of 32.09 lbs/acre. Data are from the WPLMN.

A HSPF model was developed for the Middle Minnesota River Watershed. This model output can be used to estimate conditions in stream reaches that have not been monitored. The model's estimated nitrogen flow-weighted mean concentration (FWMC) for the years 1996 through 2012 are illustrated in Figure 22. HSPF model yields are presented in Appendix 4.2.

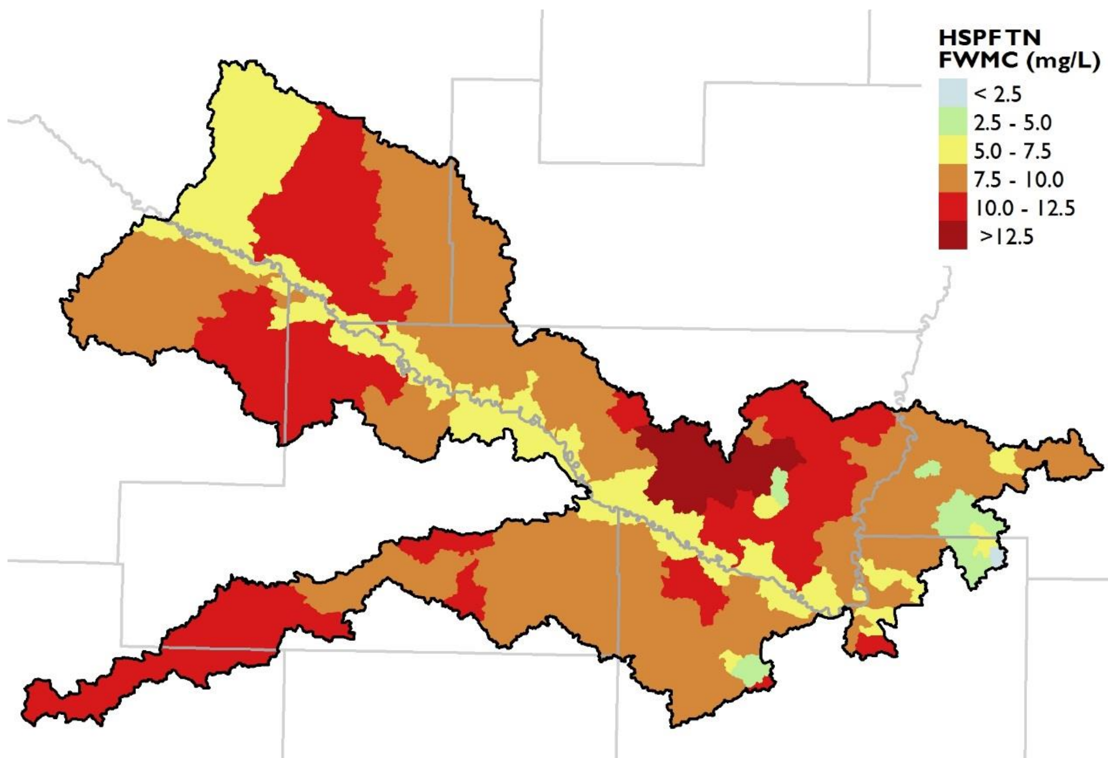


Figure 22: HSPF model output estimate the FWMC of TN for the years 1996-2012.

Sources

In the Middle Minnesota River Watershed, most nitrogen that reaches water bodies is from nonpoint sources. Point source contributions for the years of 2010 through 2014 are estimated to total about 3% of the Middle Minnesota River Watershed's TN load.

A numeric estimate of the Middle Minnesota River Watershed's nitrogen sources is presented in Figure 23; refer to the Sources Overview in Section 2.1 for more details. Crop drainage and crop groundwater dominate nitrogen contribution pathways to water bodies. Application of manure and chemical fertilizer are significant sources of nitrogen through the crop drainage and crop ground water pathways when timing and application rates are not optimal.

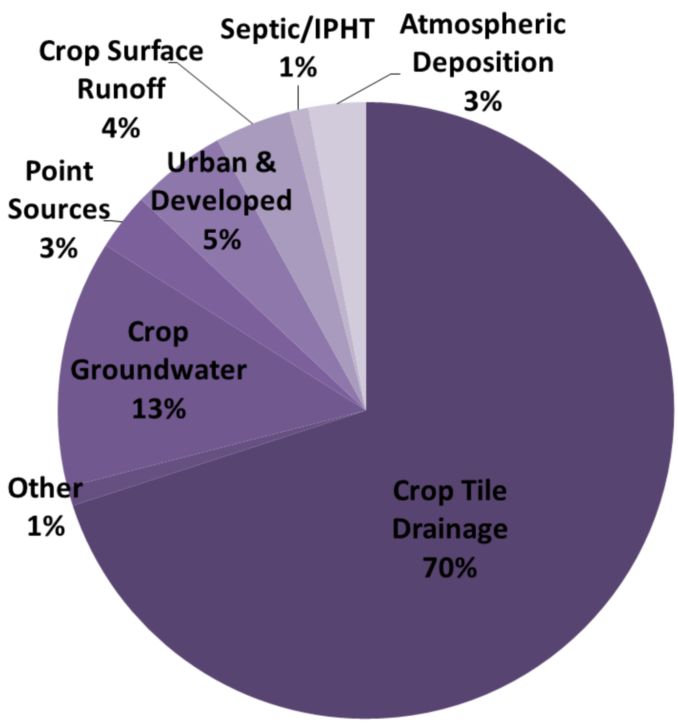


Figure 23: Source assessments in the Middle Minnesota River Watershed estimate that the sources of nitrogen are dominated by crop drainage and crop groundwater contributions. The nitrogen leaving crops is mostly from applied fertilizer or manure.

Additional information regarding the suspected sources and issues related to nitrogen were compiled for bio-impaired stream reaches in the Stressor ID Report and are summarized in Appendix 4.2.

Goal & 10-year Target

The selected watershed-wide goal for nitrogen is a 60% reduction in nitrogen at the watershed-wide scale (Figure 24), which equates to a FWMC of 5 mg/L. Nitrogen goals were set after considering multiple layers of goals both within and downstream of the watershed, including impaired reaches where a TMDL was completed (requiring concentrations less than 10 mg/L), the proposed aquatic life toxicity standard (proposed a standard of 4.9 mg/L; MPCA 2010b), and the *Minnesota Nutrient Reduction Strategy* (MPCA 2013c), which calls for a 45% reduction from the Minnesota portions of the Mississippi River Basin as a whole. Furthermore, this FWMC equivalent was the basis for goals for other southwest Minnesota WRAPS, thus making these goals comparable.

Individual reaches covered by the watershed-wide goal may actually need more or less reduction based on specific conditions in each stream reach and/or the assessment status. More reach specific data are needed to comprehensively determine the stream specific goals. Therefore, streams lacking specific and ample data to calculate an individual reach goal default to the watershed-wide goal. Cases where ample data or assessment information justified an individual reach goal are summarized below. These multiple layers of goals and the applicable areas are illustrated in Figure 24.

Three stream reaches were found to be impaired by nitrogen and required a TMDL. While the existing standard for these streams is 10 mg/L (and 10 mg/L was used in the TMDL), nitrogen values in these streams were compared to the selected watershed-wide goal of 5 mg/L. The calculated reduction goals in these reaches ranged from 58% to 78%. Refer to the TMDL summary in Appendix 4.3 for subwatershed reductions goals and calculation methods. Two of the bio-impaired stream reaches did not identify nitrogen as a stressor, and therefore have a protection goal. Nitrogen concentrations in these streams still sometimes exceeded the watershed-wide goal of 5 mg/L, and to help support downstream and state nutrient reduction goals these streams were assigned a reduction goal of 15%. Fourteen stream reaches were found to have adequate fish and/or bug communities. Nitrogen concentrations in these stream reaches often exceeded the watershed-wide goal of 5 mg/L and are assigned a reduction goal of 30%.

These goals are revisable and will be revisited in the next iteration of the Watershed Approach. Strategies to meet the goals and 10-year targets and methods to prioritize regions for nitrogen reductions are summarized in Section 3.

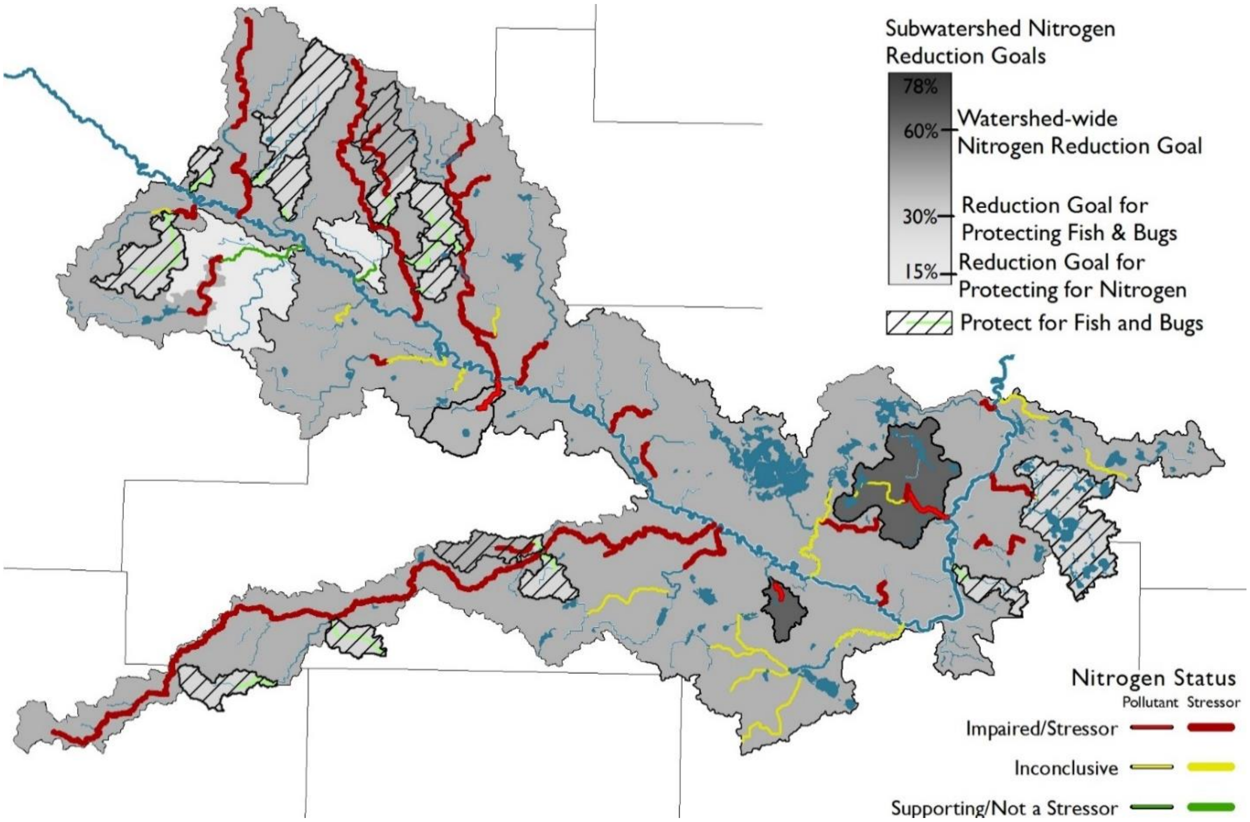


Figure 24: The overall watershed-wide reduction goal in the Middle Minnesota River Watershed is a 60% reduction. Subwatershed goals (for areas with additional information) range from 15% to 78%.

Habitat

Habitat, as identified in this report, refers to the physical stream habitat impacting aquatic life. Important stream habitat components include: stream size and channel dimensions, channel gradient (slope), channel substrate, habitat complexity and cover, vegetation cover and structure in the riparian zone, and channel-riparian interactions. Degraded habitat reduces aquatic life's ability to feed, shelter, and reproduce, which results in altered behavior, increased mortality, and decreased populations.

Status

Of the bio-impaired stream reaches, degraded habitat was identified as a stressor in 28, ruled out in 12, and inconclusive in 12. The habitat assessment results are illustrated in Figure 25 and tabulated in Table 8. The *MPCA Stream Habitat Assessment* (MSHA; MPCA 2014c) scores at biological sample locations (used in part combined with biological community attributes to assess habitat within a stream reach) are also illustrated. Generally, "good" habitat scores (>65) are necessary to support healthy, aquatic communities. While a point location may score as "good" habitat, stressor ID results consider habitat throughout the stream reach, which can be considerably lower quality than a point location. The MSHA assessment considers floodplain, riparian, instream, and channel morphology attributes at biological monitoring locations on stream reaches.

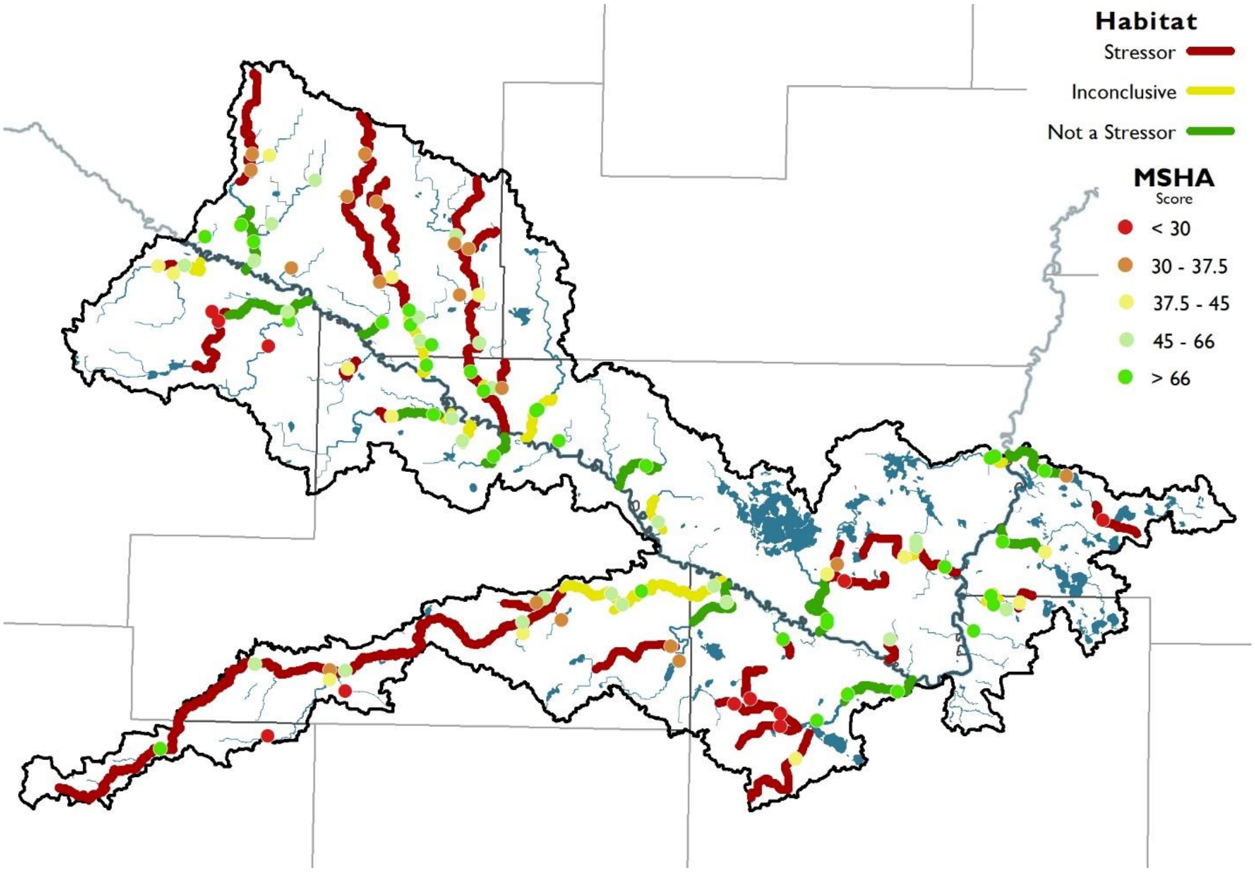


Figure 25: Assessment results show that generally, degraded habitat is stressing upstream and headwater reaches. The downstream reaches (closer to the Minnesota River) tend to have better habitat. Red indicates a stressor (habitat is problematic in that reach), green indicates habitat is not a stressor (habitat is not problematic in that reach), and yellow indicates that more data are needed to assess habitat as a stressor. The MSHA scores used in part to assess habitat are also illustrated.

Table 8: Assessment results for degraded habitat as a stressor in stream reaches in the Middle Minnesota River Watershed.

Stream Name	Reach AUID-3	Habitat Assessment
Birch Coulee Creek	587	+
Birch Coulee Creek	588	+
Cherry Creek	543	+
Cherry Creek	541	X
County Ditch 10 (John's Creek)	571	+
County Ditch 106A (Fort Ridgely Creek)	688	X
County Ditch 11	657	X
County Ditch 11	661	X
County Ditch 115	673	X
County Ditch 124	670	X
County Ditch 124	711	X
County Ditch 13	712	?
County Ditch 27	535	X
County Ditch 3	660	X
County Ditch 4/County Ditch 39	545	X
County Ditch 46A	679	?
County Ditch 46A	678	X
County Ditch 52	636	X
County Ditch 56 (Lake Crystal Inlet)	557	X
County Ditch 67	658	?
Crow Creek	569	?
Eightmile Creek	684	?
Fort Ridgely Creek	689	?
Fritsche Creek (County Ditch 77)	709	+
Heyman's Creek	675	?
Judicial Ditch 10	701	X

Stream Name	Reach AUID-3	Habitat Assessment
Judicial Ditch 13	717	?
Judicial Ditch 13	716	X
Judicial Ditch 48	593	X
Judicial Ditch 8	666	X
Little Cottonwood River	677	?
Little Cottonwood River	676	X
Little Rock Creek (Judicial Ditch 31)	686	X
Little Rock Creek (Judicial Ditch 31)	687	X
Minneopa Creek	534	+
Minneopa Creek	531	X
Morgan Creek	691	+
Rogers Creek	547	?
Sevenmile Creek	562	X
Sevenmile Creek	703	X
Shanaska Creek	693	+
Spring Creek	573	?
Spring Creek (Hindeman Creek)	574	+
Spring Creek (Judicial Ditch 29)	622	X
Swan Lake Outlet (Nicollet Creek)	683	+
Threemile Creek	704	+
Unnamed creek	550	?
Unnamed creek	577	X
Unnamed creek	696	X
Unnamed creek	715	X
Wabasha Creek	527	+
Wabasha Creek	699	X

x = stressor
? = inconclusive (need more data)
\+ = not a stressor

Sources

The specific aquatic habitat issues impacting aquatic life identified in the Middle Minnesota River Watershed Stressor ID Report show a complex, interconnected set of factors that are driven by primarily two stressors: altered hydrology and degraded riparian/vegetation. Table 9 summarizes Stressor ID results within the watershed. Issues leading to excess sediment (bedded sediment and erosion) are often due to unstable channel morphology, which is driven by altered hydrology and poor riparian conditions. Degraded riparian conditions are related to insufficient vegetation due to cropping/other land use too close to the stream, pasturing on the stream bank, and excessive stream bank erosion (accelerated by altered hydrology). Without an adequate riparian buffer, issues such as excessive flow – which causes stream instability and sediment issues - are magnified because the stream banks lack the strength to resist erosion.

Table 9: Habitat problems of bio-impaired stream reaches as identified in the Middle Minnesota River Watershed's Stressor ID reports.

		stressor source						stressor source			
AUID	**Stream Name**	Pasturing/Lack of Riparian	Channel Morphology	Bedded Sediment	Erosion	**AUID**	**Stream Name**	Pasturing/Lack of Riparian	Channel Morphology	Bedded Sediment	Erosion
541	Cherry Creek		●	●		**670**	County Ditch 124	●	●	●	
696	Unnamed Creek		●	●	●	**711**	County Ditch 124	●	●	●	
593	Judicial Ditch 48		●	●	●	**673**	County Ditch 115	●	●		
531	Minneopa Creek		●	●	●	**688**	County Ditch 106A	●	●	●	
535	County Ditch 27	●	●	●	●	**666**	Judicial Ditch 8	●	●		
557	Lake Crystal Inlet(County Ditch 56)	●	●	●	●	**686**	Little Rock Creek (Judicial Ditch 31)	●	●		
577	Unnamed Creek			●	●	**687**	Little Rock Creek (Judicial Ditch 31)	●		●	●
701	Judicial Ditch 10	●	●	●		**716**	Judicial Ditch 13	●	●	●	●
657	County Ditch 11	●	●	●	●	**545**	County Ditch 4/County Ditch 39	●	●	●	
676	Little Cottonwood River		●	●	●	**661**	County Ditch 11	●	●	●	
622	Spring Creek (Judicial Ditch 29)		●	●		**660**	County Ditch 3		●		●
715	Unnamed Creek	●	●		●	**678**	County Ditch 46A		●	●	
636	County Ditch 52		●	●		**562**	Sevenmile Creek		●	●	●
699	Wabasha Creek	●	●	●		**703**	Sevenmile Creek		●	●	
	●=source										

Goal & 10-year Target

Overall, the watershed-wide goal is a 25% increase in the MSHA score, which equates to an average watershed score of 66. The specific goals for any location are for general use streams to have a “good” habitat score (66 or better) and for modified use streams to have a “fair” habitat score (45 or better). Based on these individual location goals, the range of goals is between “protect” and a 181% increase in the MSHA score. The watershed-wide score and the individual location goals are illustrated in Figure 26.

Low habitat scores are mostly due to degraded riparian vegetation and issues related to altered hydrology (stream bank erosion and excess sediment). These factors should be the focus of restoration and protection efforts to meet the goal and 10-year target. These goals are revisable and will be revisited in the next iteration of the Watershed Approach. Strategies and methods to prioritize regions to address habitat are summarized in Section 3.

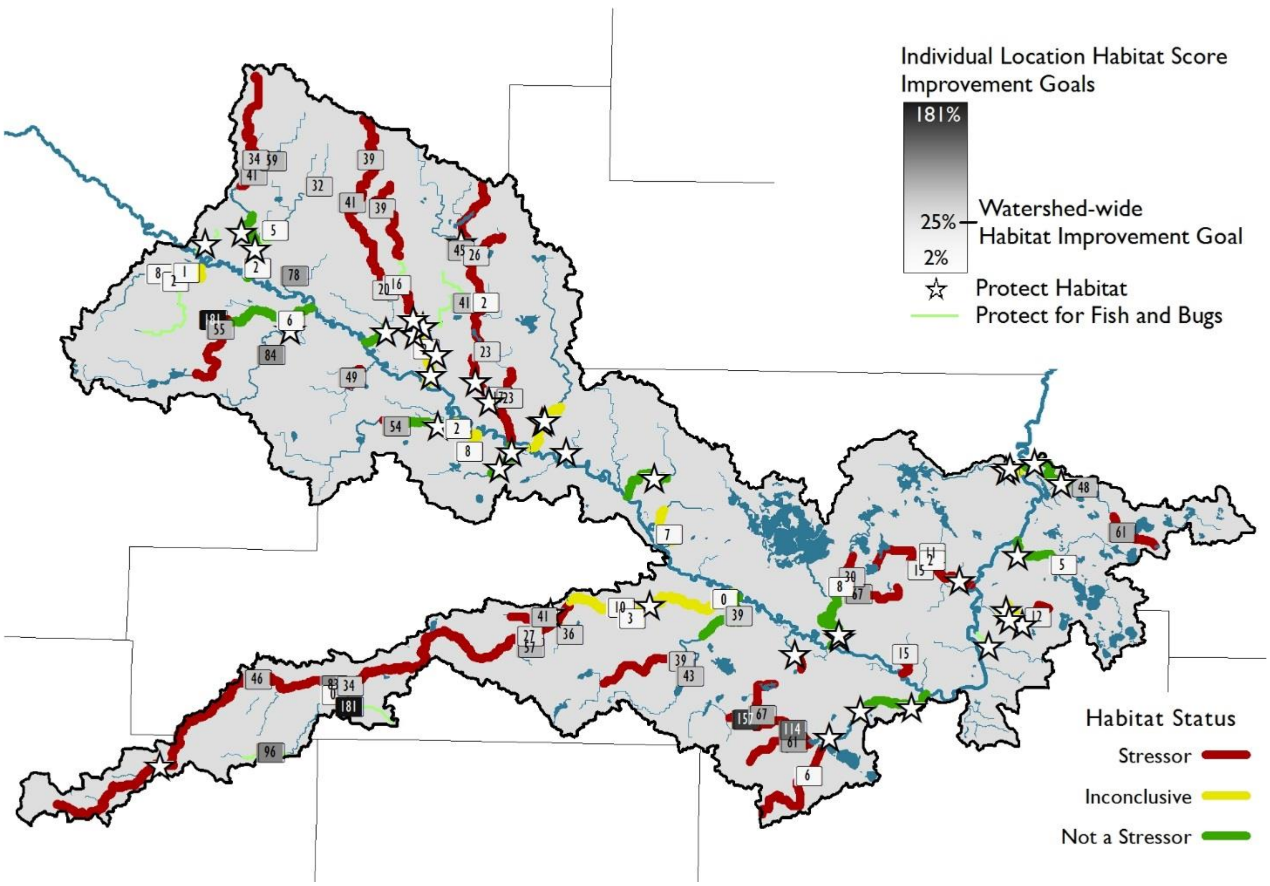


Figure 26: The watershed-wide habitat goal for the Middle Minnesota River Watershed is to increase the average MSHA score by 25%. At individual locations, the goal for modified streams is to achieve fair habitat (MSHA of 45 or better), and the goal for general use streams is to achieve good habitat (MSHA of 66 or better). The amount of change needed in the MSHA score at individual locations is illustrated by the color of the box and the number within the box. Higher numbers indicate the need for more extensive changes. Locations with stars have a protection goal.

Connectivity

Connectivity, as identified in this report, refers to the longitudinal connectivity of a stream, or the upstream to downstream connectedness of a stream. Both human-made (e.g. perched culverts) and natural (e.g. waterfalls) connectivity barriers can obstruct the movement of migratory fish and bugs (including mussels), causing negative changes in the population and community structure. Furthermore, this stressor can negatively impact the stream by affecting its sediment, habitat, and chemical characteristics.

Status

Lack of connectivity as a stressor was identified in 24 stream reaches, ruled out in 24 stream reaches, and inconclusive in four stream reaches. Streams that were not assessed for fish but had bug impairments were not evaluated. Figure 27 illustrates the stream reaches assessed for connectivity and Table 10 tabulates those results.

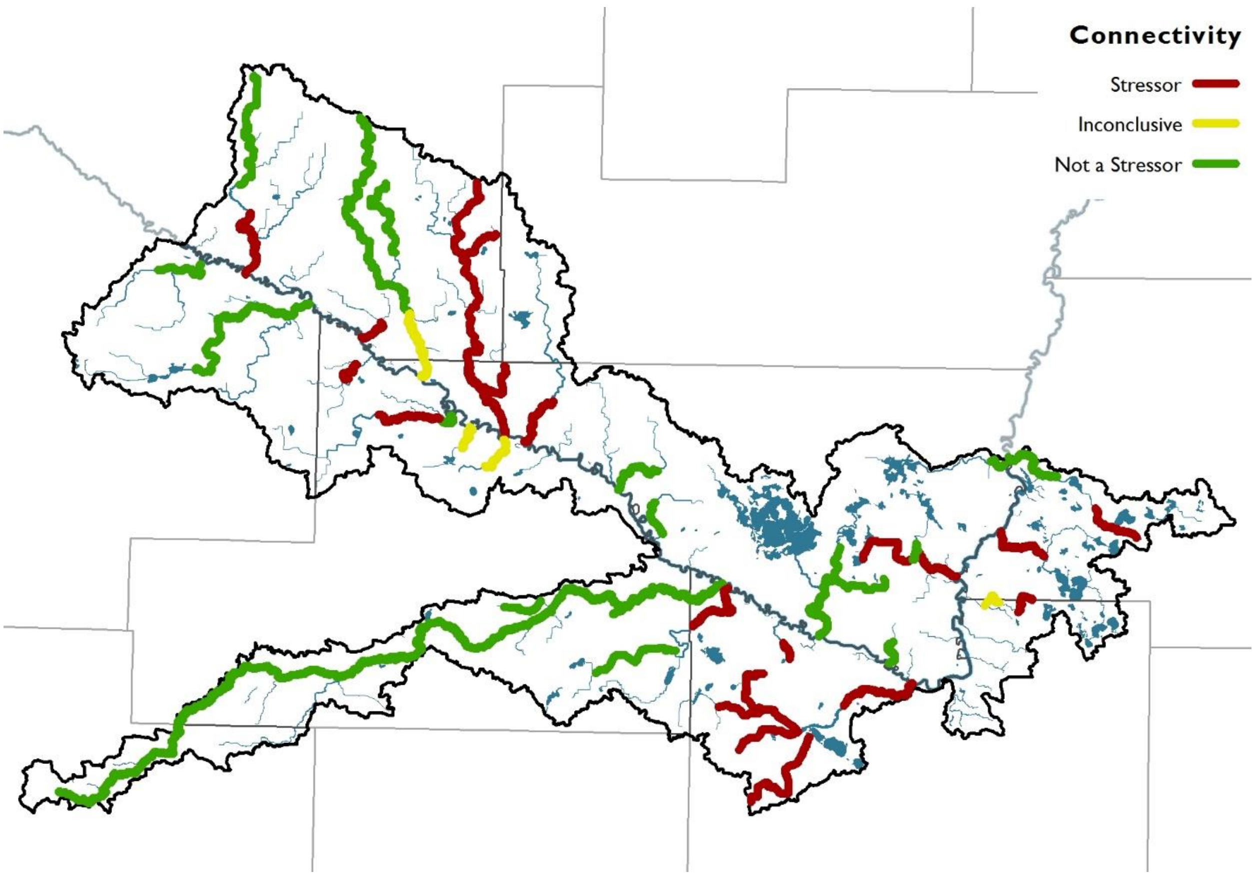


Figure 27: Assessment results show that lack of connectivity is stressing approximately half of the Middle Minnesota River Watershed's bio-impaired streams. Red indicates connectivity is a stressor (connectivity is problematic in that reach), green indicates connectivity is not a stressor (connectivity is not problematic in that reach), and yellow indicates that more data are needed to assess connectivity as a stressor.

Table 10: Assessment results for lack of connectivity as a stressor for stream reaches in the Middle Minnesota River Watershed.

Stream Name	Reach AUID-3	Connectivity Assessment
Birch Coulee Creek	587	X
Birch Coulee Creek	588	X
Cherry Creek	543	+
Cherry Creek	541	X
County Ditch 10 (John's Creek)	571	?
County Ditch 106A (Fort Ridgely Creek)	688	+
County Ditch 11	657	+
County Ditch 11	661	+
County Ditch 115	673	+
County Ditch 124	670	+
County Ditch 124	711	+
County Ditch 13	712	?
County Ditch 27	535	X
County Ditch 3	660	+
County Ditch 4/County Ditch 39	545	+
County Ditch 46A	679	+
County Ditch 46A	678	X
County Ditch 52	636	+
County Ditch 56 (Lake Crystal Inlet)	557	X
County Ditch 67	658	+
Crow Creek	569	+
Eightmile Creek	684	X
Fort Ridgely Creek	689	?
Fritsche Creek (County Ditch 77)	709	+
Heyman's Creek	675	+
Judicial Ditch 10	701	+

Stream Name	Reach AUID-3	Connectivity Assessment
Judicial Ditch 13	716	X
Judicial Ditch 13	717	X
Judicial Ditch 48	593	X
Judicial Ditch 8	666	X
Little Cottonwood River	676	+
Little Cottonwood River	677	+
Little Rock Creek (Judicial Ditch 31)	686	X
Little Rock Creek (Judicial Ditch 31)	687	X
Minneopa Creek	531	X
Minneopa Creek	534	X
Morgan Creek	691	X
Rogers Creek	547	+
Sevenmile Creek	703	+
Sevenmile Creek	562	X
Shanaska Creek	693	X
Spring Creek	573	+
Spring Creek (Hindeman Creek)	574	X
Spring Creek (Judicial Ditch 29)	622	X
Swan Lake Outlet (Nicollet Creek)	683	+
Threemile Creek	704	X
Unnamed creek	550	?
Unnamed creek	577	X
Unnamed creek	696	X
Unnamed creek	715	X
Wabasha Creek	527	+
Wabasha Creek	699	+

x = stressor
? = inconclusive (need more data)
+ = not a stressor

Sources

The connectivity issues identified in the Middle Minnesota River Watershed as reported in the Stressor ID Report include dams, perched culverts, altered hydrology, beaver dams, and natural waterfalls (Table 11).

Table 11: Connectivity problems of bio-impaired stream reaches as identified in the Middle Minnesota River Watershed's Stressor ID Report.

		stressor source							stressor source				
AUID	Stream Name	Flow Alteration/Connectivity	Dams/Impoundments	Road Crossings/Perched Culverts	Waterfalls/knickpoint (natural)	Beaver Dams	AUID	Stream Name	Flow Alteration/Connectivity	Dams/Impoundments	Road Crossings/Perched Culverts	Waterfalls/knickpoint (natural)	Beaver Dams
541	Cherry Creek	●	●				**715**	Unnamed Creek			●		
693	Shanaska Creek	●					**704**	Threemile Creek	○		●		●
696	Unnamed Creek			●			**588**	Birch Coulee Creek	○			●	
593	Judicial Ditch 48				●		**587**	Birch Coulee Creek	○			●	
531	Minneopa Creek				●		**666**	Judicial Ditch 8		●			
535	County Ditch 27				●		**686**	Little Rock Creek (Judicial Ditch 31)		●			
557	Lake Crystal Inlet(County Ditch 56)				●		**687**	Little Rock Creek (Judicial Ditch 31)	●				
534	Minneopa Creek				●		**716**	Judicial Ditch 13	●				
577	Unnamed Creek			●		●	**717**	Judicial Ditch 13	●				
691	Morgan Creek			●			**684**	Eightmile Creek			●		
622	Spring Creek (Judicial Ditch 29)			●		●	**678**	County Ditch 46A	○	●			
574	Spring Creek (Hindeman Creek)			●			**562**	Sevenmile Creek	●		●		

●=source, ○=potential source

Goal & 10-year Target

The goal for connectivity in the Middle Minnesota River Watershed is to mitigate or remove longitudinal connectivity issues for fish passage where it is relevant and feasible, including the protection of natural waterfalls. This goal is revisable and will be revisited in the next iteration of the Watershed Approach. Strategies and methods to prioritize regions to address connectivity are summarized in Section 3.

Phosphorus

Phosphorus is a nutrient that fuels algae and plant growth. While not directly harmful to aquatic life, excess phosphorus in water bodies can lead to excessive algae growth and eutrophication (Chislock et al. 2013). These responses to excess phosphorus impact aquatic life by changing food chain dynamics, impacting fish growth and development, and decreasing DO when algae/plant growth decomposes. Phosphorus also impacts aquatic recreation in lakes by fueling algae growth, making waters undesirable or even dangerous to swim in due to the potential presence of toxic blue-green algae.

In order to identify phosphorus as a pollutant or stressor, eutrophic conditions must be observed in addition to high phosphorus concentrations. Furthermore, a high phosphorus concentration does not always result in eutrophic conditions (often lack of cover and slow moving water must also be present). However, high phosphorus concentrations are the main chemical driver of eutrophication, and decreasing phosphorus is necessary to correct eutrophic conditions. Therefore, this section simplifies the phosphorus-eutrophic relationship and refers to it simply as phosphorus.

Status

Of the lakes that were monitored to determine if phosphorus is a pollutant, nine were impaired, three were supporting, and seven were inconclusive. Of the bio-impaired stream reaches, phosphorus as a stressor was identified in 13, ruled out in one, and inconclusive in 38. Minnesota River reaches in the Middle Minnesota River Watershed were assessed separately and are excluded from this report. Figure 28 illustrates the stream reaches and lakes that were assessed for phosphorus. Table 12 tabulates stream phosphorus assessment results. Table 13 displays lake phosphorus assessment results and clarity trend information.

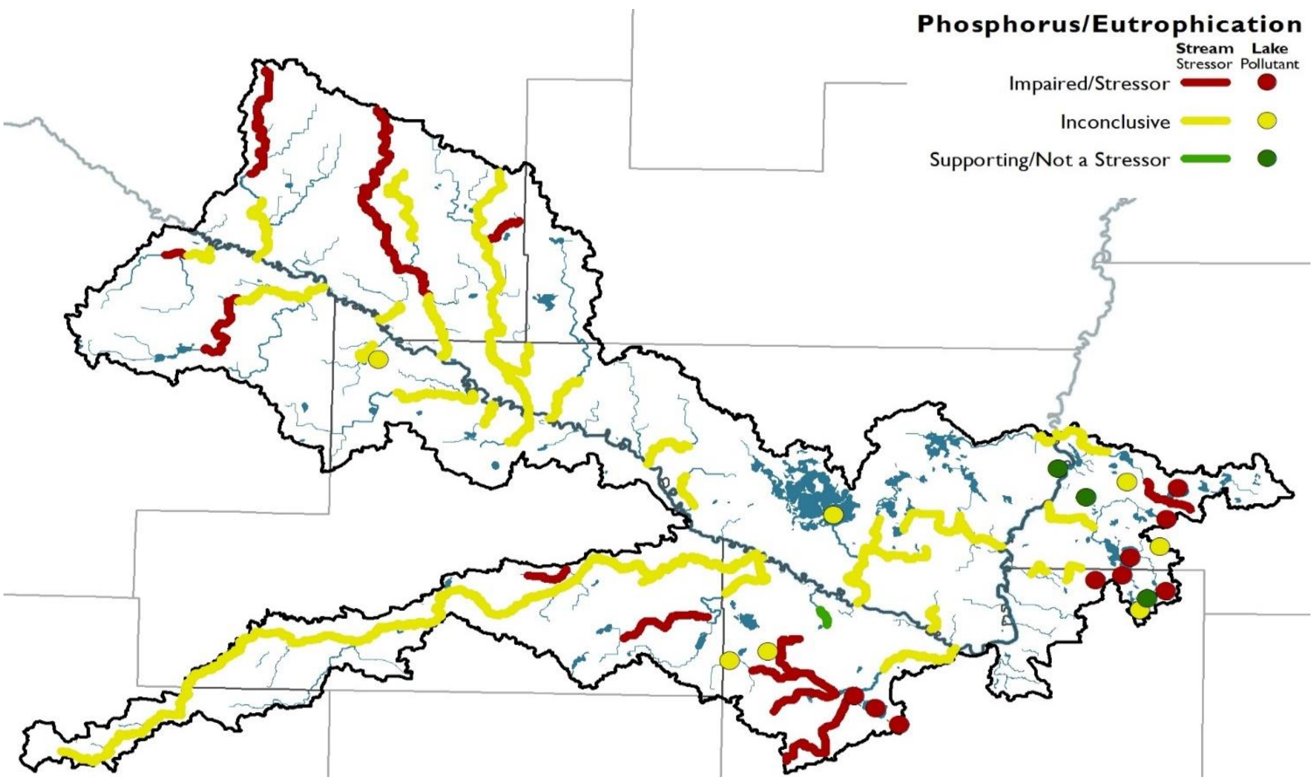


Figure 28: Assessment results indicate that phosphorus is stressing approximately a quarter of the bio-impaired stream reaches and is a pollutant in about half of the lakes in the Middle Minnesota River Watershed. Red indicates phosphorus was identified as a stressor/pollutant (phosphorus is problematic in that reach/lake), green indicates phosphorus is not a stressor/pollutant (phosphorus is not problematic in that reach/lake), and yellow indicates that more data are needed to assess phosphorus.

Table 12: Assessment results of eutrophication (phosphorus) as a stressor in the Middle Minnesota River Watershed.

Stream Name	Reach AUID-3	Eutrophication (Phosphorus)	Stream Name	Reach AUID-3	Eutrophication (Phosphorus)
Birch Coulee Creek	587	?	Judicial Ditch 13	716	?
Birch Coulee Creek	588	?	Judicial Ditch 13	717	?
Cherry Creek	543	?	Judicial Ditch 48	593	X
Cherry Creek	541	X	Judicial Ditch 8	666	X
County Ditch 10 (John's Creek)	571	?	Little Cottonwood River	676	?
County Ditch 106A (Fort Ridgely Cree	688	X	Little Cottonwood River	677	?
County Ditch 11	661	?	Little Rock Creek (Judicial Ditch 31)	686	?
County Ditch 11	657	X	Little Rock Creek (Judicial Ditch 31)	687	?
County Ditch 115	673	?	Minneopa Creek	534	?
County Ditch 124	670	X	Minneopa Creek	531	X
County Ditch 124	711	X	Morgan Creek	691	?
County Ditch 13	712	?	Rogers Creek	547	?
County Ditch 27	535	X	Sevenmile Creek	562	?
County Ditch 3	660	?	Sevenmile Creek	703	?
County Ditch 4/County Ditch 39	545	?	Shanaska Creek	693	?
County Ditch 46A	678	?	Spring Creek	573	?
County Ditch 46A	679	?	Spring Creek (Hindeman Creek)	574	?
County Ditch 52	636	X	Spring Creek (Judicial Ditch 29)	622	?
County Ditch 56 (Lake Crystal Inlet)	557	X	Swan Lake Outlet (Nicollet Creek)	683	?
County Ditch 67	658	?	Threemile Creek	704	?
Crow Creek	569	?	Unnamed creek	550	?
Eightmile Creek	684	?	Unnamed creek	696	?
Fort Ridgely Creek	689	?	Unnamed creek	715	?
Fritsche Creek (County Ditch 77)	709	?	Unnamed creek	577	+
Heyman's Creek	675	?	Wabasha Creek	527	?
Judicial Ditch 10	701	X	Wabasha Creek	699	X

x = stressor
? = inconclusive (need more data)
\+ = not a stressor

Table 13: Assessment results for phosphorus and clarity trends for lakes in the Middle Minnesota River Watershed.

Lake Name	Phosphorous Assessment	Clarity Trend	Lake Name	Phosphorous Assessment	Clarity Trend	Lake Name	Phosphorous Assessment	Clarity Trend
Ballantyne	+	+	Henry	x	?	Scotch	x	x
Crystal	x	+	Lieberg	?	?	Strom	?	
Duck	x	-	Lone Tree	?	?	Swan	?	?
Emily	+	+	Loon	x	?	Unnamed	?	?
George	x	?	Mills	x	?	Washington	x	+
Gilfillin	?	?	Savidge	?	?	Wita	x	?
Hallett	+	X						

x = impaired/declining trend
? = inconclusive (need more data)
\+ = supporting/improving trend
\- = no trend detected
<blank> = no data

From a statewide perspective, the Middle Minnesota River Watershed's phosphorus concentrations and yields are high (Figure 29) according to WPLMN data.

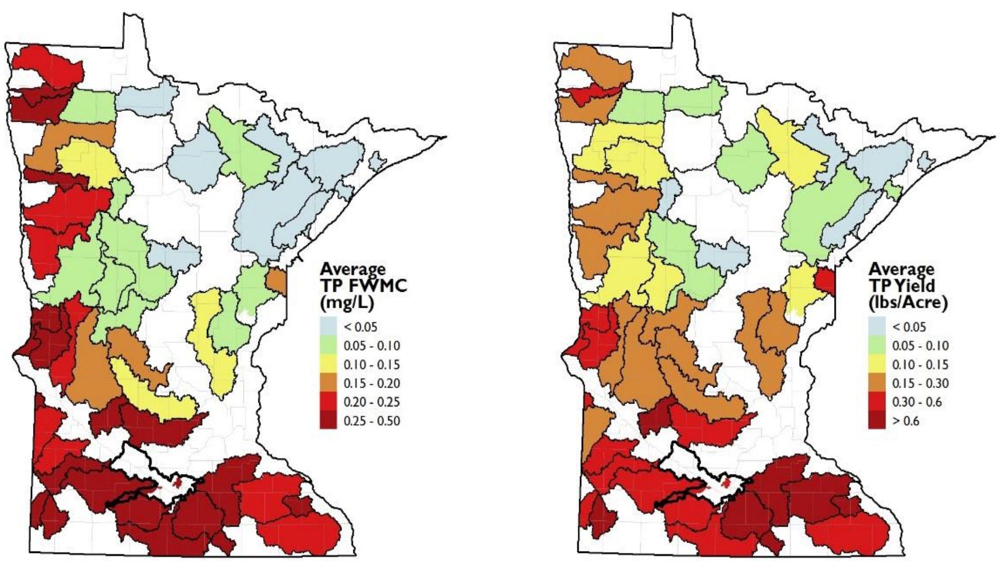


Figure 29: The Middle Minnesota River Watershed total phosphorus loads represented by the Little Cottonwood River (monitored 2014 through 2016) has FWMC of 0.28 mg/L and yield of 0.49 lbs/acre. Seven Mile Creek (monitored 2007 through 2016) Total Phosphorus has FWMC of 0.31 mg/L and yield of 0.51 lbs/acre. Data are from the WPLMN.

The HSPF model's estimated TP FWMC for the years 1996 through 2012 is illustrated in Figure 30. HSPF model yields are presented in Appendix 4.2. This model output can be used to estimate conditions in stream reaches that have not been monitored.

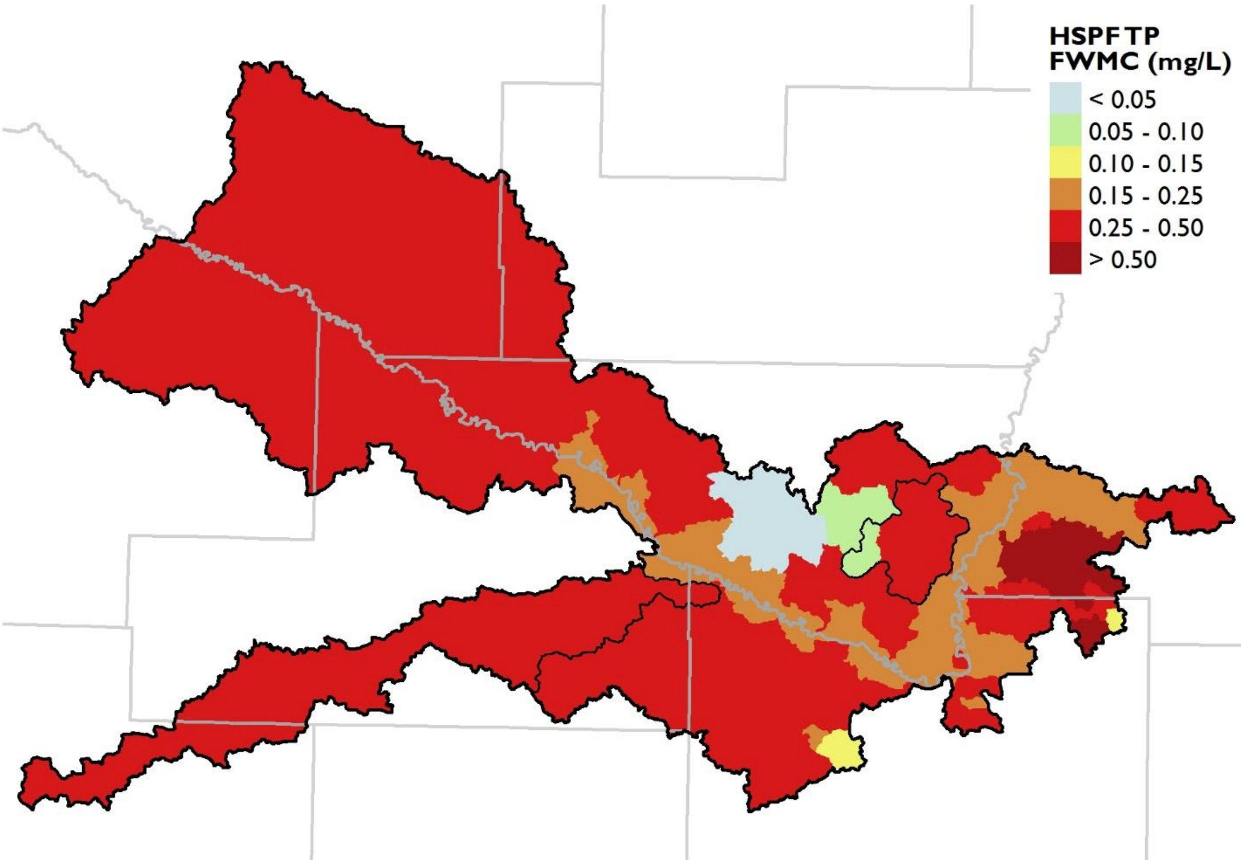


Figure 30: HSPF model output showing the FWMC of TP modeled from 1996-2012.

Sources

Phosphorus sources are dominated by nonpoint sources in the Middle Minnesota River Watershed. Point source contributions for the years of 2010 through 2014 are estimated to total less than 4% of the Middle Minnesota River Watershed's annual phosphorus load (Appendix 4.2).

A numeric estimate of the Middle Minnesota River Watershed's phosphorus sources is presented in Figure 31. Refer to the Sources Overview in Section 2.1 for more details. Agricultural land uses and drainage were estimated to be the largest source of phosphorus. Most of the phosphorus leaving agricultural fields is likely due to agricultural activities, which include fertilizer and manure application (calculations in Appendix 4.2).

Because phosphorus has an affinity for sediment particles, TP is usually associated with suspended solids and/or contained in algal cells, whereas dissolved phosphorus generally is available for immediate uptake by aquatic organisms. This should be a consideration when assessing the mobility of phosphorus in the environment.

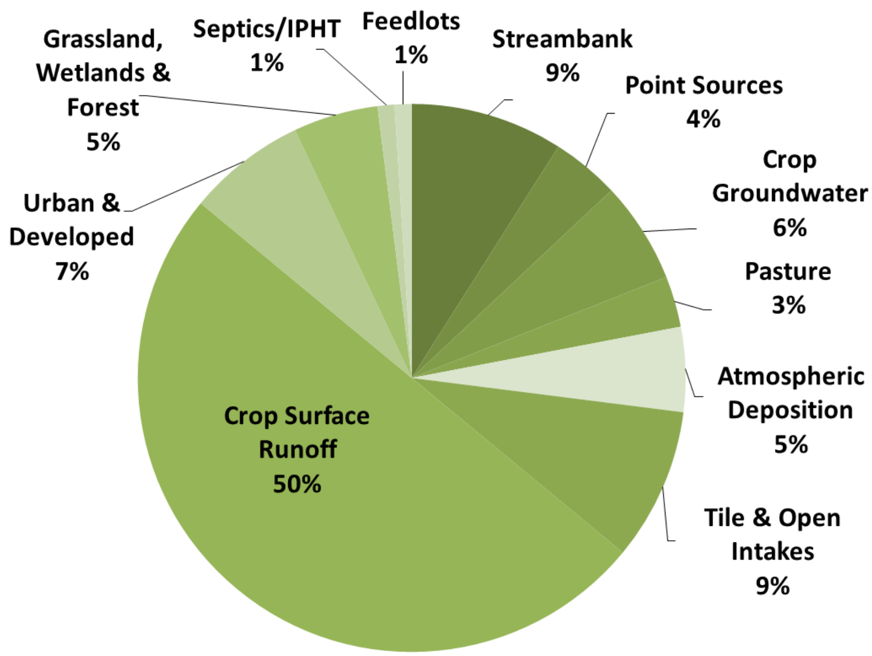


Figure 31: Source assessments in the Middle Minnesota River Watershed estimate that the sources of phosphorus are dominated by crop surface runoff. The phosphorus leaving crops is mostly from applied fertilizer or manure.

Internal lake phosphorus loads are not explicitly accounted for in the source assessment. Internal lake loads are a product of excessive, legacy phosphorus contributions from the lake's watershed, and little of the internal load is natural. When planning for lake restoration, however, knowing the magnitude of internal load is important to develop the specific strategies to address the impairment. Planners should consult the TMDL or additional lake modeling or studies to estimate the internal load accordingly.

Additional information regarding the suspected sources and issues related to eutrophication were compiled for bio-impaired stream reaches in the Stressor ID Report and are summarized in Appendix 4.2.

Goal & 10-year Target

The watershed-wide goal for phosphorus in the Middle Minnesota River Watershed is a 50% reduction (Figure 32). The watershed-wide goal was set after reviewing phosphorus data from lakes and streams in the watershed, TMDL information, model output, and the *Minnesota Nutrient Reduction Strategy* (MPCA 2013c) goals. Streams should have a maximum FWMC of 0.15 mg/L, and lakes should achieve a summer mean of between 0.04 mg/L-0.09 mg/L, depending on the specific lake. Lake phosphorus reduction goals were calculated where TMDL data were available and vary from an 83% reduction to a protection goal. For more information, refer to Goals Overview in Section 2.1 and the TMDL summary, model summary, and WPLMN data summary in Appendix 4.3

The 10-year target selected by the WRAPS Feedback Group is a 10% phosphorus reduction. Strategies to meet the goals and 10-year targets and methods to prioritize regions for phosphorus reductions are summarized in Section 3. These goals are revisable and will be revisited in the next iteration of the Watershed Approach.

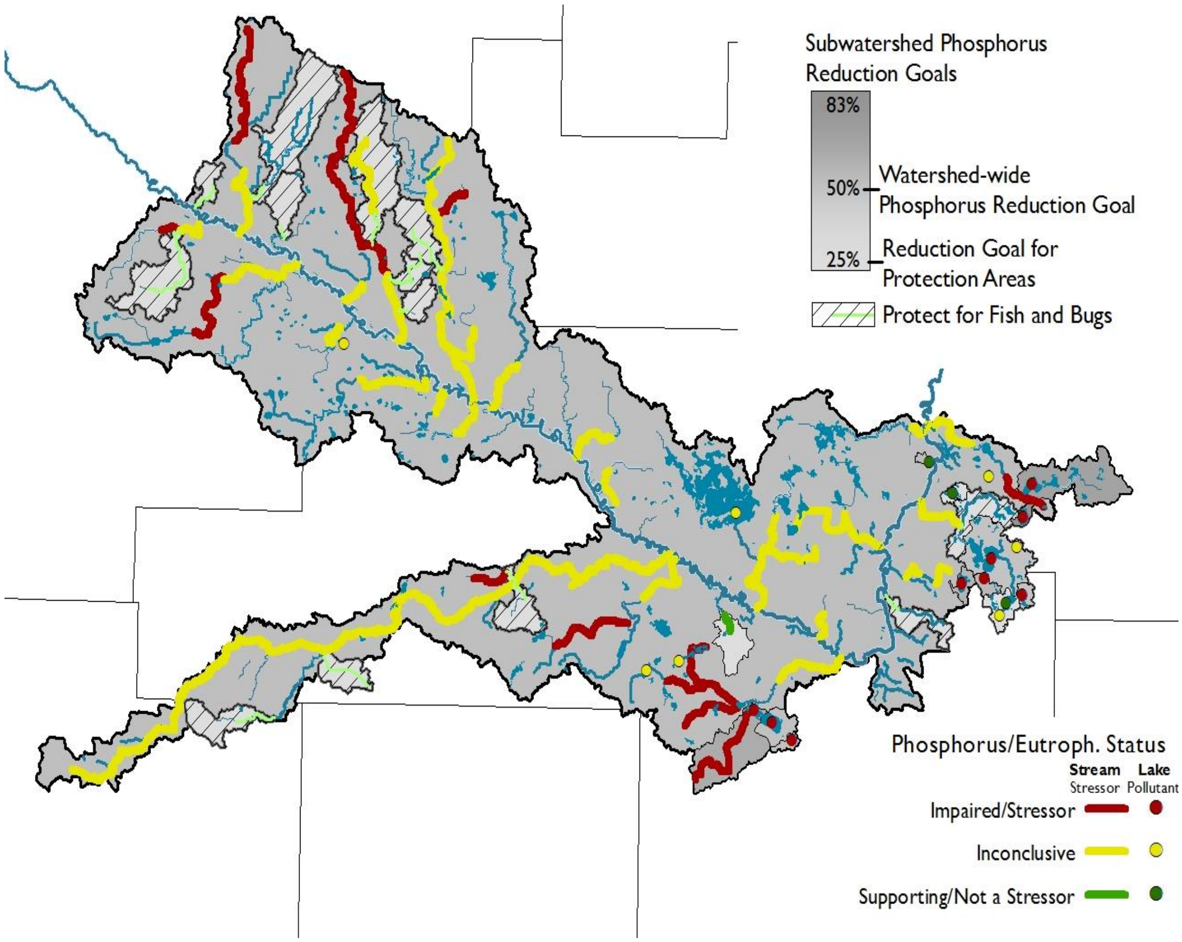


Figure 32: The watershed-wide phosphorus goal for the Middle Minnesota River Watershed is a 50% reduction. Lakes where phosphorus was found to be a pollutant have subwatershed goals based on the TMDL data. Subwatersheds where phosphorus was not found to be a stressor or was supporting the standard have a 25% or more reduction to support

Individual subwatershed reduction goals were calculated for lakes that required a TMDL. Goals for these subwatersheds ranged from 46 to 83% phosphorus reduction. Refer to the TMDL summary in Appendix 4.3 for lake subwatershed reduction goals and calculation methods. The goal for fish and bug protection areas is a 25% reduction to support downstream and state nutrient reduction goals. Supporting lakes (needing protection) with an improving trend have a 25% reduction goal; however, supporting lakes with a degrading trend default to the watershed-wide reduction goal.

These goals are revisable and will be revisited in the next iteration of the Watershed Approach. Strategies to meet the goals and 10-year targets and methods to prioritize regions for phosphorus reductions are summarized in Section 3.

Dissolved Oxygen

DO is oxygen gas within water. Low or highly fluctuating concentrations of DO can have detrimental effects on many fish and bug species. Low DO impacts aquatic life primarily by limiting respiration, which contributes to stress and disease and can cause death. If DO concentrations become limited or fluctuate dramatically, aquatic life can experience reduced growth, impacts to behavior and disease resistance, or fatality.

Status

Of the stream reaches monitored to assess DO as a pollutant, zero were impaired, 16 were supporting, and 70 were inconclusive. Of the bio-impaired stream reaches, DO as a stressor was identified in 18, ruled out in 9, and inconclusive in 25. Figure 33 illustrates the stream reaches assessed for DO and Table 14 tabulates those results.

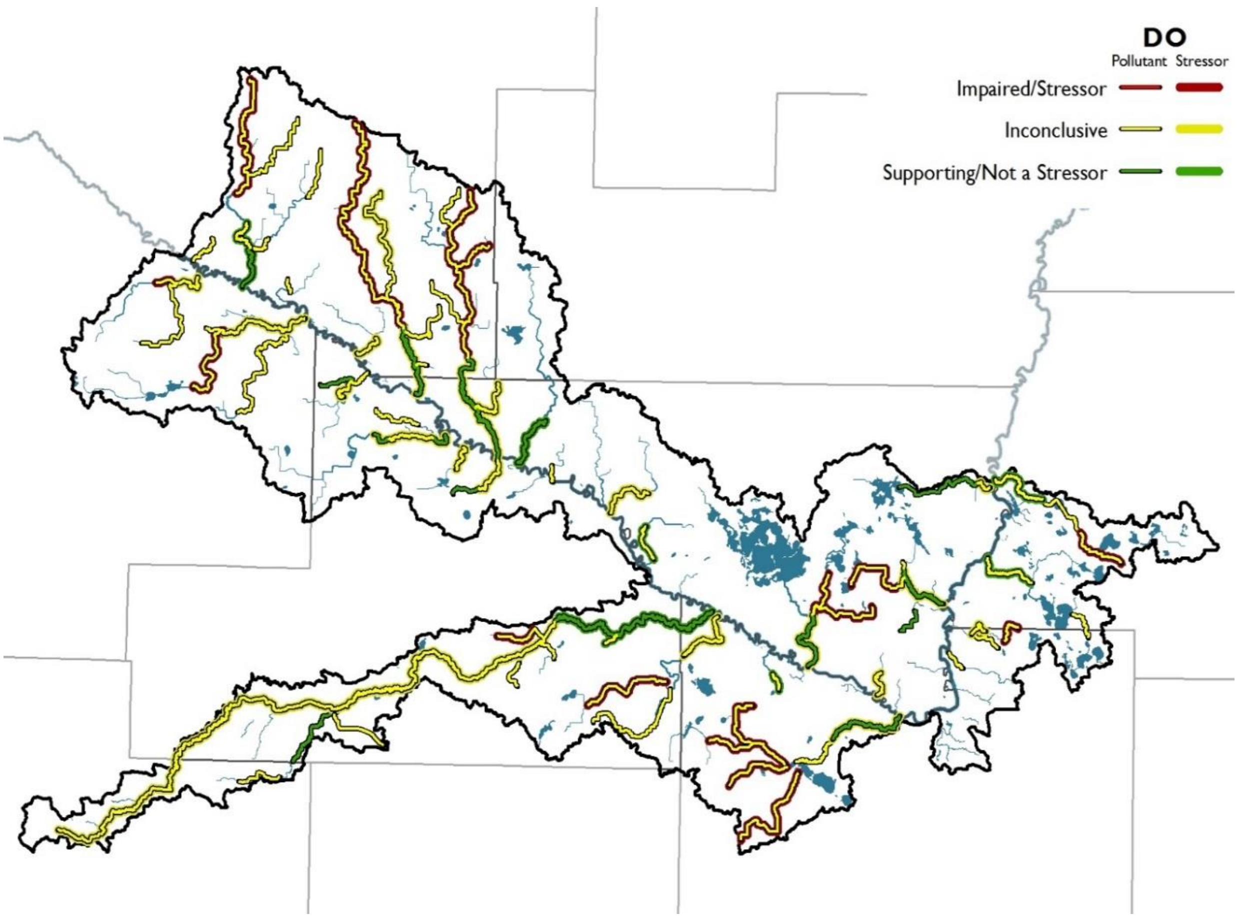


Figure 33: Assessment results show that DO is stressing several upstream reaches but not stressing several downstream reaches in the Middle Minnesota River Watershed. DO as a pollutant was found to be inconclusive or supporting in the assessed stream reaches. Red indicates DO was identified as a stressor (DO is problematic in that reach), green indicates DO is not a pollutant/stressor (DO is not problematic in that reach), and yellow indicates that more data are needed to assess DO.

Table 14: Assessment results for dissolved oxygen as a pollutant and/or stressor for stream reaches in the Middle Minnesota River Watershed.

Stream Name	Reach AUID-3	Dissolved Oxygen Stressor Assessment	Disolved Oxygen Pollutant Assessment
Altermatts Creek	681		?
Altermatts Creek	518		+
Birch Coulee Creek	588	+	?
Birch Coulee Creek	587	+	+
Cherry Creek	543	+	?
Cherry Creek	541	X	?
Cherry Creek	542		?
County Ditch 10 (John's Creek)	571	?	?
County Ditch 10 (John's Creek)	650		+
County Ditch 100	665		?
County Ditch 105	667		?
County Ditch 106A (Fort Ridgely Creek)	688	X	?
County Ditch 109	528		?
County Ditch 11	657	X	?
County Ditch 11	661	X	?
County Ditch 111	672		?
County Ditch 115	673	?	?
County Ditch 115	664		?
County Ditch 124	670	X	?
County Ditch 124	711	X	?
County Ditch 13	712	?	?
County Ditch 22	671		?
County Ditch 27	535	X	?
County Ditch 28	656		?
County Ditch 3	660	?	?
County Ditch 3	525		?
County Ditch 4/County Ditch 39	545	X	?
County Ditch 46A	679	?	?
County Ditch 46A	678	X	?
County Ditch 52	636	X	?
County Ditch 56 (Lake Crystal Inlet)	557	X	?
County Ditch 57	649		?
County Ditch 63	544		?
County Ditch 67	658	+	?
County Ditch 85A	669		?
Crow Creek	569	?	?
Eightmile Creek	684	+	+
Fort Ridgely Creek	689	?	+
Fritsche Creek (County Ditch 77)	709	?	?
Heyman's Creek	675	+	?
Judicial Ditch 10	701	X	?
Judicial Ditch 12	582		?
Judicial Ditch 12	707		?

Stream Name	Reach AUID-3	Dissolved Oxygen Stressor Assessment	Disolved Oxygen Pollutant Assessment
Judicial Ditch 13	716	?	?
Judicial Ditch 13	717	?	?
Judicial Ditch 48	593	X	?
Judicial Ditch 8	666	X	?
Little Cottonwood River	676	?	?
Little Cottonwood River	677	+	+
Little Rock Creek (Judicial Ditch 31)	687	?	+
Little Rock Creek (Judicial Ditch 31)	686	X	?
Minneopa Creek	534	?	+
Minneopa Creek	531	X	?
Minneopa Creek	533		?
Morgan Creek	691	?	?
Rogers Creek	547	?	?
Rogers Creek (County Ditch 78)	613		+
Sevenmile Creek	562	?	+
Sevenmile Creek	703	?	+
Sevenmile Creek	702		?
Shanaska Creek	693	+	?
Shanaska Creek	692		?
Spring Creek	573	?	+
Spring Creek (Hindeman Creek)	574	?	?
Spring Creek (Judicial Ditch 29)	622	?	+
Swan Lake Outlet (Nicollet Creek)	683	?	+
Threemile Creek	704	?	?
Unnamed creek	550	?	?
Unnamed creek	715	?	?
Unnamed creek	577	+	?
Unnamed creek	696	X	?
Unnamed creek	548		?
Unnamed creek	566		?
Unnamed creek	607		?
Unnamed creek	644		?
Unnamed creek	662		?
Unnamed creek	663		?
Unnamed creek	668		?
Unnamed creek	694		?
Unnamed creek	718		?
Unnamed creek	651		+
Unnamed creek (County Ditch 11)	646		?
Unnamed creek (Sevenmile Creek Tributary)	637		+
Unnamed ditch	647		?
Wabasha Creek	527	?	?
Wabasha Creek	699	X	?

+ = supporting/not a stressor
? = inconclusive (need more data)
x = impaired/stressor

Sources

Low DO concentrations in water bodies are often caused by: 1) *excessive oxygen consumption*, which is often caused by the decomposition of algae and plants, whose growth is fueled by excess phosphorus and/or 2) *too little re-oxygenation*, which is often caused by minimal turbulence from low flow conditions or high water temperatures. Highly fluctuating diurnal DO levels indicate that high levels of plant respiration are occurring during daylight, but excessive oxygen consumption occurs at night (due to the factors listed above). Table 15 summarizes the Stressor ID Report findings.

Table 15 : Dissolved oxygen problems of bio-impaired stream reaches as identified in the Middle Minnesota River Watershed's Stressor ID Report.

		Stressor Sources					Stressor Sources		
AUID	**Stream Name**	Plant/algae decomposition and respiration	Lack of flow	Wetland/Lake influcence	**AUID**	**Stream Name**	Plant/algae decomposition and respiration	Lack of flow	Wetland/Lake influcence
541	Cherry Creek	●		●	**699**	Wabasha Creek	●		
696	Unnamed Creek	●		●	**670**	County Ditch 124	●	●	
593	Judicial Ditch 48	●		○	**711**	County Ditch 124		●	
531	Minneopa Creek	●			**688**	County Ditch 106A	●	●	
535	County Ditch 27	●			**666**	Judicial Ditch 8	●		
557	Lake Crystal Inlet(County Ditch 56)	●			**686**	Little Rock Creek (Judicial Ditch 31)	●		
701	Judicial Ditch 10	●		○	**545**	County Ditch 4/County Ditch 39	●	○	○
657	County Ditch 11	●			**661**	County Ditch 11	●	●	
636	County Ditch 52	●			**678**	County Ditch 46A	●	●	○

●=source, ○=potential source

Goal & 10-year Target

The watershed-wide goal for DO is to reach the minimum standard of 5 mg/L and for diurnal DO fluctuation to be less than 4.5 mg/L. Because DO is primarily a response of other stressors, the effective goal and 10-year target for DO are to meet the altered hydrology, phosphorus, and habitat goals and 10-year targets. Changes in the total annual flow should focus on decreasing peak flows, increasing base flow, and maintaining the dynamic properties of the natural hydrograph, which are important for channel geomorphology, vegetation, and aquatic life. Strategies to accomplish these tasks must increase ET and store and infiltrate water on the landscape to increase ground water contributions (base flow) to streams during dry periods. This goal is revisable and will be revisited in the next iteration of the Watershed Approach. Strategies and methods to prioritize regions to address altered hydrology, phosphorus, and habitat are summarized in Section 3.

Sediment/TSS

TSS are material suspended in the water. This material is often dominated by sediment, but also includes algae and other solids. Suspended sediment and streambed sediment are closely related because they have similar sources but affect aquatic life differently. Due to the inter-related nature of these parameters, they are grouped together in this report. Furthermore, sediment is the focus of this section of the report, and issues related to the algae-portion of TSS are addressed in the phosphorus (eutrophication) section, which applies specifically to Minneopa Creek and others stressed by phosphorus/eutrophication.

TSS impacts aquatic life by reducing visibility which reduces feeding, clogging gills which reduces respiration, and smothering substrate which limits reproduction. Excessive TSS can also reduce the penetration of sunlight, limiting plant growth and increasing water temperatures. Sediment also impacts downstream waters used for navigation (larger rivers) and recreation (lakes).

Status

Of the stream reaches monitored to assess if TSS is a pollutant, 6 were impaired, 16 were supporting, and 59 were inconclusive. Of the bio-impaired stream reaches, TSS as a stressor was identified in 11, ruled out in 7, and could not be determined in 34. Figure 34 illustrates the stream reaches that were assessed for sediment and Table 16 tabulates those results. HSPF model yields are presented in Appendix 4.2.

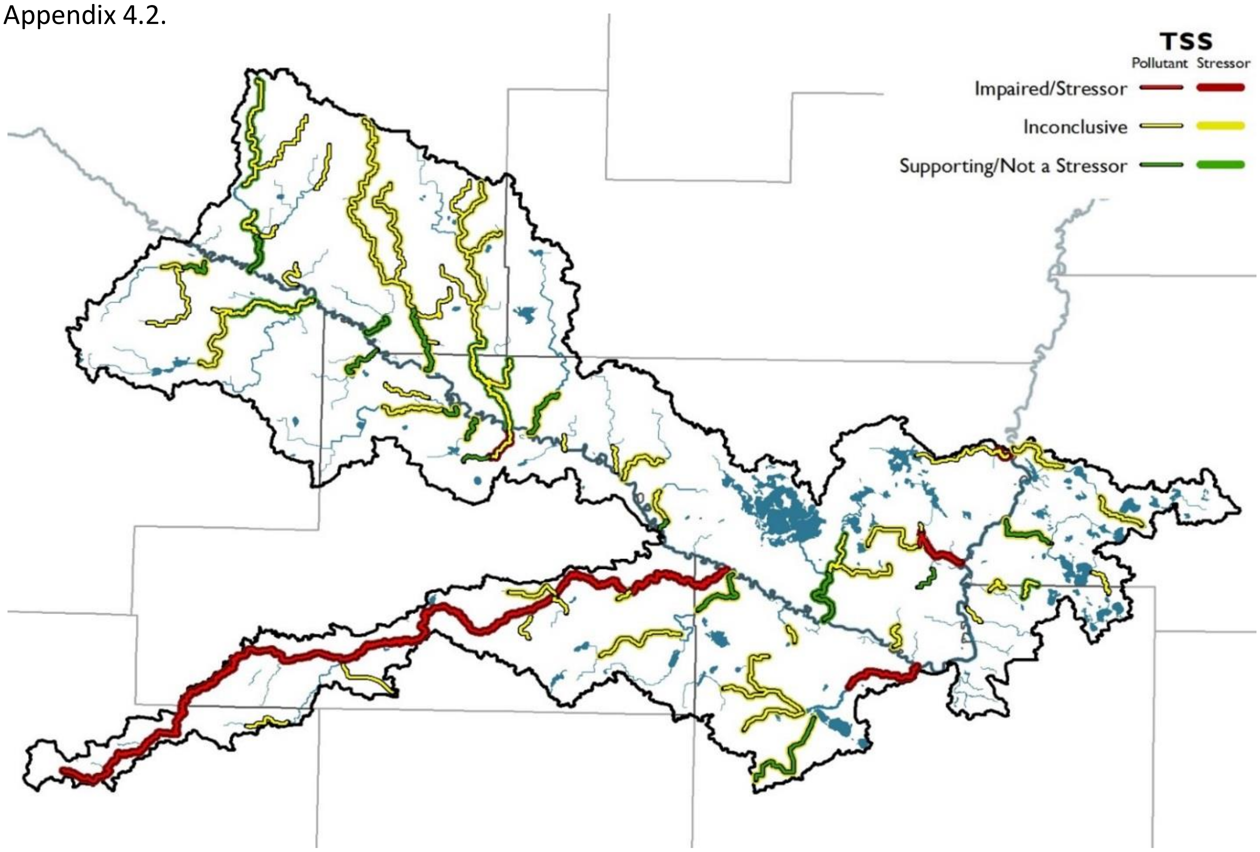


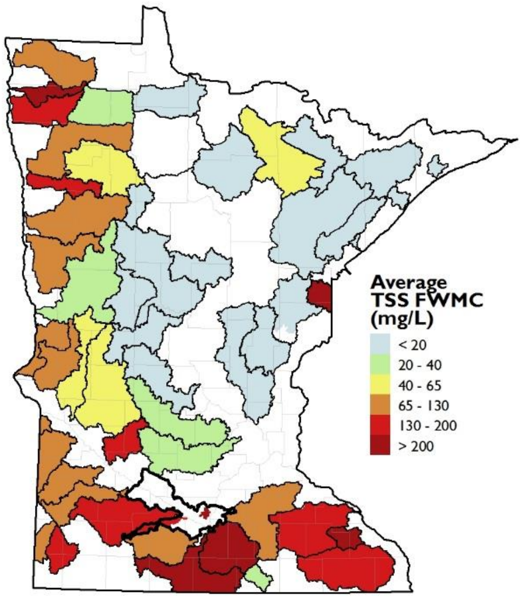
Figure 34: Assessment results show that TSS is a stressor or pollutant in only a few of the stream reaches in the Middle Minnesota River Watershed. Red indicates TSS was identified as a stressor/pollutant (TSS is problematic in that reach), green indicates TSS is not a stressor/pollutant (TSS is not problematic in that reach), and yellow indicates that more data are needed to assess TSS.

Table 16: Assessment results for TSS as a pollutant and/or stressor for stream reaches in the Middle Minnesota River Watershed.

Stream Name	Reach AUID-3	TSS Stressor Assessment	TSS Pollutant Assessment
Altermatts Creek	681		?
Birch Coulee Creek	588	+	?
Birch Coulee Creek	587	+	+
Cherry Creek	541	?	?
Cherry Creek	543	?	?
County Ditch 10 (John's Creek)	571	X	?
County Ditch 10 (John's Creek)	650		+
County Ditch 100	665		?
County Ditch 105	667		?
County Ditch 106A (Fort Ridgely Creek)	688	?	?
County Ditch 11	657	?	?
County Ditch 11	661	?	?
County Ditch 111	672		?
County Ditch 115	673	?	?
County Ditch 115	664		?
County Ditch 124	670	+	?
County Ditch 124	711	+	?
County Ditch 13	712	?	+
County Ditch 22	671		?
County Ditch 27	535	?	?
County Ditch 28	656		?
County Ditch 3	660	?	?
County Ditch 3	525		?
County Ditch 4/County Ditch 39	545	+	?
County Ditch 46A	678	?	?
County Ditch 46A	679	?	X
County Ditch 52	636	?	?
County Ditch 56 (Lake Crystal Inlet)	557	?	+
County Ditch 57	649		?
County Ditch 67	658	?	?
County Ditch 85A	669		?
Crow Creek	569	?	+
Eightmile Creek	684	?	+
Fort Ridgely Creek	689	?	+
Fritsche Creek (County Ditch 77)	709	?	?
Heyman's Creek	675	?	?
Heyman's Creek	640		+
Huelskamp Creek	641		?
Judicial Ditch 10	701	?	?
Judicial Ditch 12	582		?
Judicial Ditch 12	707		?
Judicial Ditch 13	717	?	?
Judicial Ditch 13	716	+	?
Judicial Ditch 48	593	?	?
Judicial Ditch 8	666	?	?
Little Cottonwood River	676	X	X
Little Cottonwood River	677	X	X
Little Rock Creek (Judicial Ditch 31)	686	?	?
Little Rock Creek (Judicial Ditch 31)	687	+	?
Minneopa Creek	531	?	?
Minneopa Creek	534	X	X
Morgan Creek	691	?	+
Purgatory Creek	645		?
Rogers Creek	547	X	?
Rogers Creek (County Ditch 78)	613		?
Sevenmile Creek	562	X	X
Sevenmile Creek	703	X	X
Sevenmile Creek	702		?
Shanaska Creek	693	?	+
Shanaska Creek	692		?
Spring Creek	573	?	+
Spring Creek (Hindeman Creek)	574	?	?
Spring Creek (Judicial Ditch 29)	622	?	?
Swan Lake Outlet (Nicollet Creek)	683	+	+
Threemile Creek	704	+	+
Unnamed creek	550	?	?
Unnamed creek	577	?	?
Unnamed creek	715	?	+
Unnamed creek	696	+	?
Unnamed creek	548		?
Unnamed creek	607		?
Unnamed creek	662		?
Unnamed creek	663		?
Unnamed creek	694		?
Unnamed creek	718		?
Unnamed creek	644		+
Unnamed creek (County Ditch 11)	646		?
Unnamed creek (Sevenmile Creek Tributary)	637		+
Unnamed ditch	647		?
Wabasha Creek	699	?	?
Wabasha Creek	527	+	?

+	=	supporting/not a stressor
?	=	inconclusive (need more data)
x	=	impaired/stressor

From a state-wide perspective, the Middle Minnesota River Watershed has a high yield and FWMC of TSS (Figure 35). Data from the WPLMN Seven Mile Creek and Little Cottonwood River Subwatershed sites show that those river concentrations often spike above the 65 mg/L standard.



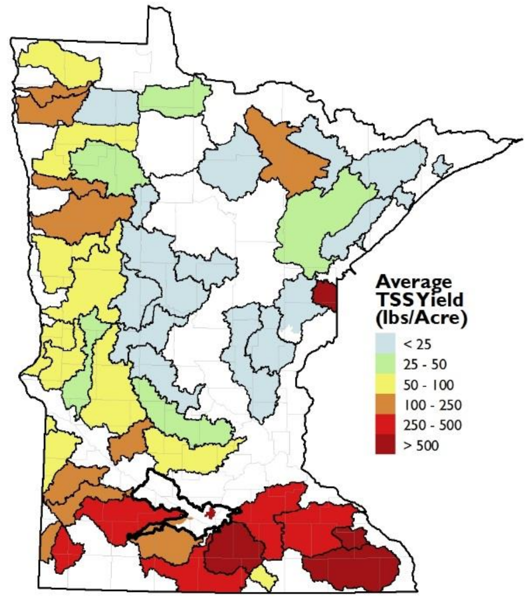


Figure 35: The Middle Minnesota River Watershed TSS loads represented by the Little Cottonwood River (monitored 2014 through 2016) has FWMC of 162 mg/L and yield of 307 lbs/acre. Seven Mile Creek (monitored 2007 through 2016) TSS has FWMC of 257 mg/L and yield of 465 lbs/acre. Data are from the WPLMN.

An HSPF model was developed for the Middle Minnesota River Watershed. The model's estimated FWMC for the years 1996 through 2012 is illustrated in Figure 36. This model output can be used to estimate conditions in stream reaches that have not been monitored.

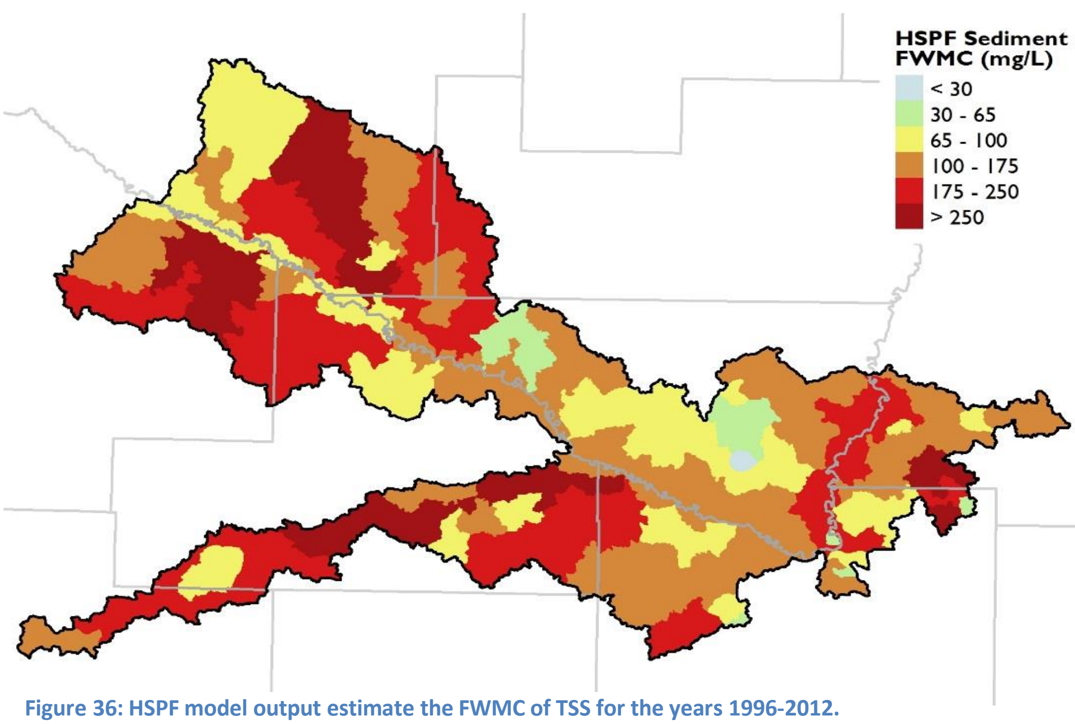


Figure 36: HSPF model output estimate the FWMC of TSS for the years 1996-2012.

Sources

The primary sources of sediment can be broken into three groups: upland, channel, and ravine. Other sources have minimal contributions: point source contributions for the years of 2011 through 2015 are estimated to total less than 0.1% of the Middle Minnesota River Watershed's sediment load (Appendix 4.2).

Upland sediment contributions include farm field surface and gully erosion, sediment that is washed away from roads and developed areas, and other surface erosion. Upland sediment contributions typically occur when bare soils erode due to rain or snow melt.

Channel sediment contributions are dominated by streambank, ditch bank, and bluff erosion but also include channel bed, sand bar, and other erosion from areas adjacent to the waterbody. While some amount of channel migration and associated bank/bluff erosion is natural, altered hydrology has likely increased stream flow, contributing to excessive bank/bluff erosion. The Minnesota Department of Natural Resources (DNR 2010) discusses the multiple causes of streambank erosion, including how altered hydrology influences streambank erosion.

Ravines occur in locations where a flow path drops elevation drastically. Because of the elevation drop in the Middle Minnesota River Watershed, ravines are common in some areas. While some ravine erosion is natural, often times the natural erosion rate is greatly accelerated when surface and subsurface drainage waters from farms, cities, rural developments, road drainage, etc. are routed down a ravine. In this way, altered hydrology can cause excessive ravine erosion.

While some streambank erosion is part of the natural channel evolution process, streambank erosion due to unstable streams is common in the Middle Minnesota River Watershed as discussed in the *Minnesota River, Mankato Watershed Characterization Report* (DNR 2016). According to this report, most stream instability in the Middle Minnesota River watershed is from poor riparian vegetation management (loss of habitat), altered hydrology (higher flows due to losses in water storage and ET, and decreased channel residence times due to stream straightening). Sites with good riparian vegetation appeared more resilent than those without dense, deep-rooted vegetation.

Some streams contain enough instream production of algae that it may be a suspended solids source of concern. In-stream algae production is due to excessive phosphorus contributions and stagnant flow conditions creating eutrophic conditions. At the watershed-wide scale, this contribution is minimal. Therefore, issues related to instream algae production are addressed in the Phosphorus/Eutrophication and Altered Hydrology sections of this report.

A numeric estimate of the Middle Minnesota River Watershed's sediment sources is presented in Figure 37; refer to the Sources Overview in Section 2.1 for more details. Cultivated crop surface runoff, ravine, and streambank erosion are the dominant sources of sediment throughout the Middle Minnesota River Watershed.

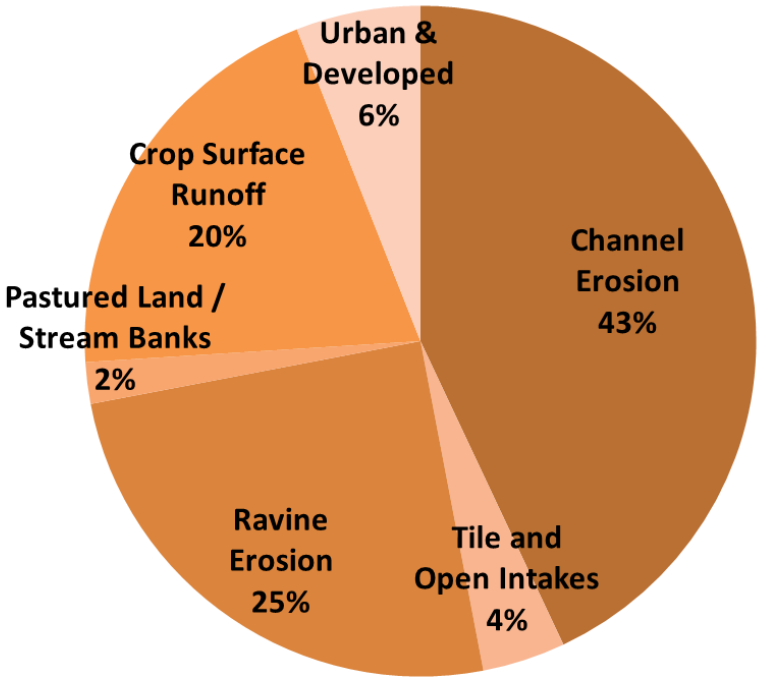


Figure 37: TSS source assessment in the Middle Minnesota River Watershed estimates that the largest sources of sediment are from channel erosion and cultivated crop surface runoff.

Additional information regarding the suspected sources and issues related to TSS were compiled for bio-impaired stream reaches in the Stressor ID Report and are summarized in Appendix 4.2.

Goal & 10-year Target

A two-part watershed-wide sediment goal was selected for the Middle Minnesota River Watershed, reflecting the dichotomy of observed conditions: many areas are supporting aquatic life and are not stressed by sediment, while others need rather substantial sediment reductions. A restoration goal of an average 50% sediment reduction applies to watershed areas with impaired and/or stressed stream reaches (roughly one quarter of the watershed). A protection goal applies to watershed areas with supporting/not stressed stream reaches, which applies to roughly three quarters of the watershed.

Subwatershed reduction goals were calculated for impaired stream reaches with TMDL data, and indicate reductions up to 88% are needed (Figure 38). Reductions and calculation methods are summarized in the TMDL summary in Appendix 4.3. Most stream reaches impaired and/or stressed by sediment are located in the nick zone of the watershed, areas prone to erosion and where altered hydrology and poor riparian health/vegetation exacerbate sediment contributions.

These goals are revisable and will be revisited in the next iteration of the Watershed Approach. Strategies to meet the goals and 10-year targets and methods to prioritize regions for sediment reductions are summarized in Section 3.

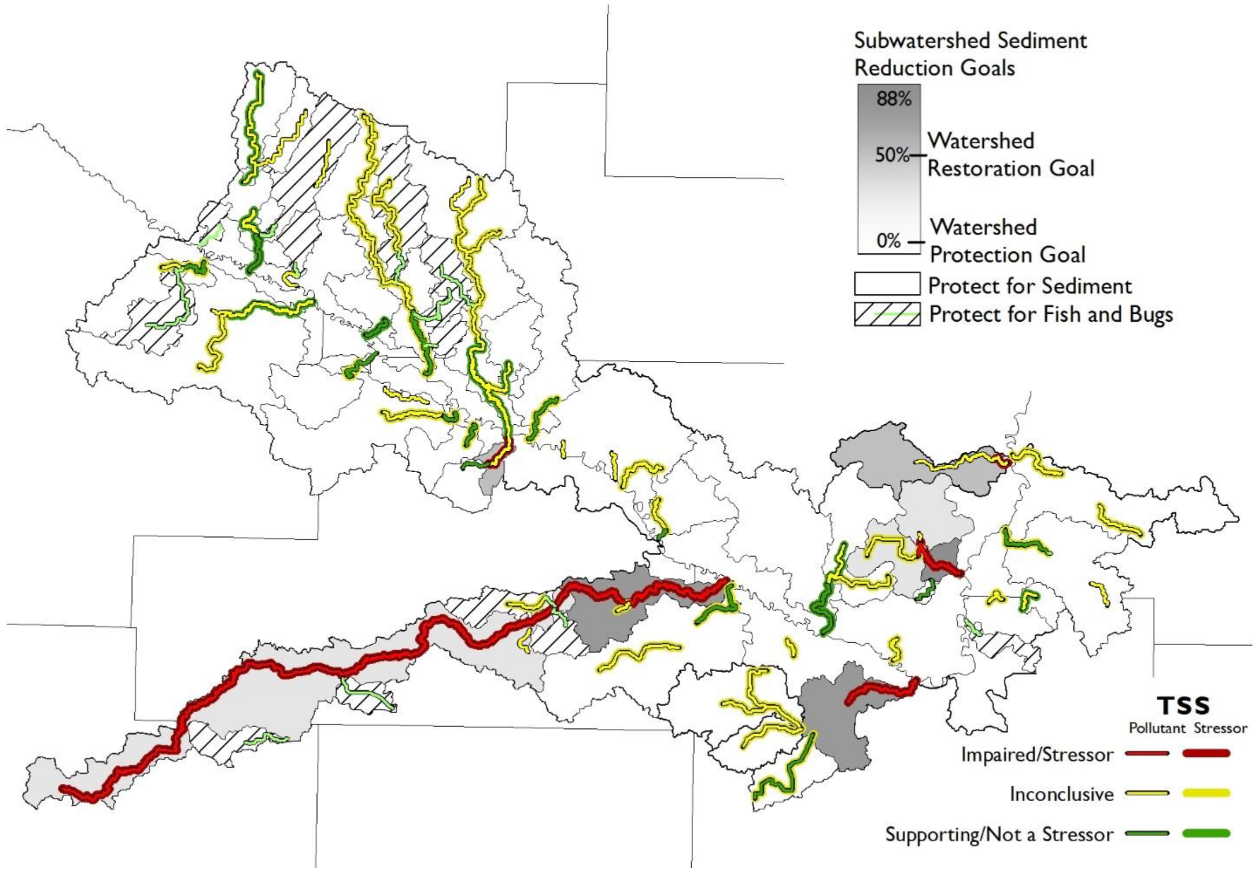


Figure 38: A two-part sediment goal was selected for the Middle Minnesota River Watershed. Subwatersheds with impaired/stressed stream reaches have an average 50% reduction goal (with individual subwatershed goals that range up to an 88% reduction). Subwatersheds with supporting/not stressed stream reaches have a protection goal.

Temperature

Temperature, as identified in this report, refers to excessively warm stream water temperatures. Warm water contains less DO than cold water, and therefore limits oxygen available for respiration. Additionally, warm water temperatures can impact growth and reproduction, cause egg mortality, increase disease rates, and cause direct mortality. Some species, such as trout, are particularly incapable of withstanding warm water temperature. When trout are present in a stream, it typically has a designated use of “cold-water” to support this aquatic life. These cold-water streams have a lower threshold to be considered stressed or impaired by warm water temperatures.

Status

Of the five stream reaches monitored to assess if temperature is a stressor, two were impaired, and three were inconclusive. Figure 39 illustrates the stream reaches that were assessed for temperature and Table 17 displays those results.

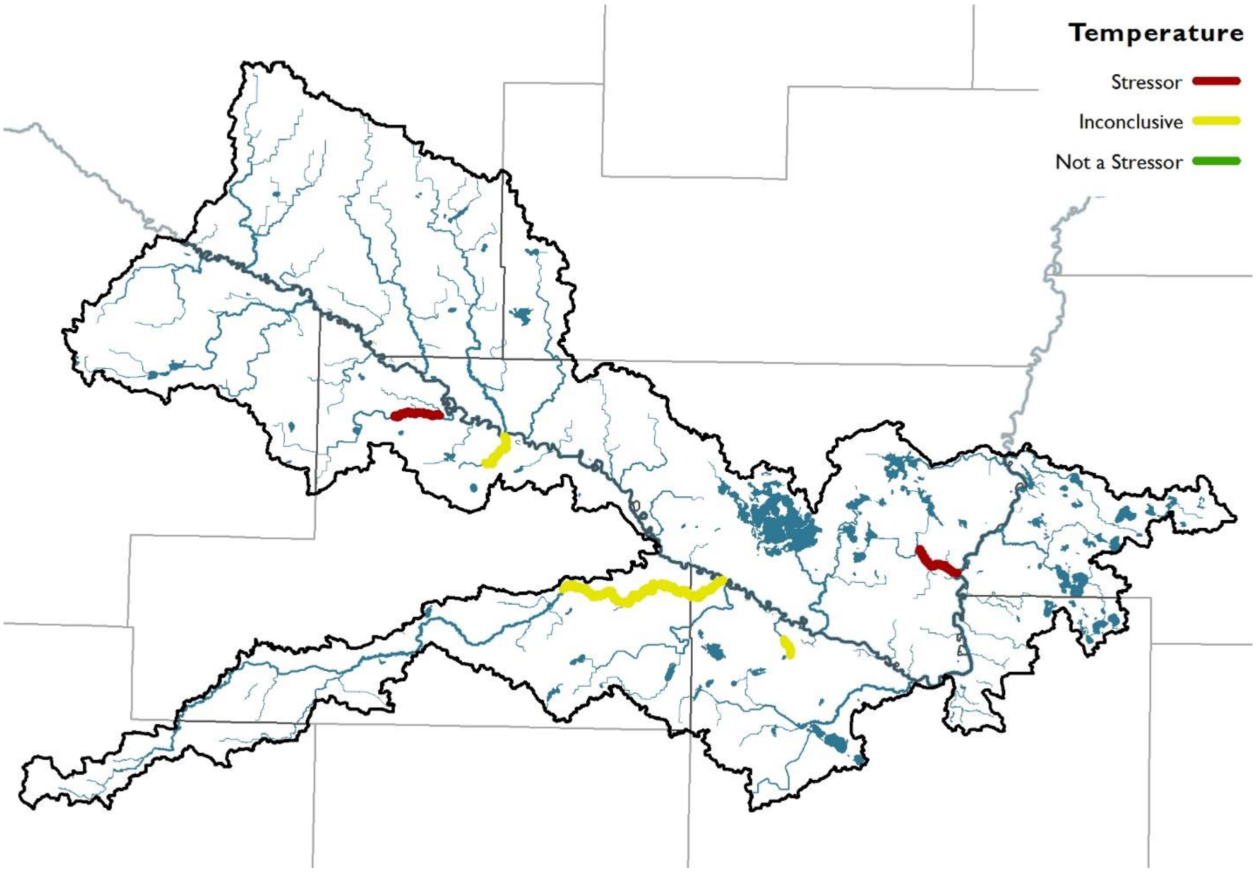


Figure 39: Assessment results show that excessively warm temperatures are stressing aquatic life in two stream reaches in the Middle Minnesota River Watershed. Red indicates a stressor (temperature is problematic in that reach), and yellow indicates that more data are needed to assess temperature as a stressor. Temperature was only assessed as a stressor in designated cold-water streams and where water temperature was observed by field staff to be obviously above normal in warm-water streams.

Table 17: Assessment results for temperature as a stressor for stream reaches in the Middle Minnesota River Watershed.

Stream Name	Reach AUID-3	Temperature Assessment
County Ditch 10 (John's Creek)	571	?
Unnamed creek	577	?
Little Cottonwood River	677	?
Sevenmile Creek	562	X
Spring Creek (Hindeman Creek)	574	X

x = stressor

? = inconclusive (need more data)

Sources

The temperature issues identified in the Middle Minnesota River Watershed Stressor ID Report are caused by other inter-connected stressors including: altered hydrology, turbid waters due to eutrophication and/or excess sediment, and degraded habitat (decreased riparian vegetation/shade) for both stressed stream reaches. Point sources do not appear to be a source of thermal stress to aquatic life in this watershed.

Goal & 10-year Target

The goal for the two cold-water stream reaches impacted by warm water temperatures is to sufficiently decrease the summer water temperature to support a cold-water fishery. Because temperature is primarily a response of other stressors, the effective goal and 10-year target for temperature is to meet the altered hydrology, habitat, eutrophication, and sediment goals and 10-year targets.

This goal is revisable and will be revisited in the next iteration of the Watershed Approach. Strategies and methods to prioritize regions to address altered hydrology, habitat, eutrophication, and sediment are summarized in Section 3.

Bacteria

Fecal coliform and *E. coli* (referred to in this report as bacteria) are indicators of animal or human fecal matter, and possibly other pathogens, presence in a water body. Aquatic recreation can become unsafe when bacteria is present, as contact with fecal matter and other pathogens can potentially lead to severe illnesses. Fecal bacteria are living organisms that can die off or reproduce, sometimes complicating detection and source assessment.

Status

Of the stream reaches monitored to assess if bacteria is a pollutant, 34 were impaired, 5 were inconclusive, and zero were supporting. Figure 40 illustrates the stream reaches assessed for bacteria and Table 18 tabulates those results.

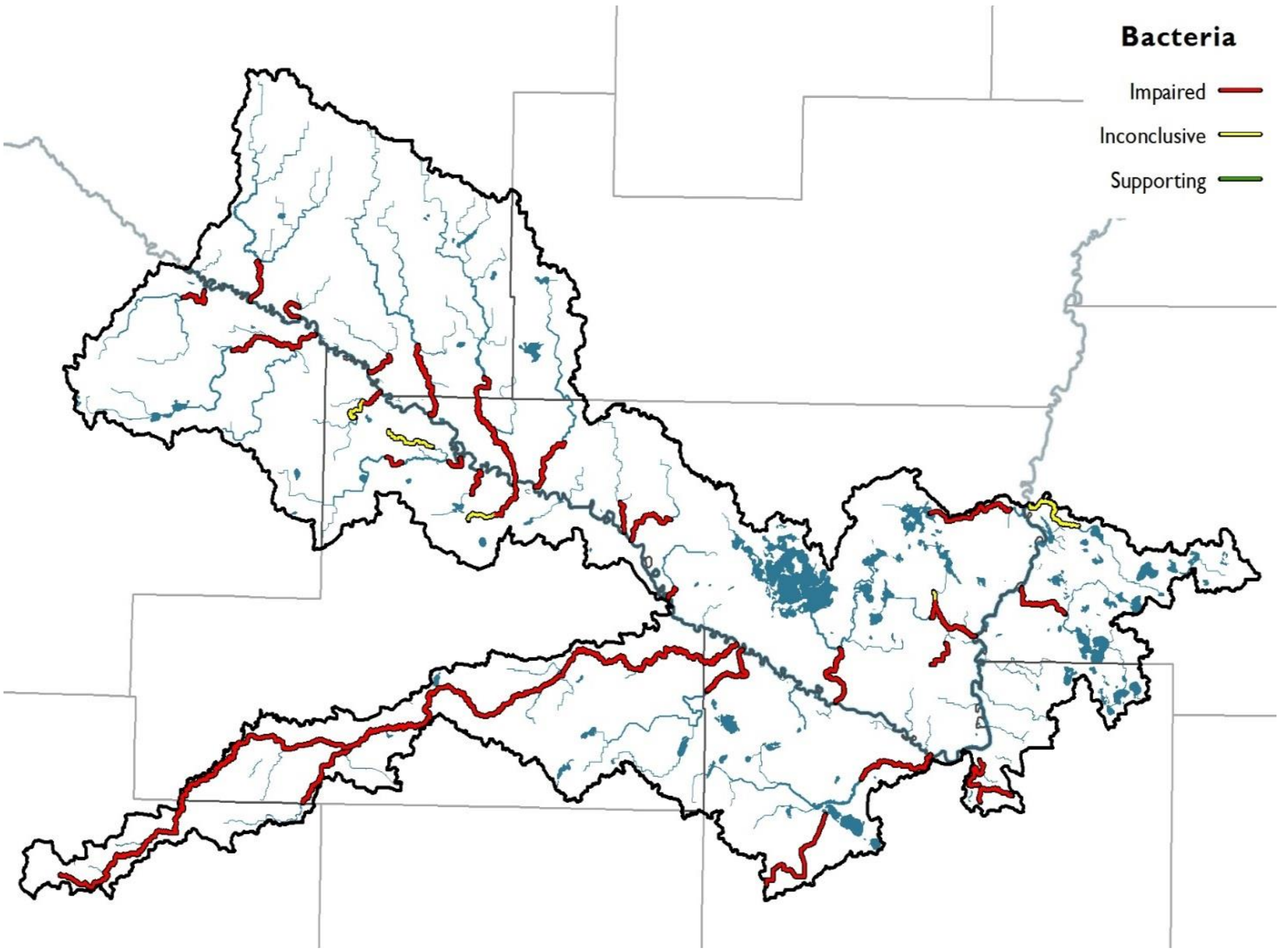


Figure 40: Assessment results show that bacteria is a pollutant across much of the Middle Minnesota River Watershed. Red indicates an impairment (bacteria is problematic in that reach), and yellow indicates that more data are needed to assess bacteria.

Unlike nutrients and sediment, statewide bacteria monitoring is not done by the WPLMN; therefore, statewide results are not readily available for comparison. Furthermore, HSPF does not model bacteria so model results are also not available.

Table 18: Assessment results for bacteria as a pollutant in stream reaches in the Middle Minnesota River Watershed.

Stream Name	Reach AUID-3	Bacteria
Altermatts Creek	518	X
Birch Coulee Creek	587	X
Cherry Creek	543	?
County Ditch 10 (John's Creek)	650	?
County Ditch 10 (John's Creek)	571	X
County Ditch 13	712	X
County Ditch 46A	679	X
County Ditch 56 (Lake Crystal Inlet)	557	X
County Ditch 57	649	?
Crow Creek	569	X
Eightmile Creek	684	X
Fort Ridgely Creek	689	X
Fritsche Creek (County Ditch 77)	709	X
Heyman's Creek	640	X
Huelskamp Creek	641	X
Little Cottonwood River	676	X
Little Cottonwood River	677	X
Little Rock Creek (Judicial Ditch 31)	687	X
Morgan Creek	691	X
Purgatory Creek	645	X

Stream Name	Reach AUID-3	Bacteria
Rogers Creek (County Ditch 78)	613	X
Sevenmile Creek	702	?
Sevenmile Creek	562	X
Sevenmile Creek	703	X
Shanaska Creek	693	X
Spring Creek	573	X
Spring Creek (Judicial Ditch 29)	622	X
Swan Lake Outlet (Nicollet Creek)	683	X
Threemile Creek	704	X
Unnamed creek	715	?
Unnamed creek	600	X
Unnamed creek	602	X
Unnamed creek	603	X
Unnamed creek	604	X
Unnamed creek	644	X
Unnamed creek (Sevenmile Creek Tributary)	637	X
Unnamed ditch	598	X
Wabasha Creek	527	X
Wabasha Creek	527	X

x = impaired

? = inconclusive (need more data)

Sources

Bacteria source assessment can be difficult due to the dynamic and living attributes of bacteria. Therefore, the factors associated with bacterial presence provide insight and confidence to bacterial source estimates. Emmons & Oliver Resources (2009) conducted a *Literature Summary of Bacteria*. The literature review summarized factors that have either a strong or a weak positive relationship to fecal bacterial contamination in streams (Table 19).

Table 19: Bacteria sourcing can be difficult due to the bacteria's ability to persist, reproduce, and migrate in unpredictable ways. Therefore, the factors associated with bacterial presence provide some confidence to bacterial source estimates.

Strong relationship to fecal bacterial contamination in water	**Weak** relationship to fecal bacterial contamination in water
• High storm flow (the single most important factor in multiple studies) • % rural or agricultural areas greater than % forested areas in the landscape (entire watershed area) • % urban areas greater than % forested riparian areas in the landscape • High water temperature • Higher % impervious surfaces • Livestock present • Suspended solids	• High nutrients • Loss of riparian wetlands • Shallow depth (bacteria decrease with depth) • Amount of sunlight (increased UV-A deactivates bacteria) • Sediment type (higher organic matter, clay content and moisture; finer-grained) • Soil characteristics (higher temperature, nutrients, organic matter content, humidity, moisture and biota; lower pH) • Stream ditching (present or when increased) • Epilithic periphyton present • Presence of waterfowl or other wildlife • Conductivity

Fecal bacteria source identification is further confounded because some bacteria may be able to survive and reproduce in streams as reported by Chandrasekaran et al. (2015) in a study of a Middle Minnesota River Watershed stream, Seven-mile Creek. This study, and a small but growing body of evidence, suggests that environmental propagation of bacteria is likely in at least some systems. However, the portion from this source type is not well understood as of yet. In order to acknowledge this source type, but without certainty, the authors of this report are assigning an assumed 13% of the watershed's bacteria population to in-stream reproduction.

A numeric estimate of the Middle Minnesota River Watershed's fecal bacteria sources is presented in Figure 41. This source assessment was calculated based on the amount of fecal matter produced by source type and estimated delivery ratios and vetted by the WRAPS Feedback Group (see calculations in Appendix 4.2).

The single largest fecal bacteria source in the Middle Minnesota River Watershed was estimated as crop surface runoff where manure has not been incorporated. Most of the manure that is applied to fields originates from feedlot operations. Refer to the Sources Overview in Section 2.1 for more information on feedlots in the Middle Minnesota River Watershed.

Human contributions come from wastewater treatment plants (WWTPs), septic systems (particularly those that are considered imminent public health threats [IPHT] or failing), and untreated homes or communities (also known as "straight-pipes", which are becoming more rare as improvements are made).

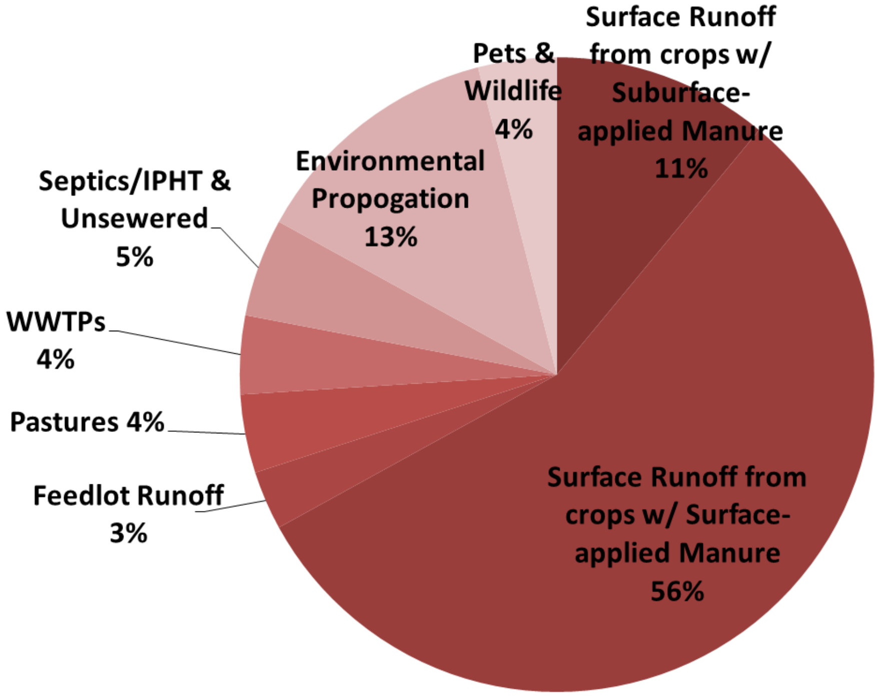


Figure 41: Source assessment work estimates that runoff from crops with surface-applied manure is the largest source of bacteria in the Middle Minnesota River Watershed.

Goal & 10-year Target

The watershed-wide bacteria goal is a 60% reduction for the Middle Minnesota River Watershed (Figure 42). Subwatershed goals, which were calculated from the TMDL, vary from a 10% to 87% reduction. Refer to the TMDL summary in Appendix 4.3 for subwatershed reduction goals and calculation methods. These goals are revisable and will be revisited in the next iteration of the Watershed Approach. Strategies to meet the goals and 10-year targets and methods to prioritize regions for bacteria reductions are summarized in Section 3.

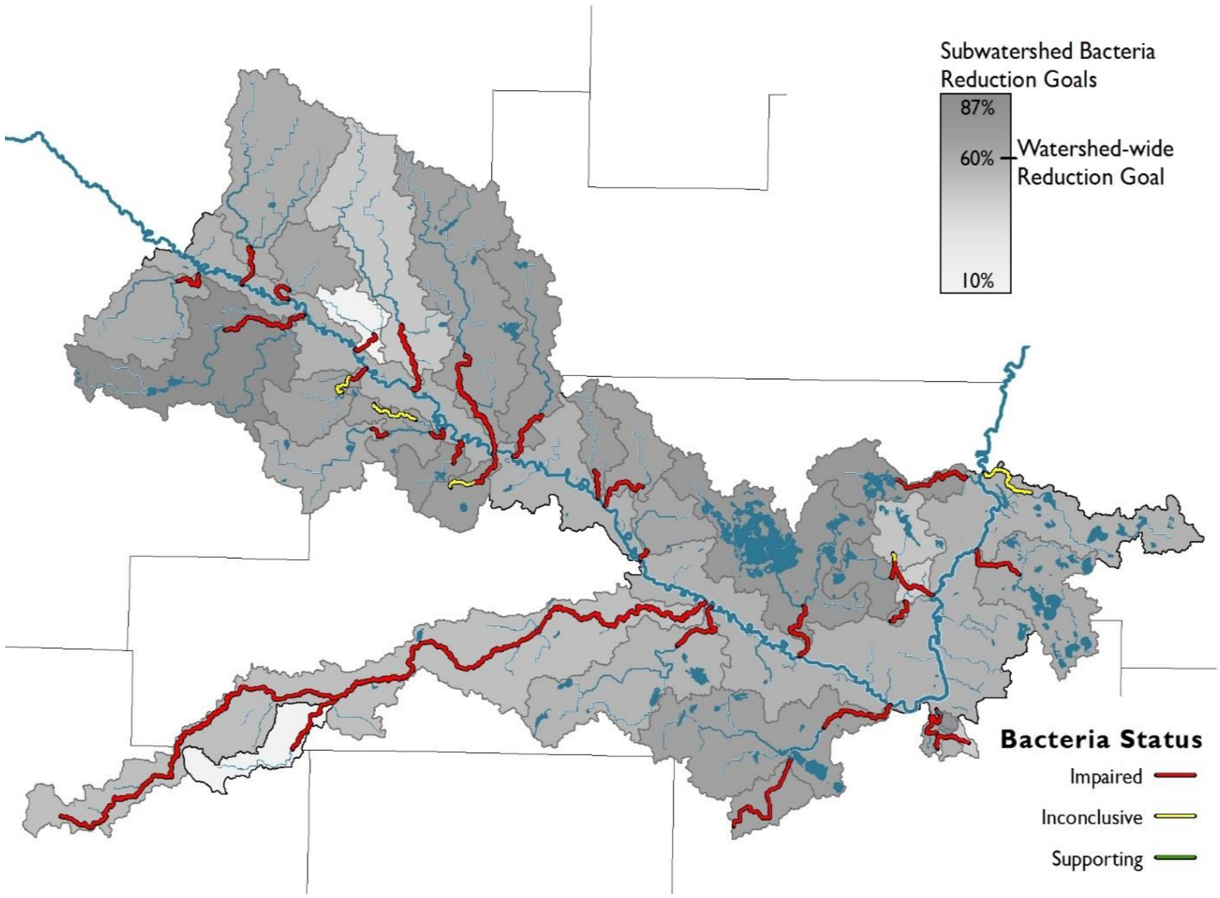


Figure 42: The watershed-wide bacteria goal is a 60% reduction in the Middle Minnesota River Watershed. Subwatershed bacteria reduction goals ranged from a 10% to 87% reduction.

3 Restoration & Protection

This section summarizes scientifically-supported strategies to restore and protect waters, information on the social dimension of restoration and protection, and priority areas to restore or protect waters. This section culminates in the “Strategies Table”, a tool intended to provide high-level information on the changes necessary to restore and protect waters within the Middle Minnesota River Watershed. Using the Strategies and Priorities Tables, local conservation planning staff can prioritize areas and spatially target BMPs or land management strategies using GIS or other tools.

3.1 Scientifically-Supported Strategies to Restore and Protect Waters

This section summarizes studies and data on land management and BMP effects on water quality. This information is more technical in nature, but these summaries may be helpful to landowners, decision makers, and citizens to understand the impact of various strategies and BMPs on water quality.

To address the widespread water quality impairments in agriculturally dominated watersheds such as the Middle Minnesota River Watershed, comprehensive and layered BMP suites are likely necessary. A conceptual model displaying this layered approach is presented by Tomer et al. (2013; Figure 43). Another model to address widespread nutrient problems is presented in the *Minnesota Nutrient Reduction Strategy* (MPCA 2015j), which calls for four major steps involving millions of acres statewide: 1) increase fertilizer use efficiencies, 2) increase and target living cover, 3) increase field erosion control, and 4) increase drainage water retention. A third example of a comprehensive, layered approach is being demonstrated with a “Treatment Train” approach in the Elm Creek Watershed (ENRTF 2013), which has demonstrated layered strategies including: 1) upland: cover crops and nutrient management, 2) tile treatment: treatment wetlands and controlled drainage, and 3) in-stream: woody debris and stream geomorphology restoration.

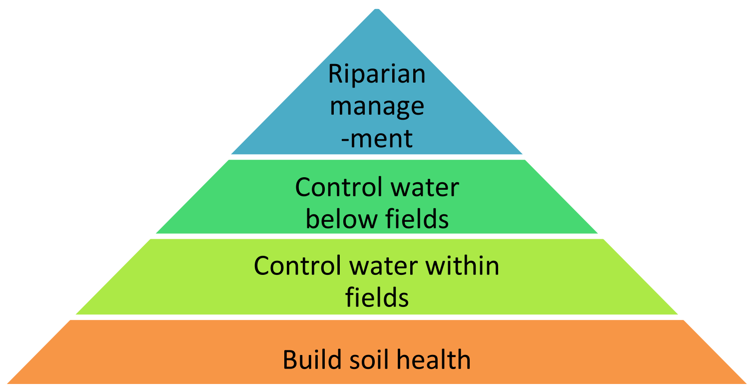


Figure 43: This conceptual model to address water quality in agricultural watersheds uses 1) soil health principles as a base: nutrient management, reduced tillage, crop rotation, etc., then 2) in-field water control: grassed waterways, controlled drainage, filter strips, etc., then 3) below-field water controls: wetlands, impounds, etc., and then 4) riparian management: buffers, stabilization, restoration, etc.

Agricultural BMPs

Since the Middle Minnesota River Watershed land use and pollutant sources are generally dominated by agriculture, reducing pollutant/stressor contributions from agricultural sources is a high priority. A comprehensive resource for agricultural BMPs is *The Agricultural BMP Handbook for Minnesota (2017 Revision)* (MDA 2017b). Additional field data has been compiled by Iowa and Minnesota for review in their respective state nutrient reduction strategies. This information is included in Appendix 4.4.

Urban, Residential, and Septic System BMPs

Developed areas (including cities and towns) and rural residents also impact water quality. A comprehensive resource for urban and residential BMPs is the *Minnesota Stormwater Manual* (MPCA 2014a). This resource is in electronic format and includes links to studies, calculators, special considerations for Minnesota, and links regarding industrial and stormwater programs. Information and BMPs for Septic Systems are provided by EPA (2014b) and the University of Minnesota.

Stream and Ravine Erosion Control

By-and-large, wide-scale stabilization of eroding streambanks and ravines is cost-prohibitive. Instead, first addressing altered hydrology (i.e. excessive flows) within the landscape can help decrease wide-scale stream and ravine erosion problems as discussed in *the Minnesota River Valley Ravine Stabilization Charrette* (E&M 2011) and the Sediment Reduction Strategy for the Minnesota River Basin and South Metro Mississippi River (MPCA 2015h). Improving practices directly adjacent to the stream/ravine (e.g. buffers) can also decrease erosion as summarized in *The River Restoration Toolbox* (IA DNR 2019). In some cases; however, infrastructure may need to be protected, or a ravine/streambank may be experiencing such severe erosion that stabilizing the streambank or ravine using engineered practices is deemed necessary.

Culverts, Bridges, and Connectivity Barriers

Strategies to address connectivity barriers include correctly sizing, removing, or otherwise mitigating the connectivity barriers, and need to be assessed on a case-by-case basis. Bridges and culverts should be sized using flow regime and stream properties using a resource such as Hillman (2015). The effects of dams and impoundments can be mitigated to minimize impacts to aquatic life. Overall system health should be considered; restoring connectivity may not be cost effective if other stressors are creating significant impacts to aquatic communities.

Lake Watershed Improvement

Strategies to protect and restore lakes include both strategies to minimize pollutant contributions from the watershed and strategies to implement adjacent to and in-lake, and are summarized in Appendix 4.4. Strategies to minimize pollutant contributions from the watershed focus mostly on agricultural and/or stormwater BMPs, depending on the land use and pollutant sources in the watershed. The DNR (2014) supplies detailed information on strategies to implement adjacent to and in the lake via *Shoreland Management* guidance.

Computer Model Results

Computer models provide a scientifically-based estimate of the pollutant reduction effectiveness of land management and BMPs. Models represent complex natural phenomena with equations and numeric estimates of natural features, which can vary substantially between models. Because of these varying assumptions and estimates, each model has its strengths and weaknesses and can provide differing results. For these reasons, multiple model results were used as multiple lines of evidence when establishing the strategies tables. N-BMP, P-BMP, and HSPF SAM scenarios are summarized in the Model Summary in Appendix 4.4.

3.2 Social Dimension of Restoration and Protection

Most of the changes that must occur to restore and protect water resources are voluntary; therefore, communities and individuals ultimately hold the power to restore and protect waters in the Middle Minnesota River Watershed. For this reason, the Clean Water Council (MPCA 2013b) recommended that agencies integrate civic engagement in watershed projects (MPCA 2010a).

A growing body of evidence detailed in *Pathways for Getting to Better Water Quality: The Citizen Effect* (Morton and Brown 2011) suggests that to achieve clean water in the voluntary-adoption system in place, a citizen-based approach is likely the most feasible means to success. Specifically, the transition to more sustainable practices must be developed, demonstrated, and spread by trusted leaders within the community. When leaders embrace a transition, communities are more likely to accept and adopt the transition. When leaders and communities develop solutions, they are likely to intertwine financial security and environmental stewardship - instead of viewing them as conflicting goals. In this way, the community is more likely to improve water quality while securing sustainable farms and cities for future generations. If this pathway to waterbody improvement is to be embraced, however, one of the most important uses for limited resources is to further develop and support local leaders to take on this challenging work.

Civic engagement and public participation was a major focus during the Middle Minnesota River Watershed project. The MPCA worked with county and SWCD staff in the watershed, consultants, and other state agency staff to work on eight projects to promote civic engagement and collaboration in the area.

The Middle Minnesota River Watershed civic engagement projects were:

- Minnesota River at Mankato: Stakeholder Identification and Analysis
- Middle Minnesota River Watershed Zonation Analysis
- Minneopa and Fort Ridgely Watershed Interpretive Signs
- Middle Minnesota River Watershed SWCD WRAPS Strategy
- Middle Minnesota River Watershed Renville County WRAPS Strategy
- Middle Minnesota River Watershed Nicollet County WRAPS Strategy
- Middle Minnesota River Watershed Lakes WRAPS Strategy
- Lake Hallett Civic Engagement Project

The following few pages contain a brief summary and results of each project. The end of this section contains opportunities and constraints to water quality improvements identified as part of these individual projects. Complete final reports and attachments are found in the *Middle Minnesota River Watershed Approach Civic Engagement Project Summary* (MPCA 2018c).

Civic Engagement Project Summaries

Minnesota River at Mankato: Stakeholder Identification and Analysis

Fortin Consulting Inc. (FCI) created a directory to identify organizations working in the watershed and develop connections between watershed stakeholders. The directory is a comprehensive network of businesses, organizations, government agencies, and some individuals who are interested in water resources for recreation and economic opportunities in the watershed. Many of the contacts were interviewed by phone or email for details about their organization as well as to ask about other organizations they thought should be included.

FCI worked with the MPCA project manager to determine the formats for the directory. The directory was created as an Excel worksheet that could be sorted by the project partners and updated as needed. The excel version of the *Middle Minnesota River Watershed Directory* (MPCA 2015k) is available online and a pdf copy is available upon request.

Middle Minnesota River Watershed Zonation Analysis

Zonation Analysis is a process that uses locally-identified preferences or values to identify and prioritize areas important for protection and restoration, based on the DNR's five-component healthy watershed conceptual model (biology, hydrology, water quality, geomorphology and connectivity). Watershed, county and SWCD staff were surveyed for their values and perceptions in relation to water resource management concerns. This "valuation data" is used to weight each of the healthy watershed categories. The valuation data was utilized by GIS analysis to identify geographic priority areas within the watershed. Data was also collected on priorities for conservation practices. This data was overlaid with geographic priorities, to identify areas for restoration and protection based on social interest, and to create maps of potential restoration and protection areas in the watershed (Figure 44). The process generated collaborative discussion among the Middle Minnesota River Watershed technical staff and helped identify focal areas and practices for implementation.

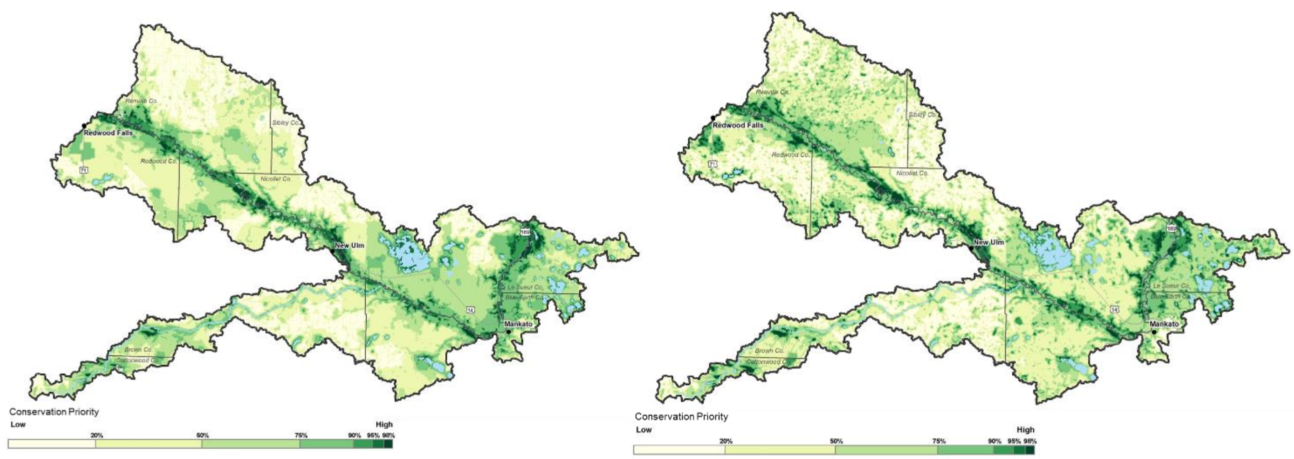


Figure 44: Zonation maps for the Middle Minnesota River Watershed for protection (left) and restoration (right). Analysis from local watershed staff input was used to identify potential areas for restoration and protection based on social interest.

Minneopa and Fort Ridgely Watershed Interpretive Signs

This education and outreach project was designed to inform the public about the subwatersheds of Minneopa Creek and Fort Ridgely Creek in the Middle Minnesota River Watershed. Interpretive signs were designed and installed by DNR and MPCA at Minneopa and Fort Ridgely State Parks to provide an overview of the subwatersheds, three major water quality issues, five examples of how to improve water quality, and how to find additional information. Both Minneopa Creek and Fort Ridgely Creek are suffering from water quality issues including excessive sediment, nutrients and fecal coliform bacteria. The interpretive signs have the potential to educate thousands of visitors annually, as these state parks are popular destinations in the Middle Minnesota River Watershed.

Middle Minnesota River Watershed SWCD WRAPS Strategy

The purpose of the Middle Minnesota River Watershed SWCD WRAPS Strategy project was to identify community/landowner opportunities, obstacles, and opinions on land management and water quality within the Middle Minnesota River Watershed portions of Blue Earth, Brown, Cottonwood, Le Sueur, and Redwood counties. There were six partners involved in this project, Brown SWCD, Brown County Water Planner, Blue Earth SWCD, Cottonwood SWCD, Le Sueur SWCD, and Redwood SWCD. Each of the partners approached the civic engagement portion of the project using varied methods, which included one-on-one landowner interviews, survey mailings, and landowner workshops/public meetings.

Middle Minnesota River Watershed Renville County WRAPS Strategy

This project was used to increase public education and outreach within the Renville and Sibley County portion of the Middle Minnesota River Watershed. Several meetings were held and communication was increased. One-on-one landowner interviews were used to gather information on landowners perspectives on water quality and BMPs. Water quality issues, priorities, and restoration and protection strategies were discussed, which will be used to target areas to implement BMPs in a cost-effective manner. Civic engagement activities have provided awareness to watershed citizens of the issues within the watershed, their impact on water quality, and the actions that need to be taken to improve our water.

Middle Minnesota River Watershed Nicollet County WRAPS Strategy

The purpose of this project was to identify community/landowner opportunities, obstacles, and opinions on land management and water quality in the Nicollet County portion of the Minnesota River Mankato Watershed. This project was a collaboration of MPCA, county staff, University of Minnesota Department of Forestry Staff, and Great River Greening staff to develop a survey that identified attitudes and beliefs surrounding water resources and conservation in the Nicollet County portion of the watershed. Survey data was compiled and presented in a report *Middle Minnesota River Watershed Approach Civic Engagement Project Summary* (MPCA 2018c). The report findings were then highlighted in a public meeting. The public meeting allowed people an opportunity to participate and provide feedback on the challenges of implementing conservation programs.

Middle Minnesota River Watershed Lakes WRAPS Strategy

The purpose of this project was to identify community/landowner opportunities, obstacles, and opinions on land management and water quality in some of the Middle Minnesota River Watershed lakes. The findings from this project informed the development of the WRAPS report regarding lakes in Blue Earth and Le Sueur counties in the Middle Minnesota River Watershed. There were three education and information meetings in the watershed, and one presentation at a lake association annual meeting. More than 200 watershed citizens, local officials, and technical staff attended the meetings. Written surveys and face-to-face interviews were used to collect citizen, landowner, land manager and local government officials' opinions about problems, solutions, and obstacles to protecting and restoring water quality in lake watersheds in the Middle Minnesota River Watershed. Lists of strategies were developed for each lake. The list of strategies include shoreland lake BMP project development, stormwater management, shoreland management, soil health, nutrient management, wetland restoration and enhancement, education and technical assistance.

Lake Hallett Civic Engagement Project

In the summer of 2015, the MPCA was contacted regarding the degrading condition of Lake Hallett (aka Hallett's Pond) in St. Peter, Minnesota. Several severe nuisance algae blooms had occurred earlier that summer. Monitoring staff added Lake Hallett into the Citizen Lake Monitoring Program plus (CLMP+) program to supplement the IWM. The MPCA staff met with a small group of citizens, whom then decided to do community engagement work. To work towards transparency and with the goal to better connect state agency water quality staff with the City of St. Peter, the MPCA staff organized an informational meeting with the city council.

A planning team of citizens, city council members, and an MPCA staff were convened to plan a community engagement meeting. Three questions were discussed at this meeting and eventually action groups were organized. Main visions for the Hallett Natural Area were identified which included: accessible trails, community caring for the space, educational use, clean water, and family friendly water activities. Unfortunately, the citizen who provided the leadership to these community organizing efforts moved out-of-state, but the Lake Hallett Association has continued to sponsor education and recreation events on Lake Hallett, local conservation groups have worked to secure funding for watershed improvements, and the city has worked to develop recreational opportunities and other outreach.

Opportunities and Constraints

Based on the efforts of the projects summarized above, opportunities and constraints for water quality improvements were identified.

Identified constraints to addressing water quality issues include:

1. Financial resources are lacking. Local partners, community leaders, state agency staff and local business partners could work together to develop new funding opportunities.
2. There is a lack of centralized local leadership for attaining watershed-wide goals. Local partners could work with community leaders to start building collaborative leadership around water quality issues of importance across county boundaries.
3. Programs are too complex and not flexible enough. Local partners and agency staff could work together to develop easier and efficient programs to suit landowner interest and need.

4. Programs should target smaller areas such as subwatersheds to build social networks and promote civic engagement in water quality. Local partners should seek new opportunities focused on subwatersheds based on local priorities and landowner interest.
5. Face-to-face conversations are needed to make significant progress in the watershed. Future opportunities to expand face-to-face conversations regarding water quality should be explored. Conversations during the civic engagement projects lead to greater interest and involvement in local conservation programs.

The future opportunities include:

1. Local conservation professionals can strategically target BMPs including stormwater management, shoreland management, soil health, nutrient management, and wetland restoration and enhancement.
2. Local conservation professionals and residents are interested in continuing education efforts focused on water quality concerns and practices in both urban and rural areas.
3. Watershed residents have a strong interest in protecting the few unimpaired lakes in the watershed.
4. Local staff and elected officials show interest in revising stormwater management policies.
5. Landowners have a new commitment and interest in nutrient management, tillage management, and cover crops. They are interested in trying denitrifying bioreactors and phosphorus removal tank systems.
6. Local conservation professionals should encourage conservation success stories, demonstration sites, and field days highlighting the effectiveness of conservation practices in improving water resources.

3.3 Selected Strategies to Restore and Protect Waters

Strategies to meet the water quality goals and 10-year targets are presented in Table 21 (goals) and Table 22 (10-year targets) for the Middle Minnesota River Watershed. Table 21 is organized by pollutant/stressor and provides a summary of the conditions, goals, 10-year targets, and high-level strategies and adoption rates (in narrative form). Table 22 provides a suite of strategies for each land use and specific practices selected by the WRAPS Feedback Group to meet the 10-year targets.

Data and models indicate that comprehensive and integrated BMP suites are necessary to bring waters in the Middle Minnesota River Watershed into supporting status (refer to model summary in Appendix 4.4). However, there are current limitations in BMP adoption, some technologies are not yet feasible, and the approximate timeframe for these comprehensive changes is 50 years. For these reasons, recommending specific practices and refined adoption rates capable of cumulatively achieving all water quality goals is not practical and would likely need substantial future revision. Therefore, the strategies and adoption rates in Table 21 are presented in a high-level, narrative format rather than a specific, practice-oriented and numerically-accounted format.

Intended to be useful for shorter-term planning, strategies and specific practices estimated to meet the 10-year water quality targets are presented in Table 22. The practices and relative (highest to lowest) adoption rate were selected by the WRAPS Feedback Group and then the numeric adoption rates that meet the selected 10-year targets were estimated with a spreadsheet calculator (see Appendix 4.4). The results were corroborated with model studies.

In order to restore impairments and protect threatened waters, strategies need to be implemented in the contributing watersheds of impaired water bodies (or supporting water bodies with declining trends). In the case of the Middle Minnesota River Watershed, impairments were found throughout the watershed. Therefore, some practices will need to be implemented in nearly all regions of the watershed. Areas with higher reduction goals (as presented in the goals maps in Section 2.2) will likely need higher adoption of practices, and the specific practices used in any one area should meet the identified sources in that area. Furthermore, not all strategies are appropriate for all locations. The strategies and regional adoption rates should be customized during locally-led prioritizing and targeting work (see Prioritizing and Targeting section below for more information).

Because 80% of land use in the Middle Minnesota River Watershed is used for cultivated crop production, this land use has the greatest opportunity to improve water quality. However, there are additional suites of strategies specifically for urban/residential, pastures, feedlots, waterbodies, point sources, etc., since all land uses/pollution sources have opportunities to reduce their contributions. Practices for cultivated crops are listed from highest recommended adoption rate to lowest. Generally, practices with the highest adoption rates should be considered highest priority. While these practices may not be the most effective at reducing pollutants/stressors *per acre* adopted compared to other practices, these practices are generally more palatable to producers, recommended by conservation staff, and more cost effective at reducing pollutants and stressors. High priority agricultural practices are soil health practices: improved fertilizer and manure management, cover crops, and conservation tillage (strip-till, no till etc.).

Protection Considerations

Water bodies that meet water quality standards should be protected to maintain or improve water quality. Furthermore, water bodies that have not been assessed should not be allowed to degrade. The strategies presented – set at the major watershed scale - are intended to not only restore but also protect waters in the Middle Minnesota River Watershed. Strategies that are high priority for protection efforts are noted with a pink cross symbol. Similar to customizing regional adoption rates of the watershed-wide strategies, strategies and adoption rates should reflect the relative amount of protection needed and any site-specific considerations.

The highest priority aspects of water quality protection in the Middle Minnesota River Watershed include:

- Maintain a high level of perennial vegetation on the landscape, especially adjacent to water bodies, in areas with high slopes, and in areas with highly-erodible soils.
- Mitigate altered hydrology by adding storage, infiltration, and ET. There are several ways to accomplish this including: adding more living vegetation to the landscape in early summer and late fall by using cover crops, implementing no-till and strip till, adding water retention

structures or wetlands to intercept and infiltrate water from drainage projects, diversifying crop rotations, and restoring stream buffers, wetlands, and grasslands.

- Maintain and spread the good things happening on the landscape: keep practices and BMPs in place, and work to spread their adoption.

The Priorities Table (Table 20) in the following Prioritizing and Targeting Section identifies specific water bodies identified as high priority for protection.

Additional protection concerns in the watershed relate to groundwater and drinking water protection. The main supply of drinking water to the residents and businesses in the Middle Minnesota River Watershed is groundwater – either from private wells, community wells, or a rural water supplier. As discussed in the Nitrogen section, nitrate concentrations have reached concerning levels in ground water in multiple areas. Restoring and protecting groundwater requires reductions in nitrate reaching ground water. Strategies to address nitrogen in surface waters (summarized in the Strategies Tables - Table 21 and Table 22) will also help reduce nitrates reaching groundwater. The Minnesota Department of Health can advise additional strategies as necessary in local planning efforts.

Prioritizing and Targeting

Local conservation implementation plans that are developed subsequent to the WRAPS report should ***prioritize*** and ***target*** the strategies and set ***measurable*** goals. Figure 45 (BWSR 2014a) represents the prioritized, targeted, and measurable concepts.

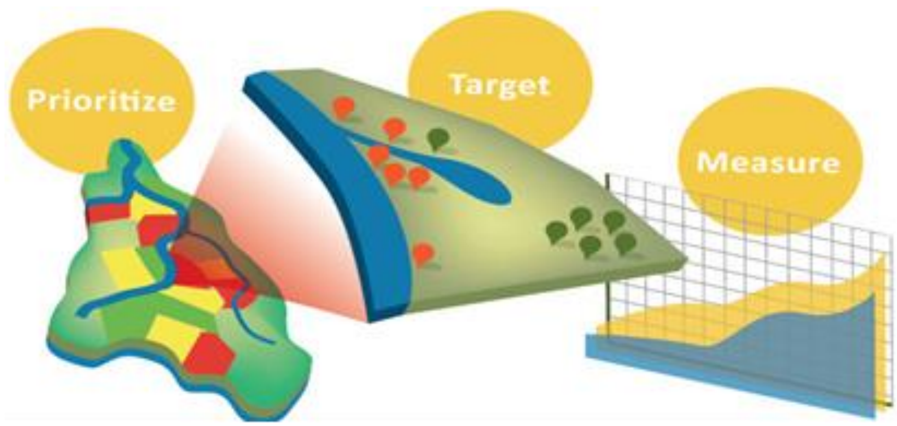


Figure 45: "Prioritized, targeted, and measurable" plans are more likely to improve water quality and have a better chance to be funded compared to those that are less strategic.

Prioritizing is the process of selecting priority areas or issues based on justified water quality, environmental, or other concerns. Priority areas can be further refined by considering additional information: other water quality, environmental, or conservation practice effectiveness models or concerns; ordinances and rules; areas to create habitat corridors; areas of high public interest/value; and many more that can be selected to meet local needs. This report has identified several priority areas for planning consideration through development of the goals maps, the HSPF model maps, and the GIS estimated altered hydrology maps. Table 20 summarizes many of these priority areas as priority areas identified by the WRAPS Feedback Group.

Targeting is the process of strategically selecting locations on the land (within a priority area) to implement strategies to meet water quality, environmental, or other concerns (that were identified in the prioritization process). The WRAPS report is not intended to target practices; rather, the work done as part of the larger Watershed Approach should empower local partners to target practices that satisfy local needs.

Measurable means that implementation activities should produce measurable results. Work plans should include information on how the results of their proposed work will be measured.

Table 20: Priority areas to restore and protect surface water quality in the Middle Minnesota River Watershed are summarized below. There are several means to select a priority area, hence the multiple types of priority areas. These priority areas include more typical priority areas for water quality restoration and protection, such as impaired waters and supporting waters, but also include priority areas such as measurable waters and highly hydrologically altered regions. Rather than this report dictating what specific areas of the watershed should be worked on first, local partners are encouraged to identify priority areas based on which prioritizing criteria is most beneficial from a local perspective. The priority areas should be further refined and specific projects and practices targeted within the selected priority areas in local planning.

"Priority Area" Prioritizing Criteria	Applicable WRAPS data	How to use/other considerations	Examples
"Tipping Point: Barely Impaired" Water bodies that are impaired but have a relatively smaller reduction or improvement goal	Use the goals maps in Section 2.2 (which illustrate the TMDL Summary table in the Appendix) to identify which impaired water bodies require the least reduction. On the goals map, the lighter the gray shading, the less reduction that is required. Aquatic life (IBI) scores are available in the Monitoring and Assessment report. Those that are closer to the threshold are likely more attainable/restorable. Additional details are provided in the SID and the DNR Hydro/geomorph reports.	Compared to "dirtier" watersheds, fewer changes are needed to address parameters and can be "easier" to achieve restoration goals. This prioritizing criteria can be especially important if the primary goal of the funding entity is to achieve restoration of impaired water bodies.	**Spring Creek (Hindeman Creek)** is one of the better/stable stream systems with good habitat in the watershed. By building on the momentum of other habitat improvement projects in this area, relatively modest improvements to headwater habitat/riparian cover and addressing the perched culvert can likely address/mitigate the identified stressors and resulting bio-impairments. **Nicollet Creek (downstream from Swan Lake)** had only one stressor with mostly good IBI scores. A relatively small improvement in the upstream ditches could bring this reach into supporting status. Headwater portions of **7-mile Creek** and the **Little Cottonwood River** are impaired by TSS, but are estimated to need only modest reductions to meet standards. Of the impaired lakes, **Loon Lake** is estimated to need the lowest phosphorus reduction to meet standards and has a small watershed.
"Protection of supporting waters" Water bodies that are currently meeting the water quality standard or not stressed by a specific parameter including **"Tipping point - nearly impaired"** Supporting waters near the threshold and/or with a declining trend	The "green" water bodies in the status maps throughout Section 2.2 show the supporting water bodies. While a stream reach may be impaired for a beneficial use, some parameters may be supporting. Refer to Monitoring and Assessment Table in the Appendix.	Additional prioritizing criteria that can be helpful to consider in tandem include: sources, hydrologic alteration, trends, and HSPF-modeled yields, phosphorus sensitivity, etc. or any other criteria presented in this table.	14 stream reaches are supporting aquatic life and 3 lakes are supporting aquatic recreation: **Lakes Ballantyne, Emily,** and **Hallett** are all ranked "highest" priority for protection according to the MPCA lakes phosphorus sensitivity analysis (Appendix 4.4). Of these three lakes, Lake Hallett has a substantial declining trend, and is the only "tipping point - nearly impaired" (supporting with a declining trend) lake in the watershed.

Table 20 (continued)

"Priority Area" Prioritizing Criteria	Applicable WRAPS data	How to use/other considerations	Examples
"Impaired Waters" Water bodies that have a 303d listed impairment	The status overview map in Section 2.1 shows the impairments by beneficial use. The status maps throughout Section 2.2 illustrate the parameters causing the beneficial use impairment. Refer to the Monitoring and Assessment Table in the Appendix for a list of the assessment status of all streams and lakes.	For any impaired lake or reach, identify what beneficial uses are impaired and what parameters are causing the impairment. Then, review the strategies table, using local knowledge of the area, and select the practices that are effective on that parameter and that would best meet local needs. Consider additional prioritizing criteria to strengthen the case for selecting a specific priority area.	Over 60 stream reaches and 9 lakes are currently impaired (too numerous to list here - see WRAPS data)
"Dirtiest Waters or Watersheds" Water bodies or watersheds that have observed data or models indicating that the area is substantially "worse" than others using either 1) estimated reductions, 2) observed data, or 3) model output	1) The goals maps (Section 2.2 - Goals Subsections) illustrate areas that need pollutant reductions- the darker the grey shading, the more reduction needed from this contributing area. The larger the needed reduction, the "dirtier" the water body (reductions also in the TMDL summary in the Appendix 4.3). 2) Data are available online and additional interpretation are available in the SID and the DNR hydro/geomorph reports. 3) HSPF-modeled subwatershed yield maps are presented in Appendix 4.2. Areas with higher yields are estimated by the model to contribute more pollutants.	1) Subwatershed goals maps can be used to estimate the dirtiest areas but are only presented when there are TMDL data and only apply to TSS, TP, and bacteria. 2) Model output is an estimate and may be limited by model mechanics or assumptions. Coupling model output with additional prioritizing criteria (versus being a single driver in selecting a priority area) is recommended.	The downstream portion of the **Little Cottonwood River and 7-Mile Creek** need high sediment reductions. Near channel sources like ravines and stream banks contribute largely in these areas. Strategies to address stream bank and ravine erosion are high priority in these areas along with those to reduce sediment and altered hydrology. **Lakes Henry, Scotch, and Crystal** need large phosphorus reductions. Selecting strategies to reduce phosphorus and improve lake shoreland and in-lake conditions are high priority in these areas. Based on a review of data by SID staff (no TMDL but data summary in SID report), **Roger's Creek** has very high nitrogen and phosphorus concentrations, and an abnormal number of fish were found to have lesions. Nutrient reduction and additional source assessment work are needed in this stream.

Table 20 (continued)

"Priority Area" Prioritizing Criteria	Applicable WRAPS data	How to use/other considerations	Examples
"Local Priority" Water bodies that are of high social importance to restore or protect	Civic engagement and the day-to-day work of local partners have identified several priority areas based on local values and special uses (e.g. state parks, recreational opportunities, historic sites, rare natural resources). Many of these are mentioned in the CE work done as part of the Watershed Approach and can be further identified and refined by local staff and citizens.	Local priorities may be the single largest driver of what areas will be prioritized and targeted for implementation work. Because there are so many ways to biophysically prioritize, there are many ways to link up the social (local) and biophysical priorities using WRAPS data. Contact WRAPS authors for assistance if needed.	Priority areas identified by local partners/CE work include (but are not limited to): **Fort Ridgely Creek, Birch Coulee Creek, Cherry Creek, Minneopa Creek, Indian Creek, Spring Creek, 7-mile Creek, Lake Washington, Lake Ballantyne, Duck Lake, Lake Emily, Lake Crystal, Swan Lake, Lake Hallett, Scotch Lake, Urban/MS4 areas, cold-water streams.**
"Highly hydrologically altered" Subwatersheds identified as highly hydrologically altered	A GIS analysis of altered hydrology is presented in Section 2.2 in the Altered Hydrology section. Areas with a higher score indicate more alteration. The six separate analyses that were combined to create the map in Section 2.2 are in Appendix 4.1.	Every stream analyzed was found to be stressed by altered hydrology. Virtually all the headwaters of the stream systems within this watershed are ditched and channelized. SID has specifically recommended minimizing ditch clean-outs and improving habitat to help mitigate altered hydrology.	Headwaters portions of **Birch Coulee Creek**, **Fort Ridgely Creek, Wabasha Creek, Minneopa Creek, 7-mile Creek, and Indian Creek** are areas with the highest degree of hydrologic alteration. Integrating more practices that use and hold water in these headwaters areas could trickle-down water quality benefits to downstream streams and lakes.
"Drinking water and Ground water" Areas contributing water or risks to drinking and ground water resources	While not technically in the scope of WRAPS, protecting drinking water and ground water is a high local priority. MDH provides information for targeting for drinking water source restoration and protection. A narrative is included in Appendix 4.1 or contact MDH for more info.	High nitrates are typically the primary concern with drinking water supply. Targeting nitrogen reduction strategies to the contributing priority areas helps achieve ground water and surface water improvements.	High nitrates in the **Mankato and St. Peter drinking water supply management area**. Aquifer vulnerability, shallow bedrock, and mining activity potentially causing issues in **Kasota Township**.

Table 20 (continued)

"Priority Area" Prioritizing Criteria	Applicable WRAPS data	How to use/other considerations	Examples
"High impact/ mitigating" Areas that have the ability to mitigate pollutants and stressors when ideally managed or a disproportionately high negative impact when poorly managed	See DNR geomorphology and hydrology report and Stressor ID report for specific areas.	Areas that typically fall into this area include stream riparian including ditches, floodplains, lake shoreland, headwater areas, high slope areas, drained wetlands.	**Reducing ditch cleanouts** will decrease erosion and increase nutrient uptake. **Restoring healthy riparian areas** of streams and ditches and **connected floodplains** throughout the watershed offer critical habitat and are able to buffer impacts of other stressors. Likewise, **lake shorelands** should be buffered to reduce erosion and uptake nutrients. **Cropland in high slope** areas are high priority for soil health and surface erosion reduction practices.
"Measurable waters" Water bodies with ample monitoring data are selected as priorities because improvements can be measured. Past data can be used to establish baseline conditions prior to work being done and future monitoring data can be used to track the magnitude of change.	The monitoring locations are illustrated on a map in Section 1.3. The three different types of monitoring locations provide different types of data. Review the data online (link at beginning of Section 2) to determine which parameter could be tracked to compare the conditions before and after BMPs are implemented.	Lakes with small watersheds will probably be the easiest in which to show changes. Solid, long-term data is taken at WPLMN sites, but the watersheds of these sites are very large and will probably take a huge amount of work before changes will be seen. Biological data (fish and bugs) may change rapidly in reaches where connectivity (e.g. perched culverts) is a primary stressor. If this prioritizing criteria is selected, local partners should work with MPCA monitoring staff to ensure those locations are monitored again.	**Little Cottonwood River, 7-mile Creek and the lakes with ample data to report trends** (see Trends Overview section), and **stream reaches with aquatic life (IWM) monitoring locations** provide a record to compare after implementing projects. In particular, areas that may show a quick response in aquatic life (IBI) scores are those primarily limited by a connectivity barrier: **8 Mile Creek** (intentionally perched culvert), **Shanaska Creek** (dam/grade control), **Spring Creek** (perched culvert), and **Little Rock Creek** (lake outlet).

Table 21 (Strategies Table A): This portion of the strategies table summarizes the conditions, goals, 10-year targets, proposed years to reach the goal, and the strategies and estimated adoption rates needed to achieve the goals in the Middle Minnesota River Watershed. The strategies and estimated adoption rates are presented in narrative form. The high-level strategies and rough estimate adoption rates are intentionally used to reflect the variety of practices, corresponding differences in practice efficiencies, and uncertainty in the exact practices and adoption rates that will be needed to achieve water quality goals throughout the watershed. These strategies and adoption rates were estimated after reviewing multiple model results (available in Appendix 4.4), the identified sources of pollutants and stressors, and the Stressor ID and Geomorphology/Hydrology reports. Strategies, practices, specific adoption rates, and responsibilities to meet the 10-year targets are identified in Table 22.

Parameter	Identified Conditions	Water Quality Goal (summarized)	Watershed-wide Goal (average/surrogate)	10-yr Target (meet by 2029)	Years to Reach Goal (from 2019)	Restoration and Protection Strategies See key in Table 23 for example practices under each strategy Estimated Adoption Rates: All= >90% Most= >60% Many/much= >30% Some= >10% Few= <10% Adoption rates indicate the final landscape outcome and include any practices already in place.
Altered Hydrology	▪51 stream reaches stressed ▪Flow reductions needed to meet downstream needs ▪Downstream waters impacted	Aquatic life populations are not stressed by altered hydrology (too high or too low river flow). Hydrology is not accelerating contributions of other parameters (sediment, nutrients, etc.).	25% reduction in peak & annual river flow	5% ↓	50	All croplands improve soil health by adding cover crops, decreasing tillage, and/or diversifying crops. Most croplands reduce and treat surface runoff and reduce and treat tile drainage. Few (marginally productive/high risk) areas are converted for critical habitat (wetlands, CRP, etc.). All residential/urban areas reduce and treat runoff. Some stream/ditch channels, banks, and floodplains are improved.
			increase dry season river base flow by enough to support aquatic life	increase	30	
Nitrogen	▪33 stream reaches stressed/impaired ▪2 stream reaches not stressed ▪Downstream waters impacted	Aquatic life populations are not stressed by nitrogen. Support statewide and downstream reduction goals.	60% reduction in river concentrations/loads	10% ↓	55	All croplands improve soil health by decreasing fertilizer use, adding cover crops, decreasing tillage, and/or diversifying crops. Most croplands reduce and treat cropland tile drainage. All streams and ditches have riparian buffer. All residential/urban areas reduce and treat runoff. All WWTPs and septic systems are providing adequate treatment.
Habitat	▪28 stream reaches stressed ▪12 stream reaches not stressed ▪Likely stressor of lake aquatic life	Aquatic life populations are not stressed by lack of habitat.	25% increase in MSHA habitat score	9% ↑	35	All streams and ditches have a riparian buffer. Most ditches reduce impacts. Many stream/ditch channels, banks, and floodplains are improved. Few marginally productive/high risk land uses are converted for critical habitat (wetlands, CRP, etc.). Most lake and wetland shorelands are restored/protected.
Phosphorus / Eutrophication	▪ 13 stream reaches and 9 lakes stressed/impaired ▪1 stream reach and 2 lakes supporting ▪Downstream waters impacted	Summer lake mean TP concentration is less than 0.09 mg/L and aquatic life populations are not stressed by eutrophication. Support statewide and downstream reduction goals.	50% reduction in lake and stream concentrations/loads	10% ↓	50	All croplands improve soil health by decreasing fertilizer use, adding cover crops, decreasing tillage, and/or diversifying crops. Most croplands reduce and treat cropland surface. All streams and ditches have riparian buffer. All residential/urban areas reduce and treat runoff. Some stream/ditch channels, banks, and floodplains are improved. All WWTPs and septic systems are providing adequate treatment.
Sediment	▪8 stream reaches stressed/impaired ▪24 stream reaches not stressed/supporting ▪Downstream waters impacted	90% of stream concentrations are below 65 mg/L. Aquatic life populations are not stressed by sediment.	50% reduction in restoration areas (1/4 of watershed) No increase in protection areas (3/4 of watershed)	12% ↓	40	All croplands improve soil health by adding cover crops, decreasing tillage, and/or diversifying crops. Most croplands reduce and treat cropland surface. All streams and ditches have riparian buffer. All residential/urban areas reduce and treat runoff. Some stream/ditch channels, banks, and floodplains are improved. Impacts from most ditches are reduced.
Bacteria	▪32 stream reaches impaired	Average monthly geomean of stream E. coli samples is below 126 cfu/100mL.	60% reduction in river concentrations/loads	13% ↓	40	All feedlot-produced manure is applied to cropland using improved application practices. All croplands improve soil health by adding cover crops, decreasing tillage, and/or diversifying crops. Most manured croplands reduce and treat cropland surface runoff. All WWTPs and septic systems are providing adequate treatment. All feedlots optimize manure storage and siting. All pastures improve livestock and manure management by improving grazing practices and restricting livestock access to water bodies. Some livestock are integrated onto the landscape.
Connect-ivity	▪24 stream reaches stressed ▪24 stream reaches not stressed	Aquatic life populations are not stressed by human-caused connectivity.	Address human-caused barriers as identified in SID and where practical	9% ↓	45	Fish barriers are addressed.
Parameters that are impacted/addressed by the above pollutants and stressors						
F-IBI & M-IBI	▪52 stream reaches impaired ▪14 stream reaches supporting	Aquatic life populations are measured and scored with IBIs. IBIs meet thresholds based on stream class/use.	Each parameter's goal is to meet the water quality standard and support downstream goals. Because these parameters are a response to (caused by) the above pollutants/stressors, the above watershed-wide goals are the (indirect) goals for these parameters.	meet other 10-year targets	50	The above strategies are implemented.
DO	▪18 stream reaches stressed/impaired ▪22 stream reaches not stressed/supporting	Stream concentrations are above 5 mg/L and DO flux is not excessive.				
Temp	▪2 stream reaches stressed	Aquatic life populations are not stressed by excessively warm water temperatures.				

Table 22 (Strategies Table B, page 1 of 2): This portion of the strategies table presents a suite of strategies and practices that are cumulatively capable of meeting the 10-year targets for the Middle Minnesota River Watershed. The strategies are presented by land use and provide target adoption rates by both watershed area and the equivalent number of acres. This level of new adoption progresses the landscape and water bodies towards clean water consistent with the total years to achieve watershed restoration as presented in Table 21. Adoption rates are for new projects and assume existing practices will be maintained. Information on the conditions, goals, and total timelines is presented in Table 21. Refer to the narrative in Section 3.3 for more information. See key on bottom of page 2 for details on table. See table 23 for information of practices and relevant NRCS practice codes.

Land use/Source Type	**Middle Minnesota River Watershed** Restoration and Protection Strategies and BMPs estimated to meet 10-year targets at specified adoption rates	Adoption Rate		Effectiveness of practice on parameter - per acre comparison							Responsibility																				
		% of Watershed Area	Watershed Acres	Sediment	Flow	Nitrogen	Phosphorus	Bacteria	Habitat‡	Connectivity	Farm Owners/Operators	Residents	Conservation Non-profit	Businesses	Municipalities	Ag Industry/Groups	Drainage Authority	SWCD	P&Z/Other County Staff	Feedlot Staff	Elected Officials	State/Local Trans. Auth.	MPCA	DNR	BWSR	MDA	MDH	UofM Extension	USDA	USFWS	US Army Corps
Cultivated Crops	**Decrease fertilizer use:** nutrient management, eliminate fall anhydrous application	10%	82,600			x	-				√		√			√		√					√		√	√		√	√		
	Add cover crops for living cover in fall/spring: cover crops on corn/beans, cover crops on early-harvest crops	10%	82,600	x	x	X	X	x	-		√		√			√		√							√	√		√	√		
	Decrease tillage: conservation tillage, no-till, strip till, ridge till	5%	41,300	-	-	-	X	x			√		√			√		√							√	√		√	√		
	Reduce and treat cropland surface runoff*: water and sediment control basins, grade stabilizations, terraces, grassed waterways	3%	24,800	x	-	-	X	x			√		√			√		√						√	√	√		√	√		
	Reduce and treat cropland tile drainage*: Treatment wetlands, saturated buffers, bioreactors, controlled drainage	3%	24,800		-	X	-				√		√			√	√	√					√		√	√		√	√		
	Replace open tile intakes*: blind, rock, sand filter, perforated pipe riser, etc. intakes	0.5%	4,100	X			X				√		√		√	√	√	√							√				√		
	Diversify crops: small grains, perennial crops, conversion to pasture	0.5%	4,100	x	x	X	x	x	-		√		√			√		√							√	√		√	√		
	Convert/protect land for critical habitat (replacing marginally productive cropped areas): Restore wetlands and drained lake beds, conservation cover/CRP, prairie, habitat management, native shrub hedgerows	0.5%	4,100	X	X	X	X	X	X		√	√	√					√							√				√		
	Mitigate new ag drainage projects by adding basin/wetland storage†	All new projects		n/a							√		√			√	√	√					√		√	√		√	√		
	Maintain existing BMPs, CRP, RIM, etc. †	All current BMPs		n/a							√		√			√		√					√	√	√	√			√	√	
	Education and outreach: peer-to-peer (farmer forums, field days, conservation tours), leadership/elected officials, school curriculum, coffee shop visits. Strategically target audiences (e.g. canning crops). Topics: nutrient management, soil health, drainage water management, cover crops, tools for farmers to estimate their fields' impact/results of practice adoption	sufficient to achieve the physical strategies listed above		n/a							√		√			√	√	√			√		√	√	√	√	√	√	√	√	
	Networking and relationships: one-on-one conversations, cold calls, peer-to-peer networking, younger and older farmer connection, partnering with ag groups/crop advisors										√		√			√	√	√			√		√	√	√	√	√	√	√	√	
	Conservation practice targeting: collaboratively develop targeted plans										√		√			√	√	√	√		√		√	√	√	√	√	√	√	√	
	Flexible and available funding: increased cost share cap, stack funding, tax credits, federal programs, plain language requirements																				√		√	√	√	√			√	√	
	Available/paid staff time: to do outreach work																√	√			√		√	√	√	√	√		√	√	
Manure Application	**Improve manure application**: improve: uniformity (necessitates equipment upgrade in cases), placement (further from water/flow path), timing and integration (right before planting cover crop, not on snow (necessitates feedlot manure storage upgrades in cases), incorporation (<24 hours), target surface appliers for improvements	2%	16,500		-	x	x	X			√		√			√	√	√		√			√	√	√	√		√	√	√	
	Education and outreach: educate producers on financial benefits (less fertilizer purchase) of application timing and scavenging cover crops and on proper application/requirements	sufficient to achieve the physical strategies listed above		n/a							√		√			√		√		√	√		√		√			√	√		
	Plain language: simplify manure management plan language															√				√			√						√		
	Permit/local ordinance: strengthen and ensure compliance															√				√	√		√						√		
Pastures	**Improve pasture/grazing management**: convert conventional pasture to rotational grazing, use alternative grazing areas/cover crops, pasture improvement/vegetation diversification	0.3%	2,500	X			X	X			√		√					√		√				√	√				√	√	
	Restrict livestock access to water bodies: exclusions, crossings, watering facilities	0.3%	2,500	X			X	X			√		√					√		√				√	√				√	√	
	Education and outreach: on economics of managed grazing (increase forage capacity), cost share for exclusion practices	sufficient to achieve the physical strategies listed above		n/a							√		√			√		√		√	√		√		√			√	√		
	Marketing: to consumers of benefits/value of grazed livestock, health, environmental, and ethical benefits of grazed animals												√	√		√							√	√					√	√	
	Flexible and adequate funding: Provide adequate funding and increase flexibility in standards for cost share																				√		√	√	√	√			√	√	
Feedlots	**Reduce/treat feedlot runoff:** feedlot runoff (vegetative) treatment	sufficient to reduce current contributions by 50%				√	√	√			√		√			√		√		√			√		√	√			√		
	Optimize manure storage: rainwater diversion (prevent from entering manure storage system), feedlot manure storage addition, use deep bedding (for less runoff from storage piles)					√	√	√			√		√			√		√		√			√		√	√			√		
	Optimize feedlot siting: increase distance between livestock and water, move feedlots out of sensitive areas					√	√	√			√		√			√		√		√			√		√	√			√		
	Integrate livestock onto the landscape: transition confined livestock to grazed systems					√	√	√			√		√	√		√		√		√			√		√	√			√		
	Reduce total number of livestock: produce higher value (grazed, organic) livestock to reduce total number of livestock while maintaining producer income					√	√	√			√		√	√		√		√		√			√		√	√			√		
	Education, outreach and build social norms to encourage producers to graze livestock	sufficient to achieve the physical strategies listed above		n/a							√		√	√		√		√		√	√		√		√	√	√		√		
	Flexible and adequate funding: Provide adequate funding and increase flexibility in standards for cost share										√		√	√		√		√		√	√		√		√	√			√		
	Permit/local ordinance: strengthen and ensure compliance, identify all feedlots with any runoff										√		√	√		√		√		√	√		√		√	√			√		

Table 22 (Strategies Table B, page 2 of 2): This portion of the strategies table presents a suite of strategies and practices that are cumulatively capable of meeting the 10-year targets for the Middle Minnesota River Watershed. The strategies are presented by land use and provide target adoption rates by both watershed area and the equivalent number of acres. This level of new adoption progresses the landscape and water bodies towards clean water consistent with the total years to achieve watershed restoration as presented in Table 21. Adoption rates are for new projects and assume existing practices will be maintained. Information on the conditions, goals, and total timelines is presented in Table 22. Refer to the narrative in Section 3.3 for more information. See table 23 for information of practices and relevant NRCS practice codes.

Land use/Source Type	**Middle Minnesota River Watershed** Restoration and Protection Strategies and BMPs estimated to meet 10-year targets at specified adoption rates	Adoption Rate	Pollutants/ Stressor addressed by strategy							Responsibility																				
			TSS	Flow	Nitrogen	Phosphorus	Bacteria	Habitat	Connectivity	Farm Owners/Operators	Residents	Conservation Non-profit	Businesses	Municipalities	Ag Industry/Groups	Drainage Authority	SWCD	P&Z/Other County Staff	Feedlot Staff	Elected Officials	State/Local Trans. Auth.	MPCA	DNR	BWSR	MDA	MDH	UofM Extension	USDA	USFWS	US Army Corps
Stream, ditches, & riparian	**Install/expand riparian buffer**: 16t, 50ft, 100ft buffers and/or riparian tree planting	All stream/ditches have req'd buffer and 5% have wider.	√	√	√	√	√	√		√	√	√		√	√	√	√	√					√	√			√	√		
	Reduce ditch impacts: reduce ditch clean-outs, install side-inlets, install grade stabilizations, etc.	All stop/reduce cleanouts. Install erosion control projects where high priority.	√			√	√	√		√				√		√	√						√	√						
	Improve stream/ditch channels, banks, and habitat: re-meander channelized stream reaches, 2-stage ditches, stream habitat improvement and management, re-connect/restore flood plains, streambank stabilization (where infrastructure is threatened)	On 160 river miles (~10%): assess and implement new projects where needed (prioritizing headwaters and for multiple benefits)	√	√	√	√		√		√		√		√	√	√	√				√		√	√			√	√		√
	Address fish barriers: dam removal, replace/properly size culverts and bridges	10% of barriers addressed. Properly design all new projects							√								√				√		√							√
	Education and outreach: demo and benefits of reducing ditch clean-outs, peer-to-peer, watershed tours, school curriculum, AIS	sufficient to achieve the physical strategies listed above										√				√	√	√		√		√	√	√			√	√	√	√
	Work with state/county/city engineers to improve designs											√				√	√	√		√	√	√	√	√				√	√	
	Flexible and adequate funding: Provide adequate funding and increase flexibility in standards for cost share																			√	√	√	√	√				√	√	√
Lakes, wetlands, & shoreland	**Restore/protect shoreland**: stabilize/restore shoreline with vegetation, increase distance (buffer) between waterbody and impacts	On 8 lakes (~10%): assess and address shoreland and in-lake management where needed				√		√		√	√	√		√		√	√				√	√	√	√					√	√
	Manage in-lake: Drawdowns, internal load controls (dredging, alum, rough fish control)					√		√			√	√					√					√	√	√			√		√	
	Regulations/zoning: improved/enforced shoreland ordinance/easement, targeted no development areas	sufficient to achieve the physical strategies listed above												√			√	√		√			√							
	Targeted communication and relationship building										√	√		√		√	√	√		√			√						√	
	Education: landowners, peer-to-peer, AIS awareness, watershed tours, school curriculum										√	√		√		√	√	√		√			√						√	
	Flexible and adequate funding: Provide adequate funding and increase flexibility in standards for cost share																			√	√	√	√	√				√	√	√
Urban and rural residential	**City/neighborhood-scale water management:** retention and infiltration areas, stormwater ponds, swales, rain gardens, wetlands, etc.	sufficient adoption to reduce current contributions by 20%	√	√	√	√	√				√	√	√	√				√		√	√				√		√			√
	Improve soil health: reduce nutrient use, diversify lawns, add trees/shrubs/prairie/forest, no-till and cover crop gardens, etc.		√	√	√	√	√				√	√	√	√			√	√		√					√		√			
	Improve street construction and management: permeable pavement on new construction, improved street sweeping frequency and timing, strategic and decreased salt use		√	√	√	√	√				√	√	√	√				√		√	√	√					√			
	Resident-scale water management: rain gardens, barrels, pet waste, lawn diversification		√	√	√	√	√				√	√	√	√				√		√		√		√			√			
	Well head sealing and vegetative protection									√	√	√					√	√								√				
	Education: residential practices, stormwater management, road/sidewalk salt	sufficient to achieve the physical strategies listed above										√	√	√			√	√		√		√				√				
	Planning: Urban forestry green infrastructure, impact zones for climate change, incorporate urban/residential practices													√			√	√		√										
Subsurface Treatment Systems (Septics)	**Maintenance and replacement:** scheduled maintenance and replace failing	sufficient adoption to reduce current contributions by 20%			√	√	√				√		√	√	√			√				√	√	√	√		√			
	Eliminate Imminent Public Health Threat (IPHT) systems				√	√	√				√			√				√				√								
	Improved septic solids application: increase buffers, application rates				√	√	√											√				√								
	Alternative systems: aerobic treatment units, graywater systems, holding tanks, etc.				√	√	√				√							√				√								
	Loans and grants: targeted to low income households	sufficient to achieve the physical strategies listed above																√		√		√								
	Uniform rules: adopted by all counties (e.g. sale and transfer, alternative systems)																	√		√		√								
	Education: of pumpers and appliers, system owners																	√				√								
	Enforcement: increase enforcement of existing rules																	√		√		√								
Point Sources	**Facility upgrades** when required by regulating party	Follow regulatory requirements			√	√	√							√								√								
	Maintain permit compliance													√								√								
	Technical assistance and funding for village and small town treatment facilities													√						√		√								

* = strategy footprint is much smaller than treated area (e.g. a grassed waterway treats many more acres than the practice footprint)

† = strategy is important for protection and reflects a key strategy to prevent current condition degradation

‡ Practices with "x" effect on flow are given a "-" on habitat. Practices that target riparian zone improvements are given "X" on habitat

Effectiveness was estimated using 1% adoption. While some practices are most effective at 1% adoption, the total effectiveness is limited by the watershed area contributing to the source. For instance, replacing open tile intakes is effective, but only a small percentage of the watershed is served by open intakes. Therefore, the total reduction achievable from this practice is minimal.

Effectiveness Scale - per acre comparison

X x - <blank>

most effective ⟷ least effective

√ = Effective on parameter. No per acre comparison made.

Table 23: Strategies (in colored headings) and the corresponding practices associated with these strategies along with the NRCS practice code are summarized.

Improve cropland soil health

Decrease fertilizer use

Nutrient Management (590)
Fertilizer rates match U of MN rec's (without gov't funding)
Eliminate fall-applied anhydrous ammonia
Precision nutrient timing & management (beyond 590 standard)

Add cover crops for living cover in fall/spring

Cover Crops with Corn & Soybeans (340)
Cover crops after early-harvest crops (340)

Decrease tillage (to increase residue)

Conservation tillage - >30% residue cover (345, 346, 329B)
No-till/ridge till/strip till (329, 329A)
Contour tillage/farming (330)

Diversify Crops

Conservation Crop Rotation - add small grains (328)
Conservation Crop Rotation - add perennials (328)
Perennial crops for regular harvest
Convert cropland to (properly managed) pasture

Decrease insecticide use

Integrated Pest Management (595)

Reduce and treat cropland surface runoff

(note: most soil health strategies also treat and reduce cropland contributions)

Water and Sediment Control Basin (638)
Sediment Basin (350)
Terrace (600)
Grassed waterway (412)
Filter Strips (386)
Contour Buffer Strips (332)
Stripcropping (585)
Field Border (393, 327) (also see buffers under stream/ditch strategies)
Grade stabilization structure

Reduce and treat cropland tile drainage

(note: most soil health strategies also treat and reduce cropland contributions)

Tile line bioreactors (747)
Wetland Restoration or Creation for treatment (657, 658)
Controlled tile drainage water management (554)
Saturated buffers (604)
Tile water storage with re-use on crops (636)

Replace open tile inlets

Alternative tile intake - perforated riser pipe (171M)
Alternative tile inlet - blind, rock, sand filter (606, 170M, 172M, 173M)

Decrease irrigation water use

Irrigation Water Management (449)

Improve forestry management

Forest erosion control on harvested lands
Roads and trails improvement
Reforestation on non-forested land and after cutting
Forestry management - comprehensive (147M)
Maintain existing forest cover

Improve livestock & manure management

Improve pasture/grazing management

Conventional pasture to prescribed rotational grazing (528)
Pasture improvement/vegetation diversification (101)
Use alternative grazing areas/graze cover crops

Restrict livestock access to water bodies

Livestock access control (472)
Livestock stream crossing
Livestock watering facilities

Reduce/treat feedlot runoff

Feedlot runoff reduction/treatment (635, 784)

Optimize manure storage

Rain water diversion
Use deep bedding (for less runoff from storage piles)
Feedlot manure/runoff storage addition (313, 784)

Optimize feedlot siting

Move feedlots out of sensitve areas
Increase distance between livestock and water

Integrate livestock onto landscape

Transition confined livestock to grazed

Reduce total number of livestock

Produce higher value livestock to reduce total number produced

Improve manure application

Uniform manure application (590)
Improved application location (590)
Improved application timing (590)
Manure incorporation (within 24 hrs)

Reduce and treat urban and residental runoff

Stormwater practices to meet TMDL & permit conditions
Constructed Stormwater Pond (urban) (155M)
Constructed Wetland (urban) (658)
Infiltration Basin (urban) (803M)
Bioretention/Biofiltration (urban) (712M)
Enhanced Road Salt Management
Permeable surfaces and pavements (800M, 804M)
Diversify vegetation & improved soil health
Supplemental Street Sweeping
Chemical Treatment of stormwater
Sand Filter
City/shared rentention and infiltration areas: stormwater ponds, swales, rain gardens, wetlands, etc.
Improve soil health: reduce nutrient use, diversify lawns, add trees/shrubs/prairie/forest, no-till and cover
Improve street construction and management: permeable pavement on new construction, improved
Resident-scale water management: rain gardens, barrels, pet waste, lawn diversification
Well head sealing and vegetative protection

Reduce Point Source Contributions

Treatment plant upgrades (to achieve ....)
Wastewater phosphorus reductions
Wastewater nitrate reductions
Wastewater bacteria reductions
Consolidation of treatment facilities/close high input facility
Conveyance system improvements (reduce/eliminate stormwater infiltration and emergency releases)

Convert/protect (marginal/high risk) land for critical habitat (can be applied to any landuse)

Conservation Cover Perennials (327, 327M, 342, 612)
Wetland Restoration for habitat (657)
Wetland Creation for habitat (658)
Wetland Wildlife Habitat Management (644)
Upland Wildlife Habitat Management (645, 643)
Restore drained lake beds
Early Successional Habitat

Restore & protect lakes, wetlands, and shoreland

Manage in-water

Internal load control (dredging, alum (563M), rough fish control, etc.)
Drawdown and hypolimnetic withdrawal
AIS (fish) management
AIS (vegetation) management
Watercraft restrictions

Restore/protect shoreline

Stabilize/restore shoreline (580)
Stabilize/restore shoreline with vegetation (580)
Increase distance (buffer) between waterbody and impacts

Restore & protect streams, ditches, and riparian

Install/expand riparian buffers

Riparian Buffers, 16+ ft (perennials replace tilled) (390, 391, 327)
Riparian Buffers, 50+ ft (perennials replace tilled) (390, 391, 327)
Riparian Buffers, 100+ ft wide (perennials replace tilled) (390, 391, 327)
Riparian Buffers, 50+ ft wide (replacing *pasture*) (390, 391, 327)
Riparian grass/forb planting (390)
Riparian tree planings (612)

Reduce ditch impacts

Reduce ditch clean-outs
Grade stabilization structure - in ditch (410)
Side inlet improvement (410)
Structure for Water Control (587)

Address fish barriers

Remove dams
Replace/properly size culverts and bridges
Replace/redesign perched culverts

Improve stream/ditch channel, banks, and habitat

Re-meander channelized stream reaches (582)
Two stage ditch (582)
Restore riffle substrate
Stream Channel Stabilization (584)
Stream habitat improvement and management (395)
Re-connect/restore floodplain
Ravine stabilization (410)
Lined Waterway or Outlet (468)
Upland storage and vegetative treatment (in area just before ravine)
Streambanks/bluffs stabilized/restored (580)

Reduce Septic System Contributions

Septic system upgrades (126M)
Sanitary sewer system extended to septic system community
Improved septic land application

key: **Strategy Group** / **Strategy** / BMP note: if there is not any strategy under a strategy group, then that group is considered the strategy

4 Appendix

4.1 Watershed Conditions and Background Information – Related Appendices

Monitoring and Assessment Results by Stream Reach

				Beneficial Use and Associated Pollutants & Stressors Assessment																		
				Aquatic Life														Aq Rec		Lim Use		
					Parameters														Par.		Par.	
AUID-3	Stream	Reach Description	Stream Class	Assessment	F-IBI	M-IBI	DO	TSS	Nitrates	Hydrology	N	DO	Eutroph (P)	Habitat	TSS	Connectivity	Temperature	Assessment	Bacteria	Assessment	Bacteria	DO
518	Altermatts Creek	T108 R34W S35 south line to Little Cottc	7	-														-		X	X	+
525	County Ditch 3	Headwaters to Fort Ridgely Cr	2Bm, 3C	+	?	+	?	?												-		
527	Wabasha Creek	T112 R34W S19 west line to Minnesota I	2Bg, 3C	X	X	X	?	?		X	+	?	?	+	+	+		X	X	-		
528	County Ditch 109	T111 R34W S17 west line to Wabasha Cr	7	-														-		?		?
531	Minneopa Creek	Headwaters to Lily Lk	2Bm, 3C	X	X	+	?	?		X	?	X	X	X	?	X				-		
533	Minneopa Creek	Lily Lk to T108 R28W S26 north line	7	-														-		?		?
534	Minneopa Creek	T108 R28W S23 south line to Minnesota	2Bg, 3C	X	X	X	+	X		X	?	?	?	+	X	X		X	X	-		
535	County Ditch 27	Headwaters to Lily Lk	2Bm, 3C	X	X	+	?	?		X	?	X	X	X	?	X				-		
541	Cherry Creek	Headwaters	2Bm, 3C	X	X	+	?	?		X	?	X	X	X	?	X				-		
542	Cherry Creek	T110 R25W S16 south line to T110 R26W	7	-														-		?		?
543	Cherry Creek	T110 R26W S1 south line to Minnesota F	2Bg, 3C	X	?	X	?	?		X	?	+	?	+	?	+		?	?	-		
544	County Ditch 63	Headwaters to JD 10	7	-														-		?		?
545	County Ditch 4/Coun	Middle Lk to Swan Lk outlet	2Bm, 3C	X		X	?	?		X	?	X	?	X	+	+				-		
547	Rogers Creek	Unnamed cr to Minnesota R	2Bg, 3C	X	X	X	?	?		X	X	?	?	?	X	+				-		
548	Unnamed creek	Unnamed ditch to Little Cottonwood R	2Bm, 3C	+	+	+	?	?												-		
550	Unnamed creek	Unnamed cr to Unnamed ditch	2Bg, 3C	X	X	X	?	?		X	X	?	?	?	?	?				-		
557	County Ditch 56 (Lake	Headwaters to Lk Crystal	2Bm, 3C	X	X	+	?	+		X	?	X	X	X	?	X		X	X	-		
562	Sevenmile Creek	T109 R27W S4 north line to Minnesota F	1B, 2Ag, 3B	X	X	X	+	X	X	X	X	?	?	X	X	X	X	X	X	-		
566	Unnamed creek	T109 R26W S28 east line to Unnamed di	7	-														-		?		?
569	Crow Creek	CD 52 to T112 R35W S2 north line	2Bg, 3C	X	X	X	?	+		X	X	?	?	?	?	+		X	X	-		
571	County Ditch 10 (Johr	T110 R32W S1 west line to Minnesota R	1B, 2Ag, 3B	X	X	X	?	?	X	X	X	?	?	+	X	?	?	X	X	-		
573	Spring Creek	T111 R32W S21 west line to Minnesota I	2Bg, 3C	X	X	X	+	+		X	?	?	?	?	?	+		X	X	-		
574	Spring Creek (Hinder	T111 R33W S24 west line to T111 R32W S	1B, 2Ag, 3B	X	X	X	?	?		X	?	?	?	+	?	X	X			-		
577	Unnamed creek	T108 R28W S6 south line to T108 R28W S	1B, 2Ag, 3B	X	X	X	?	?	X	?	X	+	+	X	?	X	?			-		
582	Judicial Ditch 12	Headwaters to Unnamed ditch	2Bg, 3C	?			?	?												-		
587	Birch Coulee Creek	JD 12 to Minnesota R	2Bg, 3C	X	X	X	+	+		X	X	+	?	+	+	X		X	X	-		
588	Birch Coulee Creek	Unnamed ditch to JD 12	2Bg, 3C	X	X	X	?	?		X	X	+	?	+	+	X				-		
593	Judicial Ditch 48	Unnamed ditch to Minneopa Cr	2Bm, 3C	X	X	+	?	?		X	?	X	X	X	?	X				-		
598	Unnamed ditch	Unnamed cr to underground pipe	2B, 3C															X	X	-		
600	Unnamed creek	Unnamed cr to Unnamed cr	2B, 3C															X	X	-		
602	Unnamed creek	Headwaters to Unnamed cr	2B, 3C															X	X	-		
603	Unnamed creek	Unnamed cr to Unnamed cr	2B, 3C															X	X	-		
604	Unnamed creek	Headwaters to Unnamed cr	2B, 3C															X	X	-		
607	Unnamed creek	Mud Lk (07	2Bg, 3C	?			?	?												-		
613	Rogers Creek (County	CD 21 to Unnamed cr	2Bg, 3C	?			+	?										X	X	-		
622	Spring Creek (Judicia	T111 R33W S23 west line to T111 R33W S	2Bg, 3C	X	X	X	+	?		X	X	?	?	X	?	X		X	X	-		
636	County Ditch 52	Unnamed ditch to CD 22	2Bm, 3C	X	+	X	?	?		X	?	X	X	X	?	+				-		
637	Unnamed creek (Seve	Headwaters to T109 R27W S15 north lin	2Bg, 3C	?			+	+										X	X	-		
640	Heyman's Creek	Unnamed cr to Minnesota R	2Bg, 3C	?				+										X	X	-		
641	Huelskamp Creek	Unnamed cr to Minnesota R	2Bg, 3C	?				?										X	X	-		
644	Unnamed creek	Unnamed cr to Minnesota R	2Bg, 3C	?			?	+										X	X	-		
645	Purgatory Creek	Unnamed cr to Minnesota R	2Bg, 3C	?				?										X	X	-		
646	Unnamed creek (Cou	CD 11 to Little Cottonwood R	2Bm, 3C	+	+	+	?	?												-		
647	Unnamed ditch	Headwaters to CD 27	2Bg, 3C	?			?	?												-		
649	County Ditch 57	Headwaters to T111 R32W S18 south lin	2Bg, 3C	?			?	?										?	?	-		
650	County Ditch 10 (Johr	Unnamed ditch to T110 R32W S2 east lir	2Bg, 3C	?			+	+										?	?	-		

x = impaired/declining trend

? = inconclusive (need more data)

\+ = supporting/improving trend

\- = no trend detected

<blank> = no data

				Beneficial Use and Associated Biology, Stessor, and Pollutant Assessment																		
				Aquatic Life														Aq Rec		Lim Use		
					Bio		Stressors								Pollutants				Pol.		Pol.	
AUID-3	Stream	Reach Description	Stream Class	Assessment*	Fish IBI	Macro IBI	Hydrology	Nitrogen	Habitat	Connectivity	DO	Eutroph (P)	TSS	Temperature	TSS	DO	Nitrogen	Assessment*	Bacteria	Assessment*	Bacteria	DO
651	Unnamed creek	Headwaters to Unnamed cr	2Bg, 3C	?												+				-		
656	County Ditch 28		2Bm, 3C	+	+	+									?	?				-		
657	County Ditch 11	Unnamed ditch to Unnamed cr	2Bm, 3C	X	+	X	X	X	X	+	X	X	?		?	?				-		
658	County Ditch 67	CD 58 to Little Cottonwood R	2Bg, 3C	X	X	X	X	X	?	+	+	?	?		?	?				-		
660	County Ditch 3		2Bg, 3C	X		X	X	X	X	+	?	?	?		?	?				-		
661	County Ditch 11	Headwaters to CD 39	2Bm, 3C	X	?	X	X	X	X	+	X	?	?		?	?				-		
662	Unnamed creek	Unnamed cr to Minnesota R	2Bg, 3C	?	?										?	?				-		
663	Unnamed creek	MN Hwy 4 to Fort Ridgely Cr	2Bg, 3C	+		+									?	?				-		
664	County Ditch 115	Unnamed cr to CD 106A	2Bm, 3C	+	+	+									?	?				-		
665	County Ditch 100	CD 28 to JD 31	2Bm, 3C	+	X	+									?	?				-		
666	Judicial Ditch 8	Unnamed cr to JD 31	2Bm, 3C	X	X	X	X	X	X	X	X	X	?		?	?				-		
667	County Ditch 105	CD 106 to Wabasha Cr	2Bm, 3C	?	X										?	?				-		
668	Unnamed creek	Headwaters to Minnesota R	1B, 2Ag, 3B	+	?	+										?				-		
669	County Ditch 85A	Headwaters to CD 124	2Bg, 3C	?											?	?				-		
670	County Ditch 124	Headwaters to CD 85A	2Bm, 3C	X		X	X	X	X	+	X	X	+		?	?				-		
671	County Ditch 22	Headwaters to Crow Cr	2Bm, 3C	+	+	+									?	?				-		
672	County Ditch 111	Unnamed cr to Purgatory Cr	2Bg, 3C	+	+										?	?				-		
673	County Ditch 115	Unnamed cr to Unnamed cr	2Bm, 3C	X		X	X	X	X	+	?	?	?		?	?				-		
675	Heyman's Creek	T110 R30W S22 north line to Unnamed c	2Bg, 3C	X	+	X	X	X	?	+	+	?	?		?	?				-		
676	Little Cottonwood Ri	Headwaters to T109 R31W S22 north lin	2Bg, 3C	X	X	X	X	X	X	+	?	?	X		X	?		X	X	-		
677	Little Cottonwood Ri	T109 R31W S15 south line to Minnesota	2Bg, 3C	X	+	X	X	X	?	+	+	?	X	?	X	+		X	X	-		
678	County Ditch 46A	Headwaters	2Bm, 3C	X	X	X	X	?	X	X	X	?	?		?	?		?		-		
679	County Ditch 46A		2Bg, 3C	X		X	X	X	?	+	?	?	?		X	?		X	X	-		
681	Altermatts Creek	Unnamed cr to T107 R34W S3 east line	2Bm, 3C	+		+									?	?				-		
683	Swan Lake Outlet (Ni	CD 39 to Minnesota R	2Bg, 3C	X	?	X	X	?	+	+	?	?	+		+	+		X	X	-		
684	Eightmile Creek	366th St/T	2Bg, 3C	X	X	X	X	X	?	X	+	?	?		+	+		X	X	-		
686	Little Rock Creek (Jud	Headwaters thru Mud Lk	2Bm, 3C	X	X	X	X	X	X	X	X	?	?		?	?				-		
687	Little Rock Creek (Jud	Mud Lk to Minnesota R	2Bg, 3C	X	X	X	X	X	X	X	?	?	+		?	+		X	X	-		
688	County Ditch 106A (F	Headwaters to T112 R33W S13 south lin	2Bm, 3C	X	+	X	X	X	X	+	X	X	?		?	?				-		
689	Fort Ridgely Creek	T112 R33W S24 north line to Minnesota	2Bg, 3C	X	X	X	X	X	?	?	?	?	?		+	+		X	X	-		
691	Morgan Creek	T109 R29W S30 south line to Minnesota	2Bg, 3C	X	X	X	X	X	+	X	?	?	?		+	?		X	X	-		
692	Shanaska Creek	Dog Cr to Shanaska Cr Rd	2Bm, 3C	+	+	+									?	?				-		
693	Shanaska Creek	Shanaska Cr Rd to Minnesota R	2Bg, 3C	X	X	X	X	X	+	X	+	?	?		+	?		X	X	-		
694	Unnamed creek	CSAH 5/3rd Ave to Minnesota R	2Bg, 3C	+	+	+									?	?				-		
696	Unnamed creek	Unnamed cr to	2Bm, 3C	X	X	X	X	X	X	X	X	?	+		?	?				-		
699	Wabasha Creek	T111 R35W S11 west line to T112 R35W S	2Bm, 3C	X	+	X	X	X	X	+	X	X	?		?	?				-		
701	Judicial Ditch 10	Unnamed cr to T108 R30W S2 east line	2Bm, 3C	X	+	X	X	?	X	+	X	X	?		?	?				-		
702	Sevenmile Creek	CD 13A to to MN Hwy 99	2Bg, 3C	?											?	?		?	?	-		
703	Sevenmile Creek	MN Hwy 99 to CD 46A	2Bg, 3C	X	?	X	X	X	X	+	?	?	X		X	+		X	X	-		
704	Threemile Creek	CD 140 to Minnesota R	2Bg, 3C	X	X	+	X	+	+	X	?	?	+		+	?		X	X	-		
707	Judicial Ditch 12	CSAH 2 to CD 136	2Bg, 3C	+	+										?	?				-		
709	Fritsche Creek (Coun		2Bg, 3C	X	+	X	X	X	+	+	?	?	?		?	?		X	X	-		
711	County Ditch 124	CD 85A to T113 R34W S5 west line	2Bm, 3C	X	+	X	X	X	X	+	X	X	+		?	?				-		
712	County Ditch 13	245th Ave to Minnesota R	2Bg, 3C	X	X	X	X	?	?	?	?	?	?		+	?		X	X	-		
715	Unnamed creek	T111 R33W S8 east line to Unnamed cr	2Bg, 3C	X	X		X	?	X	X	?	?	?		+	?		?	?	-		
716	Judicial Ditch 13	Unnamed ditch to CSAH 5	2Bm, 3C	X	X	+	X	?	X	X	?	?	+		?	?				-		
717	Judicial Ditch 13	CSAH 5 to Little Rock Cr	2Bg, 3C	X	X	X	X	X	?	X	?	?	?		?	?				-		
718	Unnamed creek	Unnamed cr to	2Bg, 3C	?	?										?	?				-		

x = impaired/declining trend
? = inconclusive (need more data)
+ = supporting/improving trend
- = no trend detected
<blank> = no data

Monitoring and Assessment Results by Lake

Lake Name	Lake ID	Aquatic Rec (Phos/Eutrop.) Assessment	Aquatic Life (Fish IBI)	Clarity Trend
Gilfillin	07-0045-00	?		?
George	07-0047-00	x	?	?
Duck	07-0053-00	x	+	-
Ballantyne	07-0054-00	+	+	+
Wita	07-0077-00	x	?	?
Loon	07-0096-00	x	?	?
Mills	07-0097-00	x	?	?
Crystal	07-0098-00	x	x	+
Lieberg	07-0124-00	?	?	?
Strom	07-0126-00	?		
Lone Tree	08-0073-00	?		?
Unnamed	40-0098-00	?	?	?
Henry	40-0104-00	x	?	?
Savidge	40-0107-00	?	?	?
Scotch	40-0109-00	x	?	x
Washington	40-0117-00	x	x	+
Emily	40-0124-00	+	?	+
Swan	52-0034-00	?	?	?
Hallett	52-0001-00	+		X

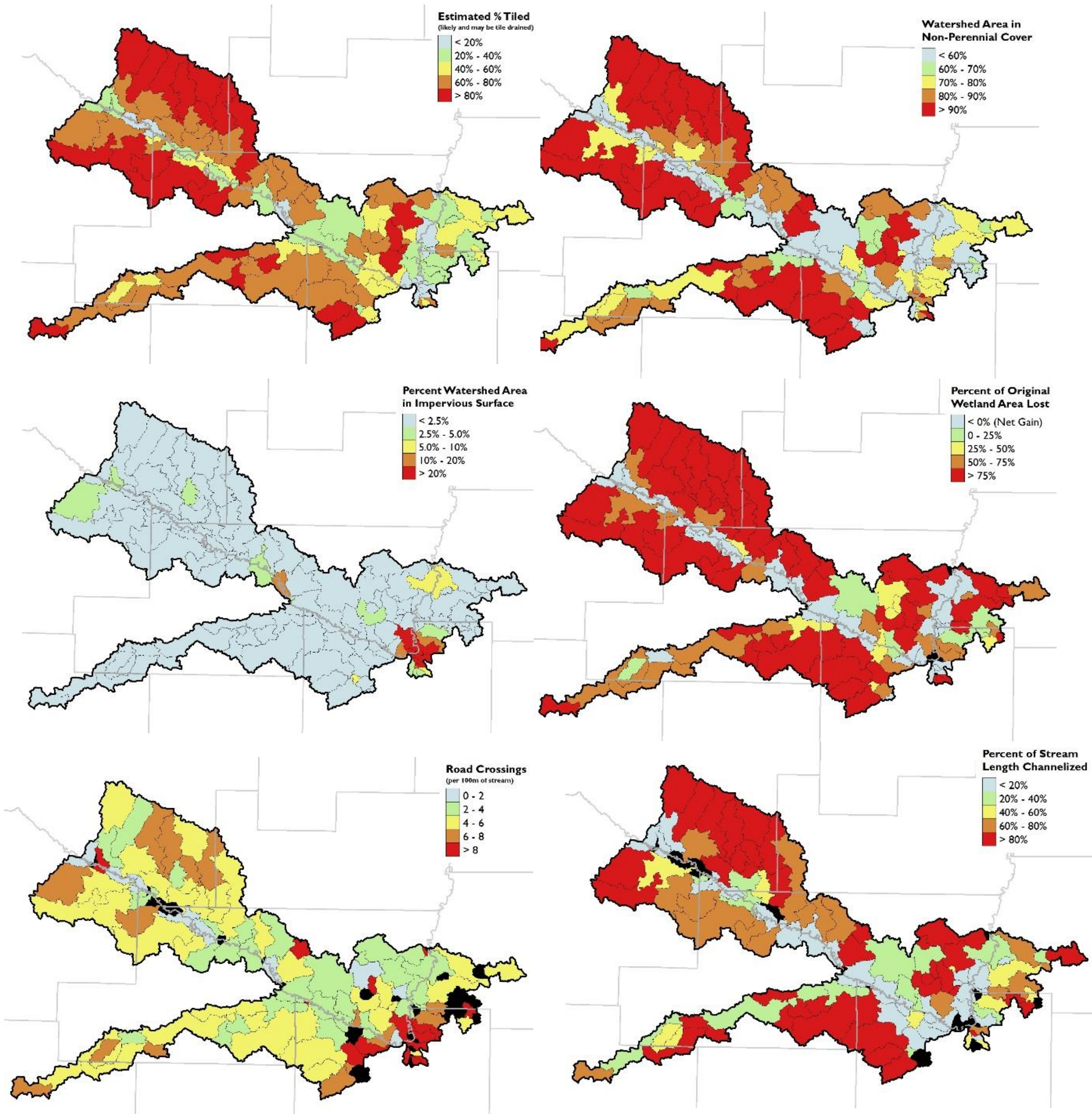
x	=	impaired/declining trend
?	=	inconclusive (need more data)
+	=	supporting/improving trend
-	=	no trend detected
<blank>	=	no data

WPLMN Data Summary

Seven Mile Creek WPLMN Data Summary	Mass (kg)	Water (ac-ft)	FWMC (mg/L)	Yield (lbs/ac)
Averaged Phosphorus			0.31	0.47
Multi year (2007-2015)	44,913	102,871	0.35	
Correcting for Seasonal only site (add 15% to yields/loads)	51,650	118,302	0.35	0.55
2014-2015 ONLY			0.34	0.44
	9,142	20,858	0.36	
Correcting for Seasonal only site (add 15% to yields/loads)	10,513	23,987	0.36	0.50
Averaged Nitrogen			21.3	28.9
Multi year (2007-2015)	2,731,187	102,871	21.5	
				33.2
2014-2015 ONLY			24.29	30.86
	647,883	20,858	25.19	35.49
Averaged			263.3	458.1
Multi year (2007-2015)	43,313,583	102,871	341.5	
				526.8
2014-2015 ONLY			545.00	764.50
	16,053,006	20,858	624.20	
				879.2
Year		Water (ac-ft)	Water (in)	Water (in) *
2007		7,719	4.0	4.6
2008		7,130	3.7	4.2
2009		2,132	1.1	1.3
2010		28,556	14.8	17.0
2011		27,784	14.4	16.5
2012		5,158	2.7	3.1
2013		3,534	1.8	2.1
2014		13,076	6.8	7.8
2015		7,782	4.0	4.6
Average				6.8
		*assume 15% not captured by seasonal site		

Little Cottonwood River nr Courtland, MN68				
Averaged Phosphorus			0.29	0.27
Multi year (2014-2015)	27,076	64,520	0.34	
Averaged Nitrogen			8.5	7.2
Multi year (2014-2015)	710,517	64,520	8.9	
Averaged Sediment			153.0	153.5
Multi year (2014-2015)	15,149,313	64,520	190.4	
				176.4675
		Water (ac-ft)	Water (in)	Water (in)*
		49179	5.4	6.2
		15341	1.7	1.9
				4.1
*assume 15% of river flow volume is not captured in seasonal site				

Altered Hydrology GIS Analysis



Maps included here were derived for the relative altered hydrology analysis described in Section 2.2 - Altered Hydrology Sources. The analysis was created by combining the above data layers using the following weights: tiled: 5, not perennial: 5, impervious surface: 50, wetland loss: 10, road crossings: 20, channelized: 7.

Nitrogen in Groundwater- Summary by MDH

The Minnesota Department of Health works with public water suppliers to develop Wellhead Protection Plans and determine DWSMAs. Within the Middle Minnesota River Watershed the cities of Comfrey, Fairfax, Kasota, Morton, New Ulm, and Redwood Falls are all community public water suppliers that have some moderately vulnerable areas to potential contamination. St. Peter and Mankato have areas of higher vulnerability to contamination.

The communities of Comfrey, Fairfax, Kasota, Morton, New Ulm, Redwood Falls, St. Peter, and Mankato have vulnerable drinking water systems that indicate a connection and influence from surface water in the watershed. Contaminants on the surface can move into the drinking water aquifers more quickly in these areas. The communities of Cleveland, Franklin, Hanska, Lake Crystal, Nicollet, North Mankato, and Mankato (Mt. Simon Aquifer wells) have low vulnerability to contamination, which means that in those areas the deep aquifers are fairly protected. There is also the potential for contamination through unused and abandoned wells. Ensuring abundant and high quality supplies of groundwater is critical; especially in light of altered hydrology and the impacts on groundwater recharge.

Wellhead protection plans have been completed for the following communities:

<u>Non-Vulnerable/Protected aquifer:</u>

Cleveland, Franklin, Hanska, Lake Crystal, Mankato deep wells, Nicollet, North Mankato

<u>Vulnerable/Susceptible to Contamination:</u>

Comfrey, Fairfax, Kasota, Morton, New Ulm, Redwood Falls, St. Peter

<u>Vulnerable/Shallow Groundwater Source:</u>

Mankato Ranney Wells

<u>Wellhead Protection Plans Not Completed:</u>

Courtland, Morgan

<u>St. Peter</u>

St. Peter has areas of high vulnerability to potential contamination with a surface water contribution area. St. Peter has many unique challenges for suppling safe drinking water to its residents. The area supply water for St. Peter’s aquifer covers 4600 acres. A portion of the water is derived from tile-drained cropland on the western edge of the DWSMA. The tile drainage discharges into ditches and then flows towards the wells where it encounters sandy soils near the western city limits where higher infiltration rates occur. The rapid movement of water through these course soils allows quick movement of contaminants into the aquifer.

Nitrate levels in the vulnerable city wells have steadily increasing since the 1980s. In the past, the city has blended water from various wells to maintain safe drinking water standards. In the spring of 2011 they started operation of a reverse osmosis treatment plant. This treatment is very expensive to install and operate. Maintenance cost savings may be attained if nitrates levels are decreased in the groundwater source.

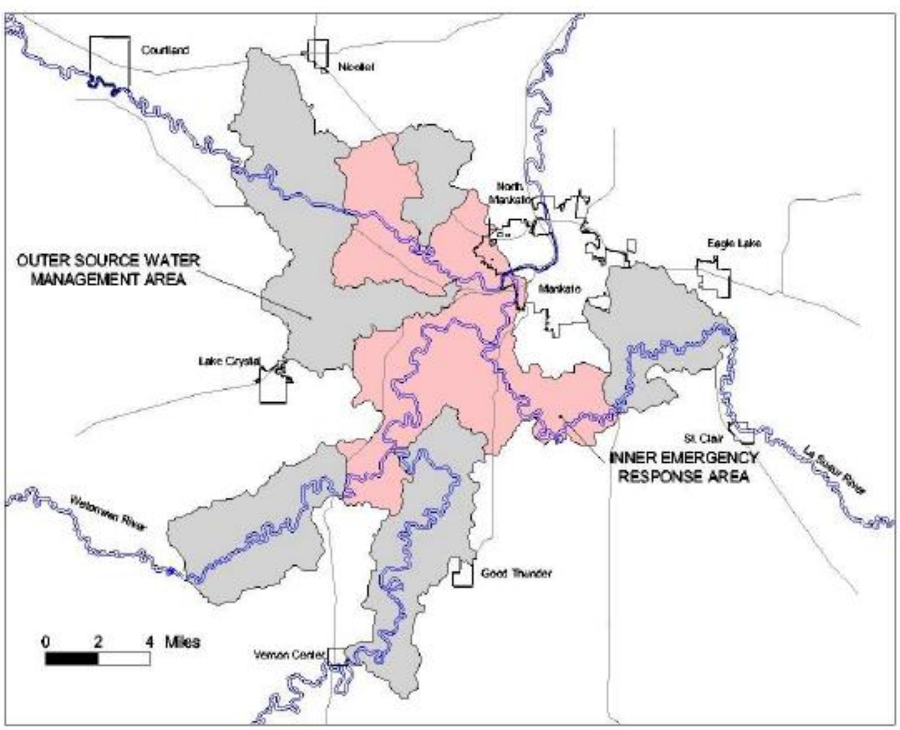
Mankato

The majority of the public water supply for Mankato is drawn from a shallow aquifer located beneath the Blue Earth River. Mankato operates two Ranney wells; well 15 is influenced by the Minnesota River and well 13 is located where the Minnesota River and Blue Earth River meet. The City also operates deeper groundwater wells that are drilled in the Mt. Simon aquifer.

In determining the sensitivity of source water relying on groundwater under the direct influence of surface waters, the intrinsic physical properties of the geologic setting or landscape within the watershed must be considered. During high flow conditions, the larger volumes of water in the river flowing past the Ranney wells help attenuate contaminants and affects the movement of the contaminants to the public water supply intake.

Variations in seasonal stream flow will also influence the sensitivity of the river to contamination. Other factors influencing the sensitivity of a public water supply relying on groundwater under the direct influence of surface water include topography, hydrology, geology, vegetation, and distribution of various soil types within the Blue Earth River Watershed and portions of the Minnesota River Watershed.

The impact of potential contaminants on the public water supply is influenced by the inherent characteristics of the contaminant of concern. If a contaminant floats, it doesn’t present the same impact to the Ranney well system as a contaminant that mixes thoroughly with the source water. Distance from the contaminant source to the Ranney wells can be a factor. The further a source is from the intake the more chance that watershed features such as wetlands, permanently vegetated areas, and storm water basins will attenuate the contamination. Of greatest concern are pesticides, microorganisms, nitrate-nitrogen, and volatile and synthetic organic compounds.

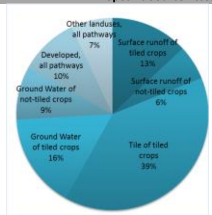


4.2 Source Assessment – Related Appendices

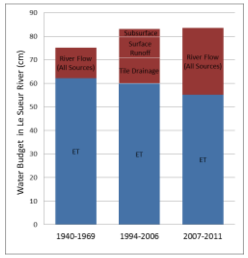
Summary of Lines of Evidence

Specific Source Assessment Analyses (including source and applicable area)	HSPF Source Assessment for Middle Minnesota (model years 1996-2012)	2013-2017 Discovery Farms Data for the tiled farms (BE1, DO1, RE1)	2009-2013 Watershed Pollutant Load Monitoring Network Data	Preliminary Professional Judgement Source Assessment

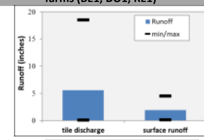
Q

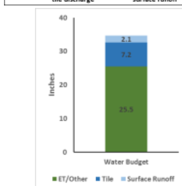


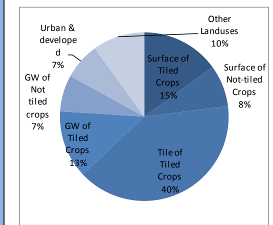
water portioning calculator (boettcher), assumes 60% of watershed tiled



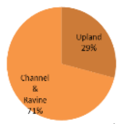
Middle bar of water budget: SWAT modeling of water budget by Folle



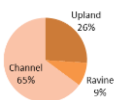




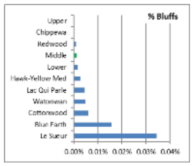
TSS

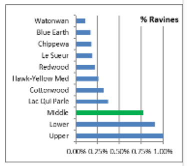


finger-printing, MN River US from mid mn (schottler)



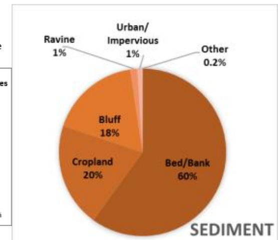
Gran Sediment Budget for Le Sueur River



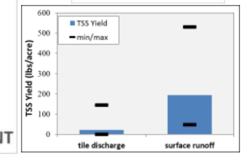


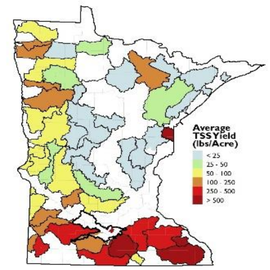
Mulla estimate of bluff and ravine areas per major watershed

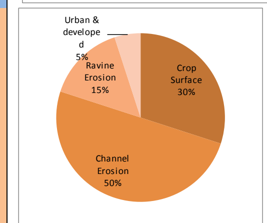
[MN River Basin Near Stream Sediment Sources (Mulla, 2010)]



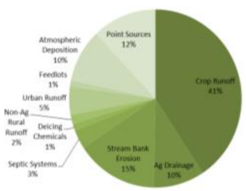
HSPF note for sediment: includes bank erosion from MN River





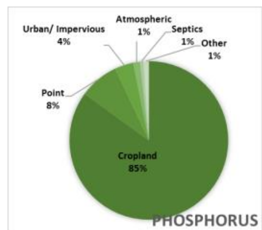


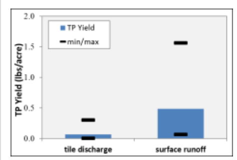
P

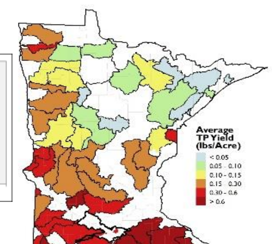


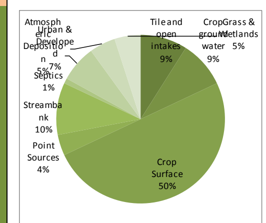
[Detailed Assessments of Phosphorus Sources to Minnesota Watersheds]

Barr Engineering and the PCA (2003 with 2007 update)

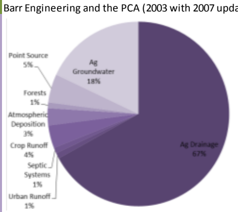




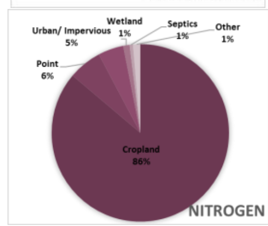


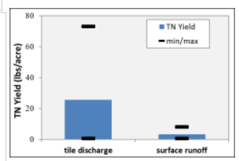


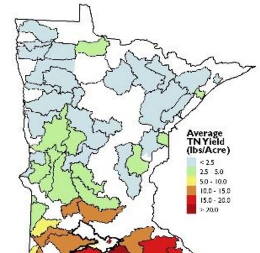
TN

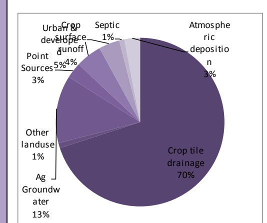


PCA Assessment for MN Basin, avg yr

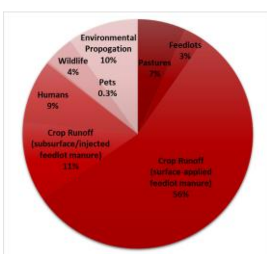








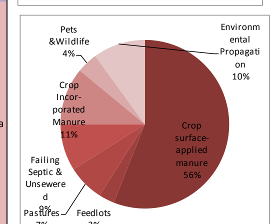
Bacteria



Bacteria Calculator, Boettcher

Strong relationship to fecal bacterial contamination in water	**Weak** relationship to fecal bacterial contamination in water
• High storm flow (the single most important factor in multiple studies) • % rural or agricultural areas greater than % forested areas in the landscape (entire watershed area) • % urban areas greater than % forested riparian areas in the landscape • High water temperature • Higher % impervious surfaces • Livestock present • Suspended solids	• High nutrients • Loss of riparian wetlands • Shallow depth (bacteria decrease with depth) • Amount of sunlight (increased UV-A deactivates bacteria) • Sediment type (higher organic matter, clay content and moisture; finer-grained) • Soil characteristics (higher temperature, nutrients, organic matter content, humidity, moisture and biota; lower pH) • Stream ditching (present or when increased) • Epilithic periphyton (plants and microbes that grow on stones in a stream) present • Presence of waterfowl or other wildlife • Conductivity

PCA/Emmons & Oliver literature summary of bacteria coorelation



Bacteria Source Assessment Calculator

Bacteria Source Estimates Calculator

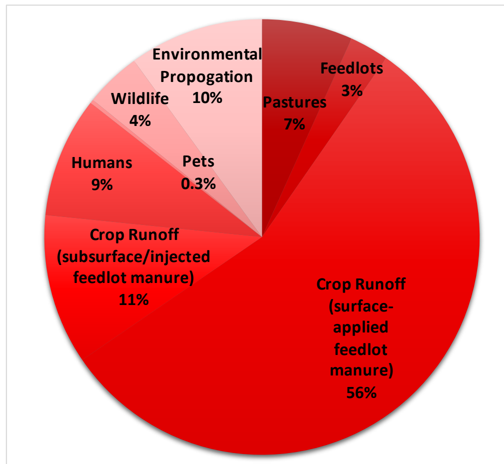
DIRECTIONS : [green cell] = enter value for watershed (known or assumption). Cells that are not green do not need to be changed/many are calcuation cells and the formulas will be erased if a value is entered.

Waterhsed	Md MN
Total area (ac)	826000
Total Pasture (ac)	7332
Pasture <1000ft (ac)	2959
Total AUs	293000
% feedlot AUs whose manure stockpiles w/o runoff controls	10%
number of pasture acres per 1 AU	2
% Feedlot manure applied Surface	25%
% Feedlot manure applied Subsurface	75%
Pasture >1000 ft (ac)	4373
pasture <1000ft AUS	1480
pasture >1000ft AUs	2187
Feedlot AUs	289334
Feedlot inadequate runoff AUs	22633
Feedlot surface applied AUs	72334
Feedlot subsurface applied AUs	217001
Human population	95035
number of failing septics per 1,000 acres	3
number of people per failing septic	3
# humans per 1 AU	7
# acres per 1 wildlife AU of total watershed	250
humans per pet (one pet for every x humans)	3
# pets per 1 AU	30
% of total load due to environmental propogation	10%
people using failing septics	7434
% of human wastewater inadequatetly treated (on failing septics)	8%
of human wastewater is adequately treated	92%
Human - inadequate treatment AUs	1062
Human - adequate treatment AUs	12514
Pet AUs	1056
Wildlife AUs	3304
Wet conditons (time with active runoff)	5%
Dry conditions (no active runoff)	95%

Total Aus data includes pastured animals

each AU produces 1 unit of manure/bacteria

	condition	Pastures adjacent waterways	Other pastures	Pastures	Feedlots	Crop Runoff (surface-applied feedlot	Crop Runoff (subsurface/injected feedlot	Humans	Pets	Wildlife	Environmental Propogation	Human - adequately treated wastewater	Human - inadequately treated wastewater	SUM of Crop applied manure
Delivery ratio (assumed)	wet	5.0%	1.0%		0.5%	3.0%	0.2%		1.0%	3.0%		0.05%	2.0%	
Production x Delivery ratio x % of time		5.0	1.1		5.7	108.5	21.7		0.5	5.0		0.3	1.1	
Delivery ratio (assumed)	dry	0.5%	0.0%		0.0%	0.0%	0.0%		0.0%	0.1%		0.05%	1.0%	
Production x Delivery ratio x % of time		7.0	0.0		0.0	0.0	0.0		0.0	3.1		5.9	10.1	
Total Delivered Units		12.0	1.1	13.1	5.7	108.5	21.7	17.4	0.5	8.1	19	6.3	11.2	130.2
Total Delivered Percentage		6.2%	0.6%	6.7%	2.9%	55.8%	11.2%	9.0%	0.3%	4.2%	10.0%	3.2%	5.7%	67.0%



Calculator by J Boettcher

Calculation method based on GBE fecal TMDL, but with other/additional assumptions and calculation methods

Water Portioning Calculator

Key
this color = known for watershed
this color = assumption, based on other available data where possible
this color = calculated using knows and assumptions
<no color> = known value/used to check calculations, value = 0 or 1

Landuse	% of crops	% of watershed	
tiled ag	79%	60.0%	Estimate tiled ag % on local knowledge, tiled acres GIS estimate, or can estimated % of shed using
not tiled ag	21%	16.0%	purple cells in check section
all ag	100%	76%	

Ratios of Water Yields				
The per acre tile water yield ratio for a tiled:not tiled field is	1.0	:	0	untiled field has no tile water path
Assume the surface runoff water yield ratio for a tiled:not tiled field is	0.60	:	1.0	see check numbers below (yellow)
Assume that in a tiled field, the tile:surface water yeild ratio is	3.0	:	1.0	see check numbers below (blue)
Assume that the GW:total ratio of river water for watershed = that of ag and is	0.30	:	1.0	see check numbers below (light blue)
Assume that the per acre GW yield ratio for a tiled:not tiled field is	1.0	:	2.1	see check logic below (light pink)
Assume that the per acre yield for all flowpaths ratio for a tiled:not tiled field is	1.23	:	1.0	see check logic below (pink)

% of water yields by flow path between tiled and untiled land

	% of ag water tile yields	% of ag water surface	% of ag water GW yields	% of total water from	% of total watershed
tiled land	100%	69.3%	64%	82%	68%
not tiled land	0%	31%	36%	18%	15%
all ag land	100%	100%	100%	100%	83%

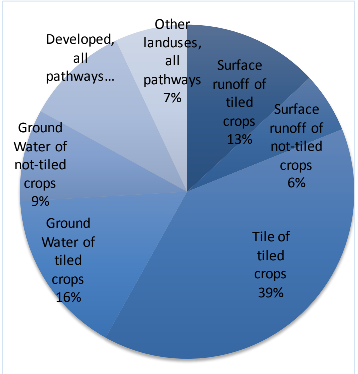
number should be similar to landuse, likely adjusted up from landused due to ag's higher water yield than other combined landuse water yield

Flow contributions by flow path toward total watershed contributions

	tiled ag	not tiled ag	all ag land
% from tile	39%	0%	39%
% from surface	13%	6%	19%
% from GW	16%	9%	25%
% from all ag paths	68%	15%	83%

Use Solver to look at effects of inputs/assumptions (peach cells), especially cells B11:D13, by setting J18=J9

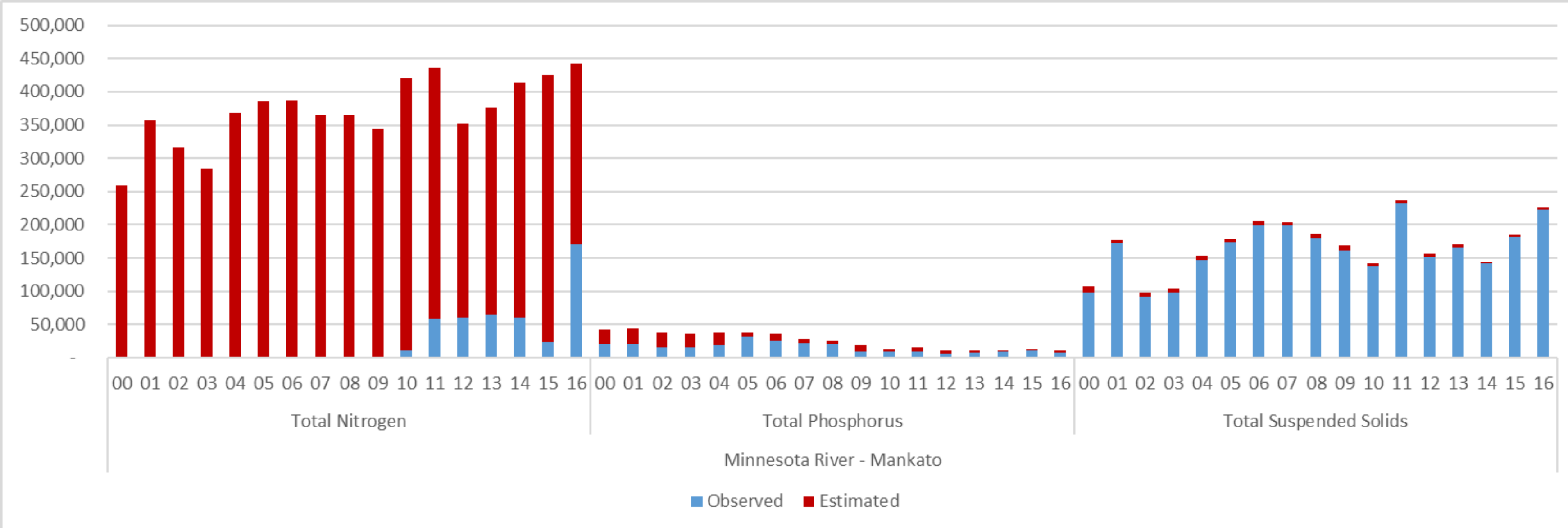
69.2%



Data and Estimates for Checks in Calculator-recalc values when updated info is available		
Watershed Yield (in) (WPLMN data)	8.0	
Change in River flow due to drainage (in) (estimated from Schottler, etc.)	1.5	assumed same as cottonwood
Average Surface Runoff from Not-tiled sites (in) (Discovery Farms)	3.5	
Average Surface+Tile from Tiled sites (in) (DiscoveryFarms)	7.4	
Average Surface+Tile yield ratio for tiled:not tiled (ratio) (Discover Farms)	1.5	
Average surface runoff ratio for a tiled:not tiled (ratio) (Discovery Farms)	0.6	
Average Tile Runoff from Tiled sites (in) (Discovery Farms)	7.2	
Average Surface Runoff from Tiled sites (in) (Discovery Farms)	2.1	
Average Tile:Surface water yield ratio in a tiled field (ratio) (Discovery Farms)	3.4	
Estimated Tile Runoff from Tile Drained Areas (in)		Assume Schottler's number is all tile from the watershed, use this and est tile %
Estimated Surface Yield from Tile Drained Areas (in)		Above number and disc farm
Estimated tile:surface ratio for a tiled field	#DIV/0!	Above 2 numbers
DNR baseflow seperation for watershed		NOT CALCULATED FOR mid mn
Tile predominately drains ground water, thus the contribution to GW on a tled field is substantially reduced compared to a not tiled field		
Schottler's analysis says 20% increase in flow is 80% due to tile drainage changes		
Estimate of % ground water (See Folle & HSPF model on sources overview)	0.2	

Water portioning calculator derives percentages based on linear algebra using assumptions developed from lines of evidence and professional judgement (as documented here on the calculator printout).

Point Source Data Summary From All Point Sources



Point Source Contribution to Total Watershed Load Calculation

Sed/TSS

		FWMC (mg/L)	Yield (lbs/ac)	estimated LOAD	% Point of Total Load
WPLMN Data* 7-mile Creek	Averaged Annual (2007-2015)	263	527		
	Multi year (2007-2015)	341			
	Averaged (2014-2015 only)	545	879		
	Multi year (2014-2015 only)	624			
WPLMN Data* Little Cottonwood	Averaged Annual (2014-2015)	153	176		
	Multi year (2014-2015)	190			
HSPF model data**	ALL Average	142	654		
	7 mile Average	83	170		
	7 mile Outlet	121			
	Little Cottonwood Average	172	339		
	Little Cottonwood Outlet	271			
Prof. Judg. Estimated Mid MN HUC-8 Totals	Low	140	150	129,333,750	0.14%
	Medium	190	300	258,667,500	0.07%
	High	300	800	689,780,000	0.03%

TN

		FWMC (mg/L)	Yield (lbs/ac)	estimated LOAD	% Point of Load
WPLMN Data* 7-mile Creek	Averaged Annual (2007-2015)	21.3	33.2		
	Multi year (2007-2015)	21.5			
	Averaged (2014-2015 only)	24.3	35.5		
	Multi year (2014-2015 only)	25.2			
WPLMN Data* Little Cottonwood	Averaged Annual (2014-2015)	8.5	8.3		
	Multi year (2014-2015)	8.9			
HSPF model data**	ALL Average	8.5	17		
	7 mile Average	9.3	20		
	7 mile Outlet	10.8			
	Little Cottonwood Average	10.3	16		
	Little Cottonwood Outlet	9.7			
Prof. Judg. Estimated Mid MN HUC-8 Totals	Low	8	8	6,897,800	5.8%
	Medium	12	20	17,244,500	2.3%
	High	25	35	30,177,875	1.3%

TP

		FWMC (mg/L)	Yield (lbs/ac)	estimated LOAD	% Point of Load
WPLMN Data* 7-mile Creek	Averaged Annual (2007-2015)	0.31	0.55		
	Multi year (2007-2015)	0.35			
	Averaged (2014-2015 only)	0.34	0.50		
	Multi year (2014-2015 only)	0.36			
WPLMN Data* Little Cottonwood	Averaged Annual (2014-2015)	0.29	0.32		
	Multi year (2014-2015)	0.34			
HSPF model data**	ALL Average	0.32	0.71		
	7 mile Average	0.31	0.75		
	7 mile Outlet	0.38			
	Little Cottonwood Average	0.34	0.62		
	Little Cottonwood Outlet	0.32			
Prof. Judg. Estimated Mid MN HUC-8 Totals	Low	0.25	0.27	232,801	5.0%
	Medium	0.3	0.35	301,779	3.8%
	High	0.36	0.47	405,246	2.8%

*WPLMN seasonal site data adjusted to annual data with 15% addition to loads and flow (affects yield not concentration) **HSPF yields are delivered gross and not net (does not include deposition/loss/consumption) and include amounts from streambank erosion of the MN River

Point Source Contribution in Mid MN

Year (Total Suspended Solids)	Observed	Estimated	Total	Averages 07-15 avg	Averages 11-15 avg
07	198791	5611	204401	177,178	
08	180586	5675	186261		
09	161501	6863	168364		
10	136912	5923	142835		
11	232458	4914	237371		178,548
12	151923	5098	157021		
13	165405	4404	169809		
14	142657	1822	144479		
15	181645	2413	184059		

Yea (Average Total Nitrogen)	Observed	Estimated	Total	Averages 07-15 avg	Averages 11-15 avg
07		365818	365818	388,814	
08		365052	365052		
09		343910	343910		
10	11124	409132	420256		
11	57724	379000	436723		400,858
12	59189	293482	352671		
13	64886	310849	375735		
14	59163	355425	414588		
15	22875	401698	424573		

Year (Total Phosphorus)	Observed	Estimated	Total	Averages 07-15 avg	Averages 11-15 avg
07	22239	5426	27665	15,841	
08	20032	5226	25257		
09	9206	9995	19200		
10	8544	4230	12775		
11	9548	5467	15015		11,534
12	6507	3921	10428		
13	7472	2743	10215		
14	9299	831	10130		
15	10252	1628	11880		

Stressor Sources (from Stressor ID Report)

key:
- Stressor
- Inconclusive
- Not a Stressor
- ●=suspected source
- ○=potential source

Identified Stressors and Probable Sources, Pathways, and Drivers of those Stressors

Reach	Stream	Temp			DO				Eutroph.					Nitrate				TSS						Habitat				Connectivity					Alt Hydro		
		Altered Hydrology	Urban runoff	Point Sources	Plant Resperation	Lack of flow	Wetland/Lake influcence	Unidentified	Wetland Influence	Lake influence	Excess Phosphorus	Algal/Plant Shift	Unidentified	Tile Drainage/Land Use	Wetland/Lake Influnce	Karst Pathways/Springs	Point Sources	Suspended Algae	Flow Alteration/velocity	Streambank erosion	tile/Channelization	Urbanization	Pasture	Pasturing/Lack of Riparian	Channel Morphology	Bedded Sediment	**Erosion**	Flow Alteration/Connectivity	Dams/Impoundments	Road Crossings/Perched Culverts	Waterfalls (natural)	Beaver Dams	Altered Waters/Channelization	Reduced Baseflow	Tile Drainage/Land Use
	City of Mankato																																		
541	Cherry Creek				●		●			●	●	●		●	●			●			●				●	●		●	●				●	●	●
543	Cherry Creek									●	●			●	●			●															●	●	●
693	Shanaska Creek									●	●			●	●			●			●							●					●	○	●
696	Unnamed Creek				●		●			●	●			●	●										●	●	●			●			●		●
550	Unnamed Creek							●		●	●	●		●	●			●		○							○	○					●	○	●
	Minneopa Creek																																		
593	Judicial Ditch 48				●		○		○		●	●		●	●			●							●	●	●				●		●		●
531	Minneopa Creek				●						●	●		●				●							●	●	●				●		●		●
535	County Ditch 27				●						●	●		●				●						●	●	●	●				●		●		●
557	Lake Crystal Inlet(County Ditch				●						●	●		●				●						●	●	●	●				●		●		●
534	Minneopa Creek				○		●			●	●			●	●			●													●		●		●
	Morgan Creek																																		
577	Unnamed Creek	●												○						●						●	●			●		●	●		●
701	Judicial Ditch 10				●		○			○	●	●		●				●		●				●	●	●							●		●
691	Morgan Creek							●			●			●	○			○			●									●			●		●
	Little Cottonwood																																		
657	County Ditch 11				●						●	●		●				●			●			●	●	●	●						●		●
658	County Ditch 67										●			●						●	●						●						●		●
676	Little Cottonwood River				●						●	●		●			○			●	●		●		●	●	●						●		●
677	Little Cottonwood River	●									●			●			○			●		○	●			●	●						●		●
	Spring Creek																																		
571	County Ditch 10 (John's Creek)	●				●					●			●						●	●							●					●	○	●
712	County Ditch 13										●			●						●	●						●	●					●	○	●
622	Spring Creek (Judicial Ditch 29)					●					●	●		●						○					●	●				●		●	●		●
574	Spring Creek (Hindeman Creek)	●						●			●			●						○										●			●		●
573	Spring Creek				●						●	●		●						●	●				●	●	●						●		●
715	Unnamed Creek										●			●						●				●	●		●			●			●		●
636	County Ditch 52				●						●	●		●				●		●	●	●			●	●							●		●
569	Crow Creek							●			●			●			○	●		●	●	●				●	●						●		●
	Wabasha Creek																																		
527	Wabasha Creek							●			●																						●		●
699	Wabasha Creek				●						●	●		●				●						●	●	●							●		●
	SPRING CREEK																																		
704	Threemile Creek				●	●					●	●																○		●		●	●	●	●
	BIRCH COULEE CREEK																																		
670	County Ditch 124				●	●					●	●		●			○							●	●	●							●	●	●
711	County Ditch 124					●					●	●		●			○							●	●	●							●	●	●
588	Birch Coulee Creek										●	○		●			○											○			●		●	○	●
587	Birch Coulee Creek										●	○		●			○											○			●		●	○	●
	FORT RIDGLEY																																		
673	County Ditch 115				●	●					●	●		●				○		○	●			●	●								●	●	●
688	County Ditch 106A				●	●					●	●		●				●			●			●	●	●							●	●	●
689	Fort Ridgley Creek					○		○			○			●				○	●	●	○							●	●				●	●	●
	LITTLE ROCK CREEK																																		
666	Judicial Ditch 8				●						●	●		●				●			●			●	●				●				●	●	●
686	Little Rock Creek (Judicial Ditch 3				●						●	○		●				○			●			●	●				●				●	●	●
687	Little Rock Creek (Judicial Ditch 3				●						●			●										●		●		●					●	●	●
716	Judicial Ditch 13				●	●					●	○		●										●	●	●		●					●	●	●
717	Judicial Ditch 13				●	●					○			●						○						○		●					●	●	●
	CITY OF NEW ULM																																		
684	Eightmile Creek										●			●						●					●					●			●		●
709	Fritsche Creek (CD 77)										●			●																			●		●
675	Heyman's Creek										●			●			○								●	●							●		●
	SWAN LAKE																																		
545	County Ditch 4/County Ditch 39				●	○	○		○		●			●	○									●	●	●							●	●	●
661	County Ditch 11				●	●					●	●		●				○			●			●	●	●							●	●	●
683	Swan Lake Outlet (Nicollet Creek)				●	●				○	●			●	○																		●	●	●
	MORGAN CREEK																																		
660	County Ditch 3				○						●	○		●					●	●	●				●								●	○	●
	CITY OF MANKATO																																		
678	County Ditch 46A				●	●	○		○		○	●		●	○			●	●			●			●	●		○	●				●	○	●
679	County Ditch 46A				●	●	○		○		●	●		●	○			●	●			●				●							●	○	●
562	Sevenmile Creek	●				○			○		●			●	○					●					●	●		●		●			●	●	●
703	Sevenmile Creek							●			○			●					●		●				●	●							●		●
547	Rogers Creek				○			●			●	●		●			○			●			○			●							●	○	●

Pre-Settlement Landscape Map Data Sources

This map graphic (Figure 12) is an approximation of the pre-European settlement landscape. It is not intended for numerical analysis, but rather offers a small scale illustration (or paints the picture) of the pre-European settlement, which was predominantly prairie with water bodies and wetlands (prairie wetlands, some streams, and some forested riparian areas). The pre-settlement landscape was estimated using the following data sources:

1. A digitized copy of the streams from the U.S. General Land Office Survey survey maps and notes (from 1848 – 1907; MnGeo 2011). Note that this digitization was intended to generally represent the features as captured in the U.S. General Land Office Survey maps and notes as documented 110 – 169 years ago. It cannot be used to calculate miles or to do analysis at a large (close up) scale. The image of this data layer may be used at a smaller (far away) scale, but is not visible at the scale presented.
2. Drained wetlands were pulled from the National Wetland Inventory (USFSW 2016) and Restorable Wetlands were pulled from the Restorable Wetland Inventory (USFWS 2009).
3. Additional wetland areas were pulled from Marschner's analysis. The Original Vegetation of Minnesota: data was first compiled in 1930 by F. J. Marschner (of the Office of Agricultural Economics, USDA) from the data created by the U.S. General Land Office Survey notes. In 1974 the Marschner's data was interpreted and mapped by M.L. Heinselman and others at the U.S. Forest Service (North Central Forest Experiment Station in St. Paul). This map was then digitized and modified by the DNR Natural Heritage and Nongame Research Program in the 1980s and later. The original map was done at 1:500,000 and then attributes and geography generalized for display, at approximately 1:1 million, at which the presented map is approximately shown. The purpose of the data is to analyze presettlement vegetation patterns for the purpose of determining natural community potential, productivity indexes and patterns of natural disturbance.

P Export Analysis

The amount of phosphorus (P) native to the soil does not necessarily indicate the likeliness of P to runoff (or export). Instead, we can compare P export of native prairie to P export from cultivated crops to deduce the relative amount of P export due to agricultural activities. Several ranges of grassland and prairie P export are available in the literature. The MPCA's Detailed P Assessment (completed by Barr Engineering) cited a large range of P export from grasslands and restored prairies ranging from 0.05-0.22 lb/ac/yr. In a more recent study of native prairie in the neighboring Cottonwood River Watershed, native prairie P export rates ranged from 0.02-0.09 lb/ac/yr (report reference provided in Sources Overview section). Discovery Farms field data (summarized in Appendix 2.2) has measured Minnesota cultivated crop P export rates of roughly 0.5 lb/ac (data and references in Appendix). Furthermore, we know that that typical cultivated crop P application rates on MN River basin farms is typically in the 10's of lb/ac/yr and that at the major watershed scale, P export is roughly 0.5 lb/ac/yr. This means that farm P export is roughly 10 times greater than native P export; roughly 10 to 20 times more P is applied to a farm fields than is exported from a farm field, and roughly, the export rate of a farm field is about the same as the P export from the major watershed. Deducing from these ratios, agricultural activities (on what were natively prairie lands) are likely accounting for the majority of P export from farm fields.

Although, the particular aspect of the agricultural activities (e.g. fertilizer application, tillage, change in vegetation, change in OM, etc.) that causes the P export cannot be determined from this. However, based on the ratio of applied P to exported P, fertilizer and manure application are likely causes of this increased P export.

Interpretation of the Feedlot Statistics

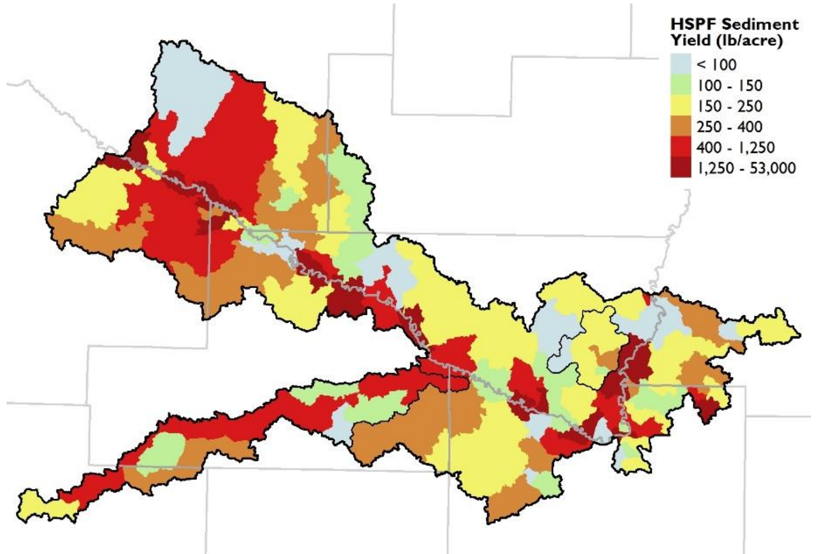
This interpretation of feedlot statistics for the Middle Minnesota River Watershed was provided by the MPCA feedlot staff.

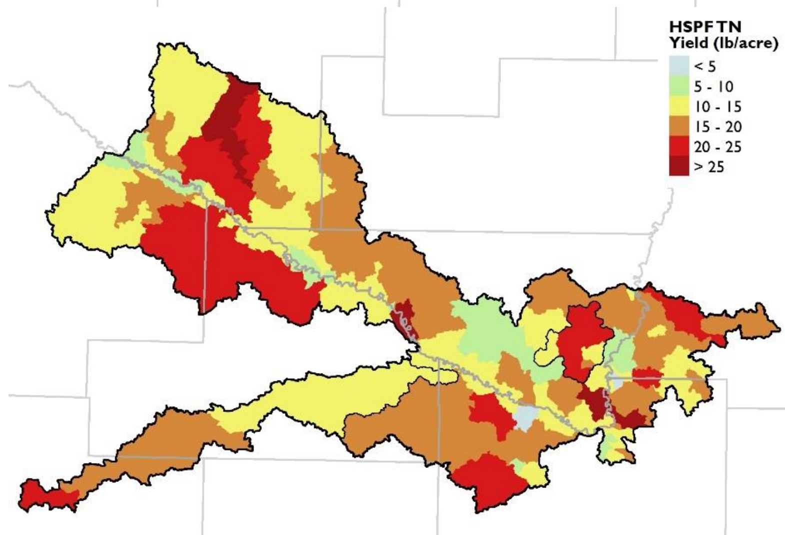
- Surface applied manure generally tends to come from smaller feedlots or "smaller" dairies or poultry.
- Facilities with <300 AU generally have limited manure storage so manure application occurs on a more frequent basis and is not required to have a manure management plan or test their soils for P.
- Facilities with <100 AU have even less restrictions under the feedlot rules.
- Poultry litter does not follow the general rule of being spread close to a facility. It is generally brokered out to area crop farmers who are willing to pay for the manure and because of the higher nutrient value and ease at which it can be hauled in a semi make this type of manure more "mobile" than other manures. Implications of this include:
  - most of the manure is surface applied
  - generally, manure from these facilities is sold to non-livestock farmers
  - barns are cleaned out when barns are emptied of mature birds so tends to lead to a significant amount of temporary manure stockpiles in field which can have their own issues (they must meet setback requirements but generally do not have runoff controls like permanent stockpile sites) since they are exposed to weather extremes
- Most feedlots have to keep records of manure application and the MPCA and/or delegated counties have the authority to request these records but because of lack of staffing generally do not request them. The NPDES permitted sites have to submit annual reports with their manure records but lack of staffing does not allow comprehensive tracking of the acres.

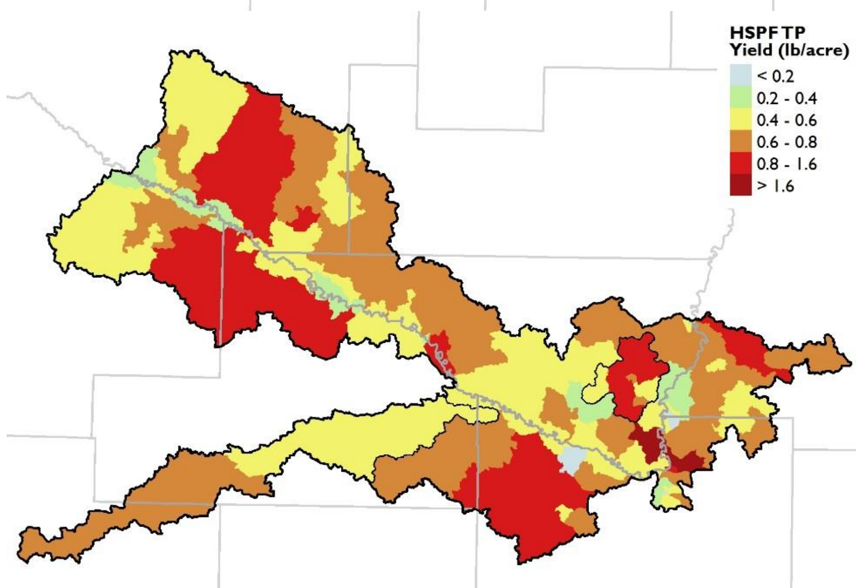
Regulated Facilities that do not Discharge to Surface Waters

Non-Discharging Facilities	County
Lane Ridge Farms LLC	Nicollet
Magellan Pipeline Co LP - Mankato	Blue Earth
Minnesota Elevator Inc	Blue Earth
TBEI Inc	Blue Earth

HSPF Estimated Subwatershed Yields







ET Rate Data & Calculation

The presented ET rates are from the following sources/methodologies:

ET rate	Formula/specifics	Reference	Applicable Data
Wetland	$ET_W = 0.9 * ET_{pan}$	Wallace, Nivala, and Parkin (2005)	Waseca station pan ET 1989-2008 average
Lake	$ET_L = 0.7 * ET_{pan}$	Dadaser-Celik and Heinz (2008)	
Crops	Crop ET, Climate II	NRCS (1977)	Table from source

The NRCS crop ET source, despite the source age, was selected because it provided the highest estimates of crop ET. To illustrate this point, the seasonal corn ET rates, as determined from several sources, are presented below:

Methodology, data	Source	May-Sept Corn ET
1. Irrigation table	NRCS (1977)	64 cm
2. SWAT modeling in the Lake Pepin Full Cost Accounting	Dalzell et al. (2012)	54 cm
3. MN Irrigation Scheduling Checkbook, Waseca station temp	NDSU (2012)	42 cm
4. MN Crop Coefficient Curve for Pan ET, Waseca station pan ET	Seeley and Spoden (1982)	39 cm

Using the highest crop ET rates for comparison was desired for multiple reasons: 1) pan coefficients were developed using older data sets and it is likely that corn, with higher crop densities and larger plant sizes, uses more water today than it did when the coefficients were determined, 2) using lower crop ET rates may appear to exaggerate the difference between crop and non-crop ET rates, and 3) error associated with pan ET rates could result in exaggerated differences between estimated wetland/lake ET and crop ET. More information on calculating ET rates is available here: http://deepcreekanswers.com/info/evaporation/ET_water_surf.pdf.

4.3 Water Quality Goals– Related Appendices

TMDL Summary & Goals Calculation

Lake phosphorus reduction calculations

*	= indicates the method and result used to calculate the % reduction estimate presented in the WRAPS							
								*
Lake Name	Modeled Inflow	Modeled Inflow at Standard	Modeled Inflow Load Reduction (Consultant Method)	Mean Concentration (Avg each year then average all years, cons. provided)	Standard	Reduction from Mean Observed Lake Concentration (Jun-Sep, Years Avg'd)	Data Months Years	Mean Concentration (Avg each month per year, then avg by year, then average all years)	Reduction from Mean Observed Lake Concentration (Jun-Sep Months & Years Avg'd)
Crystal					90		6-9, 2008, 2009	253	64%
Duck	530.4	149.9	72%	87	40	54%	6-9 2006	75	46%
George	226.2	70	69%	89	40	55%	6-9 2006, 2014	85	53%
Henry	3515.7	333.4	91%	359	60	83%	6-9 2014 (7 2007 not used)	359	83%
Loon	2163.6	958.1	56%	150	90	40%	6-9 2006, 2008, 2009	150	40%
Mills	845	220.9	74%	174	90	48%	6-9 2008, 2009	174	48%
Scotch	5624.8	997	82%	208	60	71%	6-9 2014	208	71%
Washington	3188	1276.2	60%	74	40	46%	6-9 2006, 2007, 2011, 2012; 6-8 2014	74	46%
Wita	774.5	192.6	75%	145	60	59%	6-9 2014	145	58%
			72%			57%			56%

						*				*			*	
	Bacteria % Reductions (Standard Applies Apr-Oct)						TSS % Reductions (Standard Apr-Sep)				NOx (Year-round)			
	Whole Data set				Jun-Aug Data Set			Whole Data Set		Jun-Aug Data		Whole Data Set		
Reach	Months with Data (in which Std applies)	Max Monthly Geomean	Avg'd Monthly Geomean	Flow Wt'd Monthly Geomean	Avg'd Monthly Geomean	Flow Wt'd Monthly Geomean	Months with Data (in which Std applies)	90% Percentile Observation compared to Standard	Observed Load Sum compared to Standard Load Sum	Observed Load Sum compared to Standard Load Sum	Months with Data	2nd Highest Concentration	Observed Load Sum compared to Standard Load Sum	Load Sum compared to 5 mg/L (proposed aql std)
518	Jun-Aug	12%	-30%	-24%	-30%	-24%								
527	Apr-Sep	90%	82%	83%	85%	87%								
534	Jun-Aug	87%	82%	74%	82%	74%	May-Aug	35%	75%	80%				
557	Apr-Oct	80%	54%	38%	73%	73%								
562	Apr-Oct	40%	-3%	0%	43%	38%	Apr-Sep	96%	83%	88%	Mar-Oct	75%	56%	78%
569	Apr-Sep	91%	75%	69%	74%	67%								
571	Apr-Sep	90%	79%	81%	83%	76%					Mar-Oct	52%	13%	56%
573	Apr-Sep	81%	60%	64%	67%	73%								
577											May-Jun, Aug-Sep	57%	51%	76%
587	Apr-Aug	66%	42%	49%	61%	64%								
598	Apr-Sep	97%	90%	86%	92%	85%								
600	Apr-Sep	88%	73%	69%	82%	70%								
602	Apr-Sep	97%	88%	65%	68%	13%								
603	Apr-Sep	92%	72%	67%	60%	61%								
604	Apr-Sep	92%	77%	56%	73%	38%								
613	Jun-Aug	80%	74%	79%	74%	79%								
622	Jun-Aug	70%	59%	64%	59%	64%								
637	Apr-Aug, Oct	88%	72%	52%	83%	76%								
640	Apr-Aug	88%	69%	62%	80%	70%								
641	Apr-Sep	95%	84%	83%	80%	77%								
644	Apr-Sep	81%	67%	57%	75%	72%								
645	Apr-Aug	87%	67%	60%	79%	70%								
676	Apr-Aug	89%	59%	39%	72%	75%	May, Jun, Aug	58%	-16%	-3%				
677	Apr-Oct	72%	55%	7%	61%	50%	Apr-Sep	78%	72%	80%				
679	Apr-Oct	85%	61%	-5%	79%	80%	Apr-Sep	-5%	-26%	-50%				
683	Apr-Sep	90%	77%	78%	77%	82%								
684	Apr-Sep	78%	56%	70%	76%	77%								
687	Apr-Aug	79%	61%	64%	76%	73%								
689	Apr-Sep	47%	-20%	25%	28%	44%								
691	Apr-Aug	77%	59%	55%	61%	59%								
693	Apr-Aug	88%	65%	56%	77%	66%								
703	Apr-Oct	73%	40%	0%	64%	45%	Apr-Sep	-124%	-126%	-82%				
704	Apr-Aug	44%	-22%	-65%	23%	-23%								
709	Apr-Aug	92%	74%	68%	83%	73%								
712	Apr-Sep	83%	78%	78%	79%	80%								
AVERAGE		79%	58%	50%	68%	61%	AVERAGE	23%	10%	19%	Average	61%	40%	70%

Nitrogen calculation

Reduction goals for nitrogen impaired reaches were calculated based on all data from the past 10 years, and calculated by taking the difference of the total observed load for the time period compared to what the load would have been at the standard over the same flows using the year round standard.

Phosphorus calculation

For lake reductions, the mean of the within year concentration averages for all available years was compared to the lake standard for each lake.

Sediment calculation

The method of calculation for the reduction was to take the loading values from June through August (due to lacking consistent data outside of these months) in the most recent 10 years. The percent difference of the total observed load for the time period was then compared to what the load would have been at the seasonal standard over the same flows.

Bacteria Calculation

The method to calculate the reduction used the monthly geometric mean of samples (June through August, due to consistent data outside of these months) for the last 10 years. Monthly geometric means per month were then averaged. The average value was then compared to the standard.

Comparison of Model and WPLMN Data and Professional Judgement Watershed-wide Pollutant Concentration & Yield Estimate

	Sed/TSS		
		FWMC (mg/L)	Yield (lbs/ac)
WPLMN Data* 7-mile Creek	Averaged Annual (2007-2015)	263	527
	Multi year (2007-2015)	341	
	Averaged (2014-2015 only)	545	879
	Multi year (2014-2015 only)	624	
WPLMN Data* Little Cottonwood	Averaged Annual (2014-2015)	153	176
	Multi year (2014-2015)	190	
HSPF model data**	ALL Average	142	654
	7 mile Average	83	170
	7 mile Outlet	121	
	Little Cottonwood Average	172	339
	Little Cottonwood Outlet	271	
Prof. Judg. Estimated Mid MN HUC-8 Totals	Low	140	150
	Medium	190	300
	High	300	800
*WPLMN seasonal site			
Standard		65	
Standard vs. Prof Jug Med FWMC Est		66%	

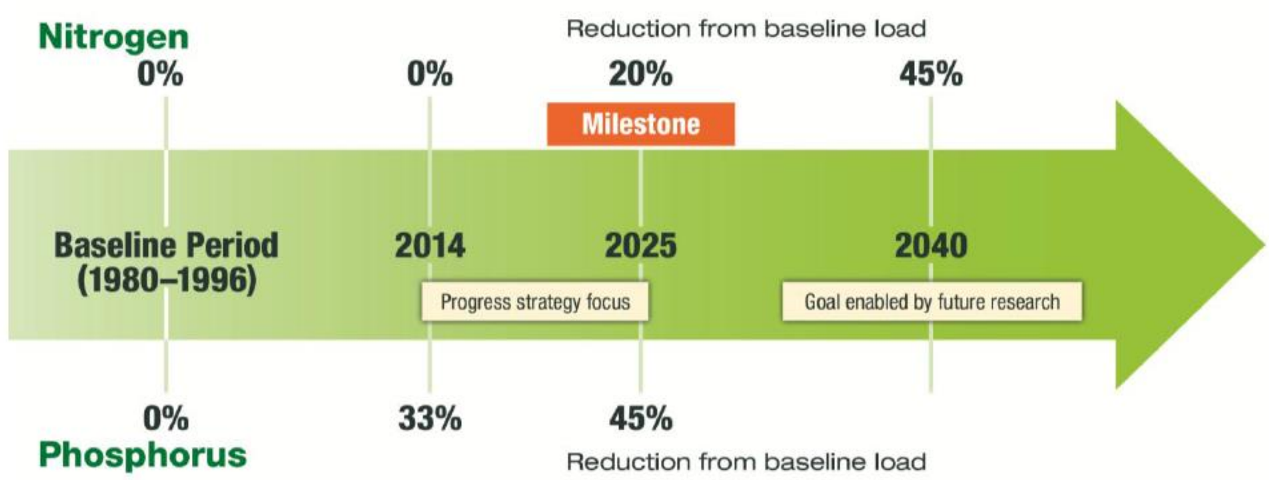
	TN		
		FWMC (mg/L)	Yield (lbs/ac)
WPLMN Data* 7-mile Creek	eraged Annual (2007-2015)	21.3	33.2
	Multi year (2007-2015)	21.5	
	Averaged (2014-2015 only)	24.3	35.5
	Multi year (2014-2015 only)	25.2	
WPLMN Data* Little Cottonwood	eraged Annual (2014-2015)	8.5	8.3
	Multi year (2014-2015)	8.9	
HSPF model data**	ALL Average	8.5	17
	7 mile Average	9.3	20
	7 mile Outlet	10.8	
	Little Cottonwood Average	10.3	16
	Little Cottonwood Outlet	9.7	
Prof. Judg. Estimated Mid MN HUC-8 Totals	Low	8	8
	Medium	12	20
	High	25	35
		5	
		58%	

	TP		
		FWMC (mg/L)	Yield (lbs/ac)
WPLMN Data* 7-mile Creek	veraged Annual (2007-2015)	0.31	0.55
	Multi year (2007-2015)	0.35	
	Averaged (2014-2015 only)	0.34	0.50
	Multi year (2014-2015 only)	0.36	
WPLMN Data* Little Cottonwood	veraged Annual (2014-2015)	0.29	0.32
	Multi year (2014-2015)	0.34	
HSPF model data**	ALL Average	0.32	0.71
	7 mile Average	0.31	0.75
	7 mile Outlet	0.38	
	Little Cottonwood Average	0.34	0.62
	Little Cottonwood Outlet	0.32	
Prof. Judg. Estimated Mid MN HUC-8 Totals	Low	0.25	0.27
	Medium	0.3	0.35
	High	0.36	0.47
		0.15	
		50%	

Watershed-wide goals are typically set and applied to a baseline data set that represents the watershed as a whole. In most watersheds, a WPLMN monitoring site near the outlet of the watershed is able to measure the water leaving the watershed. The Middle Minnesota River Watershed, however, is composed of multiple subwatersheds that directly outlet to the Minnesota River, and only two of these watersheds have WPLMN data coverage. By comparing the actual WPLMN data results and model results, one can observe how well the model is simulating the observed data. Furthermore, model data covers the entire watershed area, but does not represent the same baseline data years, and model data may not have ideal calibration and validation information due to the lack of WPLMN sites. Therefore, from these lines of data, we can apply professional judgement to estimate low and high brackets and a medium estimate on what the actual pollutant concentrations were over the baseline years. The medium estimate was compared to the water quality standard and used to calculate the watershed-wide goal.

MN State Nutrient Reduction Strategy

https://www.pca.state.mn.us/sites/default/files/wq-s1-80.pdf



The Minnesota State Nutrient Reduction Strategy goals are summarized in the above figure.

The Minnesota State phosphorus strategy calls for an additional 12% reduction (in addition to the already reached 33% reduction) between a 1980 through 1996 baseline period and 2025. To calculate what percent-reduction this equates to between the current (2014) loads and the total goal, the 33% reduction already made must be factored into the reduction calculation.

The percent reduction calculation is illustrated by assigning the baseline period a load equal to 100 units. The total goal is to reduce this by 45% (45 units), which means the goal is to reach 100 units-45 units = 55 units. Since a 33% (33 unit) reduction in baseline levels was already achieved, the 2014 load equals 100 units - 33 units = 67 units. The reduction from 2014 to the final goal is (67units -55units)/67units = 18% reduction. This goal is for the Mississippi River Basin as a whole, whereas the Minnesota River Basin is a much higher yielding area. Therefore, the total goals for major watersheds in the Minnesota River Basin will likely be higher than the Mississippi River Basin reduction goal.

4.4 Strategies & Priorities – Related Appendices

Model Summary

Model(s) & Reference	Summary & Notes	Scenario	Modeled BMPs/Landscape	Reduction in Parameter: Sediment	Reduction in Parameter: Phosphorus	Reduction in Parameter: Nitrogen	Cost
N-BMP Spreadsheet Tool Minnesota Watershed Nitrogen Reduction Planning Tool (Lazarus et al., 2014)	The BMPs outlined here were developed using the N-BMP spreadsheet tool with inputs specifically for the Middle MN watershed for average weather conditions. All of the practices in the tool were applied to some degree in both scenarios. The first/top scenario achieves a 12% N reduction from all crop lands, which is roughly a 10.5% reduction of the total watershed N load. The second/bottom scenario achieves a 58% N reduction from all crop lands, which is roughly a 50% reduction of the total watershed N load and represents using the listed BMPS everywhere feasible, according to the assumptions in the model. Parameter load reductions are presented as the pounds per treated acre (how many pounds of N reduction are estimated for each acre where the practice is adopted). The costs are represented as the cost per pound of nitrogen removed.	12% N Reduction from Crops	25% of land receives target N fertilizer rate			4 lb/ac	**$-3/lb**
			2% of land receives Fall N inhibitor			2 lb/ac	$2/lb
			2% of land switches from fall to spring fertilizer application			5 lb/ac	**$-1/lb**
			2% of land switches from fall to split fertilizer application			5 lb/ac	$3/lb
			3% of land uses rye cover crop			2 lb/ac	$34/lb
			0.7% of land short season crops adopt a rye cover crop			4 lb/ac	$14/lb
			1% of land adopts riparian buffers 50 feet wide			10 lb/ac	$18/lb
			0.2% of land converts to perennial crop			13 lb/ac	$4/lb
			0.2% of land is treated by tile line bioreactors			2 lb/ac	$24/lb
			0.2% of land adopts controlled drainage			4 lb/ac	$3/lb
			0.2% of land adopts saturated buffers			5 lb/ac	$2/lb
			0.1% of land is drained to treatment wetlands			6 lb/ac	$2/lb
		58% N Reduction from Crops	82% of land (corn & bean crops) uses rye cover crop			2 lb/ac	$34/lb
			7% of land (short season crops) adopt a rye cover crop			4 lb/ac	$14/lb
			26% of land receives target N fertilizer rate			4 lb/ac	$-3/lb
			20% of land receives Fall N inhibitor			3 lb/ac	$2/lb
			16% of land adopts saturated buffers			5 lb/ac	$2/lb
			15% of land is treated by tile line bioreactors			2 lb/ac	$24/lb
			14% of land is drained to treatment wetlands			6 lb/ac	$2/lb
			14%of land adopts controlled drainage			4 lb/ac	$3/lb
			5% of land converts to perennial crop			13 lb/ac	$4/lb
			1% of land adopts riparian buffers 50 feet wide			10 lb/ac	$18/lb
P-BMP Spreadsheet Tool Minnesota Watershed Phosphorus Reduction Planning Tool (Lazarus et al., 2015)	The BMPs outlined here were developed using the P-BMP spreadsheet tool with inputs specifically for the Middle MN watershed for average weather conditions. All of the practices in the tool were applied to some degree in both scenarios. The first/top scenario achieves a 14% P reduction from all crop lands, which is roughly a 10.5% reduction of the total watershed P load. The second/bottom scenario achieves a 56% P reduction from all crop lands, which is roughly a 37% reduction of the total watershed N load and represents using the listed BMPS everywhere feasible, according to the assumptions in the model. Parameter load reductions are presented as the pounds per treated acre (how many pounds of P reduction are estimated for each acre where the practice is adopted). The costs are represented as the cost per pound of phosphorus removed.	14% P Reduction from Crops	61% of land adopts reduced P application rate		0.04 lb/ac		$-315/lb
			1% of land switches to preplant/starter fertilizer application		0.02 lb/ac		$1096/lb
			3% of land (>2% slopes) uses reduced tillage		0.08 lb/ac		$-186/lb
			0.6% of land converts to 50 ft stream buffers		2.4 lb/ac		$25/lb
			0.2% of land converts to perennial crop		0.25 lb/ac		$133/lb
			3% of land (corn & bean crops) uses rye cover crop		0.05 lb/ac		$1022/lb
			1% of land (short season crops) adopt a rye cover crop		0.11 lb/ac		$522/lb
			14%of land adopts controlled drainage		0.17 lb/ac		$60/lb
			1% of land injects/incorporates manure		0.16 lb/ac		$54/lb
		56% P Reduction from Crops	92% of land adopts reduced P application rate		0.04 lb/ac		$-343/lb
			12% of land switches to preplant/starter fertilizer application		0.03 lb/ac		$1007/lb
			35% of land (>2% slopes) uses reduced tillage		0.11 lb/ac		$-149/lb
			3% of land converts to 50 ft buffers		2.4 lb/ac		$37/lb
			5% of land converts to perennial crop		1.75 lb/ac		$1236/lb
			88% of land (corn & bean crops) uses rye cover crop		0.05 lb/ac		$1022/lb
			7% of land (short season crops) adopt a rye cover crop		0.11 lb/ac		$522/lb
			16% of land adopts controlled drainage		0.17 lb/ac		$60/lb
			29% of land adopts alternative tile intakes		0.12 lb/ac		$5/lb
			5% of land injects/incorporates manure		0.16 lb/ac		$54/lb

Model(s) & Reference	Summary & Notes	Scen	Modeled BMPs/Landscape		Reduction in Parameter			Cost
					Sediment	Phosphorus	Nitrogen	
HSPF SAM Scenarios https://www.respec.com/sam-file-sharing/	6 total scenarios ran in the Middle Minnesota. 2 scenarios for each of the following watersheds: Little Conttonwood (LC), 7-mile Creek (7M), and Shanaska Creek. The first scenario (1) ran for each area achieved modest reductions using moderate adoption rates of only 4 specified BMPs (by optimizing/ minimizing cost for a 10% P reduction). The second (2) scenario ran for each area looked at large reductions using a wide selection of BMPs (by optimizing/minimizing cost for a 50% P reduction at sometimes high adoption rates.)	LC - 1	82%	of area adopts Nutrient Management	3%	10%	17%	$834,000/yr ($8/ac/yr)
			82%	of area adopts Corn & Soybeans with Cover Crop				
			11%	of area adopts Reduced Tillage (30%+ residue cover)				
			2%	of area adopts Alternative Tile Intakes				
		7M-1	75%	of area adopts Nutrient Management	8%	10%	16%	$212,000/yr ($10/ac/yr)
			15%	of area adopts Corn & Soybeans with Cover Crop				
			3%	of area adopts Reduced Tillage (30%+ residue cover)				
			6%	of area adopts Alternative Tile Intakes				
		SC-1	51%	of area adopts Nutrient Management	7%	9%	19%	$116,000/yr ($5/ac/yr)
			19%	of area adopts Reduced Tillage (30%+ residue cover)				
		LC-2	82%	of area adopts Nutrient Management	15%	47%	15%	$3.6M/yr ($33/ac/yr)
			11%	of area adopts Reduced Tillage (30%+ residue cover)				
			2%	of area adopts Alternative Tile Intakes				
			12%	of area adopts Controlled Tile Drainage				
			23%	of area adopts Riparian Buffers, 100 ft wide (replacing row crops)				
			18%	of area adopts Filter Strips, 50 ft wide (Cropland field edge)				
			13%	of area adopts Conservation Crop Rotation				
			15%	of area adopts Water and Sediment Control Basin (Cropland)				
			20%	of area adopts Restore Tiled Wetlands (Cropland)				
			1%	of area adopts Corn & Soybeans with Cover Crop				
		7M-2	75%	of area adopts Nutrient Management	25%	50%	56%	$703,000/yr ($31/ac/yr)
			3%	of area adopts Reduced Tillage (30%+ residue cover)				
			6%	of area adopts Alternative Tile Intakes				
			43%	of area adopts Controlled Tile Drainage				
			13%	of area adopts Riparian Buffers, 100 ft wide (replacing row crops)				
			10%	of area adopts Filter Strips, 50 ft wide (Cropland field edge)				
			11%	of area adopts Conservation Crop Rotation				
			7%	of area adopts Water and Sediment Control Basin (Cropland)				
			28%	of area adopts Restore Tiled Wetlands (Cropland)				
			3%	of area adopts Conservation Crop Rotation				
		SC-1	61%	of area adopts Nutrient Management	21%	41%	53%	$776,000 /yr ($32/ac/yr)
			9%	of area adopts Restore Tiled Wetlands (Cropland)				
			5%	of area adopts Controlled Tile Drainage				
			12%	of area adopts Riparian Buffers, 100 ft wide (replacing row crops)				
			10%	of area adopts Filter Strips, 50 ft wide (Cropland field edge)				
			34%	of area adopts Reduced Tillage (30%+ residue cover)				
			32%	of area adopts Water and Sediment Control Basin (Cropland)				
			1%	of area adopts Alternative Tile Intakes				
			0%	of area adopts Water and Sediment Control Basin (Cropland)				

Model(s) & Reference	Summary & Notes	Scenario		Modeled BMPs/Landscape									Reduction in Parameter			Cost
													Sediment	Phosphorus	Nitrogen	
SWAT, InVEST, Sediment Rating Curve Regression, and Optimization Lake Pepin Watershed Full Cost Accounting (Dalzell et al., 2012)	Models 6 BMPs in the 7-mile Creek watershed either: **1**) placed by rule of thumb recommendations (not optimal) or **2**) to maximize TSS reduction for dollars spent (optimal). Completed economic analyses including: **A**) current market value only (using 2011 $) and **B**) integrated, which adds a valuation of ecosystem services (relatively modest value). Does not allow multiple BMPs on same pixel of land. Scenarios are described by percentages of land in each land use. Analysis of 2002-2008 data.	Land uses:		Normal	Cons til	1/2 P	Pasture	Grass	Forest	Wetland	Water	Urban				
		Baseline		83%	0%	0%	2%	0%	4%	5%	1%	5%	0%	0%		0%
		2A	A	3%	14%	64%	3%	1%	5%	5%	1%	5%	4%	-1%		-4%
			B	35%	1%	38%	10%	1%	4%	5%	1%	5%	25%	22%		4%
			C	8%	0%	35%	32%	10%	4%	5%	1%	5%	50%	46%		21%
			D	2%	0%	10%	43%	29%	4%	5%	1%	5%	76%	69%		51%
		2B	a	30%	1%	44%	2%	0%	11%	5%	1%	5%	15%	19%		-8%
			b	26%	0%	41%	13%	1%	7%	5%	1%	5%	25%	28%		-7%
			c	13%	0%	29%	38%	2%	7%	5%	1%	5%	50%	48%		0%
			d	3%	0%	8%	68%	3%	6%	5%	1%	5%	76%	70%		19%
		1A	F	25m grass buffers around waterways									3%	3%		4%
			G	250m grass buffers around waterways									15%	15%		28%
			H	Converting highly erodible lands to grasslands									15%	17%		10%
SPARROW The Minnesota Nutrient Reduction Strategy (draft) (PCA, 2013i)	Statewide nutrient reduction goals and strategies are developed for the three major drainage basins in Minnesota. For the Mississippi River basin, the milestones (interim targets) between 2014 and 2025 are 20% reduction in N and 8% reduction in P. The scenario to meet those reductions is summarized.	20% N, 8% P Reduc		43% of total area (80% of suitable area) uses target N fertilizer rates 6% of total area (90% of suitable area) uses P test and soil banding 1% of total area (10% of suitable area) in cover crops 1% of total area (25% of suitable area) in riparian buffers 25% of total area (91% of suitable area) in conservation tillage 4% of total area (18% of suitable area) uses wetlands or controlled drainage										8%	20%	
HSPF Minnesota River Basin Turbidity Scenario Report (Tetra Tech, 2009)	5 scenarios (BMP suites) evaluated for effect on TSS and TP in MN River tributaries and mainstem. Scenarios 1, 2 were minimally effective. Scenarios 3, 4, & 5 are summarized here. Analysis on 2001-2005 data.	3		20% land in pasture (perennial veg), targeting steepest land 75% of >3% slope land in cons. tillage (30% residue) and cover crop 50% of surface inlets eliminated Comprehensive nutrient management Drop structures installed on eroding ravines Effluent max P of 0.3mg/L for mechanical facilities For MS4 cities, install ponds to hold and treat 1" of runoff									~20% (Le Sueur watershed)	17% (MN basin)		
		4		All BMPs in Scenario 3 with these additions: Target (20% land in) pasture to knickpoint regions as well Increase residue (on 75% of >3% slope land) to 37.5% Increase eliminated surface inlets to 100% Controlled drainage on land with <1% slope Water basins to store 1" of runoff Minor bank/bluff improvements Eliminate baseflow sediment load									50% (Yellow Med watershed)	26% (MN basin)		
		5		All BMPs in Scenarios 3&4 with these additions: Improved management of the pasture land (CRP) Very major bluff/bank improvements Urban (outside MS4s) source reductions of 50-85%									87% (MN basin)	49% (MN basin)		

Lake Restoration and Protection Strategies

This is a summary of strategies and not an exhaustive list. Not all strategies are applicable or appropriate for all lakes or regions.

Watershed Strategies – These strategies reduce phosphorus delivered to a lake and are the basis for any restoration work.

- **Manage nutrients** – carefully planning for and applying phosphorus fertilizers decreases the total amount of phosphorus runoff from cities and fields.
  - Examples: crop nutrient management, city rules on phosphorus fertilizer use, etc.
- **Reduce erosion** – preventing erosion keeps sediment (and attached phosphorus) in place.
  - Examples: construction controls, vegetation (see below)
- **Increase vegetation** – more vegetative cover on the ground uses more water and phosphorus and decreases the total amount of runoff coming from fields and cities.
  - Examples: cover crops, grass buffers, wetlands, prairie gardens/restorations, channel vegetation, etc..
- **Install/restore basins** – capturing runoff and decreasing peak flows in a basin allows the sediment (and attached phosphorus) to settle out.
  - Examples: water and sediment control basins, wetlands, etc..
- **Improve soil health** – soils that are healthy need less fertilizer and hold more water.
  - Examples: reduce/no-till fields, diversified plants in fields and yards

Lake Shore-specific Strategies – These strategies are a subset of watershed strategies that can be directly implemented by lake-shore residents.

- **Eco-friendly landscaping** – poor landscape design and impervious surfaces increase runoff and loading of nutrients into lakes.
  - Examples: aerate, rain barrels or cisterns, rain gardens, permeable pavers, sprinkler and drainage systems, maintain septic systems, etc..
- **Manage upland buffer zone vegetation** – Upland buffer zone vegetation selection can greatly affect nutrient absorbance, watering needs, erosion potential, need for drainage, etc..
  - Examples: properly landscape, maintain canopy and address terrestrial invasive species that may prevent regeneration of native trees, proper turf grass no mow lawns in highly utilized areas and planting native grasses and forbs with deep root systems in underutilized areas of lawn, reduce watering needs, controlled fertilization and grass clippings.
- **Naturalize transition buffer zone** – a natural transition buffer zone increases absorption of nutrients and decreases erosion potential of the water-shore interface.
  - Examples: balance natural landscaping by minimizing recreational impact area, utilize natural materials for erosion control bioengineering using wood or biodegradable materials in combination with stabilizing native vegetation to restore a shoreline, minimize beach blankets, draw down water levels for consecutive seasons to allow existing seed banks to develop deep rooted native vegetation or plant diverse mixes of grasses, sedges, forbs, shrubs and trees to create a complex root mass to hold the bank soils, preserve and restore native emergent aquatic vegetation sedges, rushes, forbs, shrubs and trees, do not remove natural wood features that supply cover and food sources for aquatic species and invertebrates while serving as a wave break along the shoreline.
- **Preserve aquatic buffer zone** – The aquatic buffer zone is difficult to restore, so the best approach is preservation and providing best opportunity for aquatic plants through watershed improvements to increase water quality. Draw down water levels to allow natural seed banks of emergent and aquatic vegetation to establish naturally, supplement more plant diversity with lower water levels as restoration of emergent and aquatic vegetation have higher success rates.

   - Examples: reduce recreational impact area, minimize control of aquatic plants, reduce dock footprint, preserve and/or restore native emergent and floating-leaf aquatic plants.

In-Lake Strategies – These strategies use, remove, or seal internal phosphorus (from within the lake). These strategies are only effective if external phosphorus sources are first minimized to the point that water quality of incoming water is not the limiting factor in order to meet water quality standards. Incorporating Lake Shore specific strategies is also essential for long term success.

- **Biomanipulation** – changing the fish population. Rough fish are generally bottom feeders and through feeding activity re-suspend sediments and decrease water clarity; thus, removing rough fish through mechanical or biological methods can improve water clarity, increase aquatic vegetation, and improve water quality overall.
   - Examples: commercial netting (not a standalone tool, implement in conjunction with other fisheries management methods to augment reduced populations for a short term period allowing desirable fish populations to develop adequate size to manage rough fish populations), balanced fish management increasing fish species diversity for a balanced fish population and introducing large predator fish populations, preserve and restore diverse spawning, cover, and feeding habitat that favors specific fish species that maintain a diverse fish population, reclamation (kill all fish and start over) inlets for rough fish should be considered when planning reclamation to prevent immediate re-introduction. In lake shore strategies are essential to incorporate to develop habitat for desirable species of fish once the rough fish population is removed.
- **Invasive species control of plants and/or animals** – invasive species alter the ecology of a lake and can decrease diversity of habitat. Removing native vegetation or incorporating non-native vegetation into landscaping can allow for invasive species to establish and spread taking over larger blocks of native species that maintain the natural systems health. Therefore, reducing disturbance to near shore habitat is important.
   - Examples: prevention, early detection, lake vegetation management plan (LVMP)
- **Chemical treatment to seal sediments** – re-suspension of nutrients through wind action can cause internal nutrient loading.
   - Examples: alum treatments. Consider the long term effectiveness in shallow lakes that experience wind driven turning, where stratification of the lake does not occur. Incorporating establishment of lake shore habitat is important to absorb phosphorus in the lake as part of a long term approach to phosphorus level management.
- **Dredging** – Sedimentation after years of poor watershed practices increases nutrient laden sediments and decreases depth. Dredging should only be considered when the source of the sediment and the banks of the lake are stable to prevent sediment from redepositing. Dredging can: create channels for access, increase habitat diversity, and accommodate recreational use.

Lake Phosphorus Sensitivity Analysis

Middle Minnesota Watershed Lakes		
LAKE NAME	Protection Class	Score
Gilfillin	High	0.00
Lone Tree	High	0.00
Strom	High	0.06
Savidge	High	2.61
Oak Leaf	Higher	3.69
Swan	Higher	8.21
Ballantyne	Highest	15.89
Emily	Highest	25.49
Unnamed (Hallett)	Highest	38.37
Henry	Impaired	0.00
Crystal	Impaired	0.00
Mills	Impaired	0.10
Loon	Impaired	0.18
George	Impaired	0.47
Wita	Impaired	0.68
Washington	Impaired	3.32
Scotch	Impaired	20.17
Duck	Impaired	26.93

Modeled Nutrient Reductions from MN and IA State Reduction Strategy Reports

MN: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/nutrient-reduction/nutrient-reduction-strategy.html
IA: http://www.nutrientstrategy.iastate.edu/sites/default/files/documents/NRS2-141001.pdf

Table 1. Effectiveness of hydrological management practices to reduce nitrate (NO_3-N) concentrations under tile drainage management.

Type of study	Reference	Site	% Reduction in NO_3-N loss
Drainage	Sands et al. (2006)	Minnesota	15%
	Nangia et al. (2010)	Minnesota	59 to 78%
	Kalita and Kanwar (1993)	Iowa	39%
	Lalonde et al. (1996)	Quebec, Canada	62 to 96%
	Drury et al. (1996)	Ontario, Canada	49%
	Drury et al. (2009)	Ontario, Canada	31 to 44%
	Thorp et al. (2009)	Midwestern U.S.	31%
	Tan et al. (1998)	Ontario, Canada	14 to 26%
	Fausey (2005)	Ohio	46%
	Feser 2012	Minnesota	25%
	Ng et al. (2002)	Ontario, Canada	36%
	Woli et al. (2010)	Illinois	70%
	Range of % reduction		**14 to 96%**
Bioreactors	Blowes et al. (1994)	Ontario (field)	99%
	Roberson and Cherry (1995)	Canada (septic systems)	58 to 96%
	Schipper and Vojvodić-Vuković (1998)	New Zealand (field)	60 to 88%
	Schipper and Vojvodić-Vuković (2001)	New Zealand (field)	>95%
	Greenan et al. (2009)	Laboratory experiment	30 to 100%
	Greenan et al. (2006)	Laboratory experiment	80 to 96%
	Chun et al. (2009)	Laboratory experiment	10-40 to 100%
	Chun et al. (2010)	Illinois (field)	47%
	Christianson et al. (2011)	Iowa (field)	30-70%
	Verma et al. (2010)	Illinois (field)	42 to 98%
	Woli et al. (2010)	Illinois (field)	33%
	van Driel et al. (2006)	Ontario (field)	33 to 53%
	Jaynes et al. (2008)	Iowa (field)	55%
	Robertson et al. (2000)	Ontario (field)	58%
	Ranaivoson et al. (2012)	Minnesota (snowmelt+ rainfall-field)	31 to 74%
	Ranaivoson et al. (2012)	Minnesota (field)	47%
	Range of % reduction		**10 to 99%**

Table 2. Effectiveness of N management practices to reduce nitrate (NO_3-N) concentrations under tile drainage management.

Type of study	Reference	Site	% of Reduction in NO_3-N loss
N rates	Buzicky et al. (1983)	Minnesota	28%
	Nangia et al. (2005a)	Minnesota (model)	12 to 15%
	Gowda et al. (2006)	Minnesota (model)	11 to 14%
	Jaynes et al. (2004a)‡	Iowa	30%
	Baksh et al. (2004)	Iowa	17%
	Nangia et al. (2010)	Minnesota (model)	23%
	Kladivko et al. (2004)†	Indiana	70%
	Range of % reduction		**11 to 70%**
N application time and Inhibitors			
	Smiciklas and Moore (1999)	Illinois	58%
	Randall and Mulla (2001)	Minnesota	36%
	Gowda et al (2006)	Minnesota	34%
	Nangia et al. (2005b)	Minnesota	6%
	Randall et al (2003)	Minnesota	17 to 18%
	Randall and Vetsch (2005)	Minnesota	10 to 14%
	Range of % reduction		**10 to 58%**
Split applications	Randall et al. (2003)	Minnesota	13%
	Jaynes et al. (2004)	Iowa	30%
	Range of % reduction		**13 to 30%**

† This reduction also includes the effect of changing crop rotation and adding cover crops plus changing N rate over time.
‡ This reduction is also related to changing time of application.

Table 3. Effectiveness of landscape diversification management practices to reduce nitrate (NO_3-N) concentrations.

Type of study	Reference	Site	% Reduction NO_3-N
Riparian Buffers*	Barfield et al. (1998)	Kentucky	95 to 98%
	Blanco-Canqui et al (2004a)	Missouri	94%
	Blanco-Canqui et al (2004b)	Missouri	47 to 69%
	Dillaha et al (1989)	Virginia	54 to 77%
	Magette et al. (1989)	Maryland	17 to 72%
	Schmitt et al. (1999)	Nebraska	57 to 91%
	Lowrance and Sheridan (2005)	Georgia	59 to 78 %
	Duff et al (2007)	Minnesota	67 to 99%
	Range of % reduction		**17 to 99%**
Wetlands	Appelboom and Fouss (2006)		37 to 83%
	Kovacic et al. (2000)	Illinois	33 to 55%
	Crumpton et al. (2006)	Iowa	25 to 78%
	Hunt et al. (1999)	North Carolina	70%
	Xue et al. (1999)	Illinois	19 to 59%
	Iovanna et al. (2008)	Iowa	40 to 90%
	Range of % reduction		**19 to 90%**

*Note: none of the riparian buffer studies referenced here were at sites with subsurface tile drainage.

Table 4. Effectiveness of landscape diversification management practices to reduce nitrate (NO_3-N) concentrations under tile drainage management.

Type of study	Reference	Site	% Reduction in NO_3-N loss
Alternative cropping systems	Randall et al. (1997)	Minnesota	7 to 98%
	Boody et al. (2005)	Minnesota	51 to 74%
	Simpkins et al. (2002)	Iowa	5 to 15%
	Range of % reduction		**5 to 98%**
Cover crops			
	Kladivko et al. (2004)	Indiana	<60%
	Feyereisen et al. (2006)	Minnesota	11 to 30%
	Strock et al. (2004)	Minnesota	13%
	Jaynes et al. (2004b)	Iowa	60%
	Kaspar et al. (2007)	Iowa	61%
	Range of % reduction		**11 to 60%**

Table 2. Nitrogen reduction practices – potential impact on nitrate-N reduction and corn yield based on literature review.

	Practice	Comments	% Nitrate-N Reduction[+]	% Corn Yield Change++
			Average (SD*)	Average (SD*)
Nitrogen Management	Timing	Moving from Fall to Spring Pre-plant Application	6 (25)	4 (16)
		Spring pre-plant/sidedress 40-60 split Compared to Fall Applied	5 (28)	10 (7)
		Sidedress - Compared to Pre-plant Application	7 (37)	0 (3)
		Sidedress – Soil Test Based Compared to Pre-plant	4 (20)	13 (22)
	Source	Liquid Swine Manure Compared to Spring Applied Fertilizer	4 (11)	0 (13)
		Poultry Manure Compared to Spring Applied Fertilizer	-3 (20)	-2 (14)
	Nitrogen Application Rate	Reduce to Maximum Return to Nitrogen value 149 kg N/ha (133 lb N/ac) for CS and 213 kg N/ha (190 lb N/ac) for CC	10‡	-1‡‡
	Nitrification Inhibitor	Nitrapyrin – Fall - Compared to Fall-Applied without Nitrapyrin	9 (19)	6 (22)
	Cover Crops	Rye	31 (29)	-6 (7)
		Oat	28 (2)**	-5 (1)
	Living Mulches	e.g. Kura clover - Nitrate-N reduction from one site	41 (16)	-9 (32)
Land Use	Perennial	Energy Crops Compared to Spring- Applied Fertilizer	72 (23)	-100ɣ
		Land Retirement (CRP) Compared to Spring- Applied Fertilizer	85 (9)	-100ɣ
	Extended Rotations	At least 2 years of alfalfa in a 4 or 5 year rotation	42 (12)	7 (7)
	Grazed Pastures	No pertinent information from Iowa - Assume similar to CRP	85***	NA
Edge-of-Field	Drainage Water Mgmt.	No impact on concentration	33 (32)^	
	Shallow Drainage	No impact on concentration	32 (15)^	
	Wetlands	Targeted Water Quality	52†	
	Bioreactors		43 (21)	
	Buffers	Only for water that interacts with active zone below the buffer - a small fraction of all water that makes it to a stream.	91 (20)	

+ A positive number is nitrate concentration or load reduction and a negative number is increased nitrate.
++ A positive corn yield change is increased yield and a negative number is decreased yield. Soybean yield is not included as the practices are not expected to affect soybean yield.
* SD = standard deviation.
‡ Reduction calculated based on initial application rate for each Major Land Resource Area (MLRA).
‡‡ Calculated based on the Maximum Return to Nitrogen (MRTN) relative yield at the given rates.
** Based on 1 study with 3 years of corn and 2 years of soybean.
*** This number is based on the Land Retirement number – there are no observations to develop a SD.
^ These numbers are based on load reduction since there is no impact on concentration with these practices
† Based on one report looking at multiple wetlands in Iowa (Helmers et al., 2008a).

Table 3. Practices with the largest potential impact on phosphorus load reduction.

Notes: Corn yield impacts associated with each practice also are shown as some practices may be increase or decrease corn production. See text for information on value calculations.

	Practice	Comments	% Phosphorus Load Reduction[a]	% Corn Yield Change[b]
			Average (SD[c])	Average (SD[c])
Phosphorus Management Practices	Phosphorus Application	Applying P based on crop removal - Assuming optimal soil-test P level and P incorporation	0.6[d] [70[e]]	0[f]
		Soil-Test P – Producer does not apply P until soil-test P drops to the optimal level	17[g] [40[h]]	0[f]
		Site-specific P management		0[f]
	Source of Phosphorus	Liquid swine, dairy, and poultry manure compared to commercial fertilizer – Runoff shortly after application	46 (45)	-1 (13)
		Beef manure compared to commercial fertilizer – Runoff shortly after application	46 (96)	
	Placement of Phosphorus	Broadcast incorporated within one week compared to no incorporation – Same tillage	36 (27)	0[f]
		With Seed or knifed bands compared to surface application without incorporation	24 (46) [35[i]]	0[f]
Erosion Control and Land Use Change Practices	Tillage	Conservation till – chisel plowing compared to moldboard plowing	33 (49)	0 (6)
		No till compared to chisel plowing	90 (17)	-6 (8)
	Crop Choice	Extended rotation	[j]	7 (7)[k]
	Perennial	Energy crops	34 (34)	NA
		Land retirement (CRP)	75	NA
		Grazed pastures	59 (42)	NA
	Terraces		77 (19)	
Edge-of-Field Practices	Wetlands	Targeted water quality	[l]	
	Buffers		58 (32)	
	Sediment Control	Sedimentation basins	85	

a - A positive number is phosphorus reduction and a negative number is increased phosphorus.

b - A positive corn yield change is increased yield and a negative number is decreased yield. Practices are not expected to affect soybean yield.

c - SD = standard deviation.

d - Maximum and average estimated by comparing application of 200 and 125 kg P_2O_5/ha, respectively, to 58 kg P_2O_5/ha (corn-soybean rotation requirements) (Mallarino et al., 2002).

e - This represents the worst case scenario as data is based on runoff events 24 hours after P application. Maximum and average were estimated as application of 200 and 125 kg P_2O_5/ha, respectively, compared to 58 kg P_2O_5/ha (corn-soybean rotation requirements), considering results of two Iowa P rate studies (Allen and Mallarino, 2008; Tabbara, 2003).

f - Indicates no impact on yield should be observed.

g - Maximum and average estimates based on reducing the average STP (Bray-1) of the two highest counties in Iowa and the statewide average STP (Mallarino et al., 2011a), respectively to an optimum level of 20 ppm (Mallarino et al., 2002). Minimum value assumes soil is at the optimum level.

h - Estimates made from unpublished work by Mallarino (2011) in conjunction with the Iowa P Index and Mallarino and Prater (2007). These studies were conducted at several locations and over several years but may, or may not, represent conditions in all Iowa fields.

i - Numbers are from a report by (Dinnes, 2004) and are the author's professional judgment.

j - There is scarce water quality data for P loss on extended rotations in Iowa compared to a corn-soybean rotation.

k - This increase is only seen in the corn year of the rotation – one of five years.

l - Specific conditions are important in wetlands with regards to P as with changing inflow loads.

Table 28. Example Statewide Combination Scenarios that Achieve the Targeted Nitrate-N Reductions, Associated Phosphorous Reductions and Estimated Equal Annualized Costs based on 21.009 Million Acres of Corn-Corn and Corn-Soybean Rotation.

Notes: Research indicates large variation in reductions from practices that is not reflected in this table. Additional costs could be incurred for some of these scenarios due to industry costs or market impacts.

Name	Practice/Scenario**	Nitrate-N	Phosphorus	Cost of N Reduction from baseline ($/lb)	Initial Investment (million $)	Total EAC* Cost (million $/year)	Statewide Average EAC Costs ($/acre)
		% Reduction from baseline					
NCS1	Combined Scenario (MRTN Rate, 60% Acreage with Cover Crop, 27% of ag land treated with wetland and 60% of drained land has bioreactor)	42	30	2.95	3,218	756	36
NCS2	Combined Scenario (MRTN Rate, 100% Acreage with Cover Crop in all MLRAs but 103 and 104, 45% of ag land in MLRA 103 and 104 treated with wetland, and 100% of tile drained land in MLRA 103 and 104 treated with bioreactor)	39	40	2.61	2,357	631	30
NCS3	Combined Scenario (MRTN Rate, 95% of acreage in all MLRAs with Cover Crops, 34% of ag land in MLRA 103 and 104 treated with wetland, and 5% land retirement in all MLRAs)	42	50	4.67	1,222	1,214	58
NCS4	Combined Scenario (MRTN Rate, Inhibitor with all Fall Commercial N, Sidedress All Spring N, 85% of all tile drained acres treated with bioreactor, 85% of all applicable land has controlled drainage, 38.25% of ag land treated with a wetland)	42	0	0.88	4,810	225	11
NCS5	Combined Scenario (MRTN Rate, Inhibitor with all Fall Commercial N, Sidedress All Spring N, 65% of all tile drained acres treated with bioreactor, 65% of all applicable land has controlled drainage, 29.25% of ag land treated with a wetland, and 15% of corn-soybean and continuous corn acres converted to perennial-based energy crop production)	41	11	5.58	3,678	1,418	67
NCS6	Combined Scenario (MRTN Rate, 25% Acreage with Cover Crop, 25% of acreage with Extended Rotations, 27% of ag land treated with wetland, and 60% of drained land has bioreactor)	41	19	2.13	3,218	542	26
NCS7	Combined Scenario (MRTN Rate, Inhibitor with all Fall Commercial N, Sidedress All Spring N, 70% of all tile drained acres treated with bioreactor, 70% of all applicable land has controlled drainage, 31.5% of ag land treated with wetland, and 70% of all agricultural streams have a buffer)	42	20	0.95	4,041	240	11

Table 26. Example Statewide Combination Scenarios that Achieve Targeted P Reductions and Associated Nitrate-N Reductions

Notes: Estimated EAC based on 21.009 Million Acres of Corn-Corn and Corn-Soybean Rotation.
Research indicates large variation in reductions. Some practices interact such that the reductions are not additive.
Additional costs could be incurred for some of these scenarios due to industry costs or market impacts.

		Phosphorus	Nitrate-N	Cost of P Reduction $/lb (from baseline)	Total EAC Cost* (million $/year)	Average EAC Costs ($/acre)
Name	Practice/Scenario**	% Reduction (from baseline)				
BS	Baseline					
PCS1	Phosphorus rate reduction on all ag acres (CS, CC, EXT, and pasture); Conservation tillage on all CS and CC acres; Buffers on all CS and CC acres	30	7	-18.03	-182.7	-$8
PCS2	Phosphorus rate reduction on 56% of all ag acres (CS, CC, EXT, and pasture); Convert 56% of tilled CS and CC acres to No-Till; Buffers on 56% CS and CC acres	29	4	-4.41	-43.0	-$2
PCS3	Phosphorus rate reduction on 53% of all ag acres (CS, CC, EXT, and pasture); Convert 53% of tilled CS and CC acres to No-Till; Cover crops on No-till CS and CC acres	29	14	45.76	449.9	$20
PCS4	Phosphorus rate reduction on 63% of ag acres (CS, CC, EXT, and pasture); Convert 63% of tilled CS & CC acres to No-till and cover crops on No-till crop acres except for MLRAs 103 and 104	29	9	19.55	189.5	$8
PCS5	Phosphorus rate reduction on 48% of ag acres (CS, CC, EXT, and pasture); Convert 48% of tilled CS and CC acres to No-till with Cover Crop on No-till acres; Buffers on 48% CS and CC acres	29	16	-3.41	-33.2	-$1

***EAC stands for Equal Annualized Cost (50-year life and 4% discount rate) and factors in the cost of any corn yield impact as well as the cost of physically implementing the practice. Average cost based on 21.009 million acres, costs will differ by region, farm and field.**

****These practices include substantial initial investment costs.**

Strategies Table Calculator Notes and Assumptions

Land use (known): 76% cultivated ag, 3% grass/pasture, 7% all developed, 5% wetland

50% of watershed is tile drained none are treating or keeping drained water on the land (all tile water is untreated and drained into ditch/stream)

2% of the watershed (4% of tiled field acres) drain to open intakes and none of these have effective control of nutrient/sediment runoff

66% of watershed has nutrient/sediment loss from crop groundwater or croprunoff => equivalent of 10% of cultivated crops (8% of watershed) prevents nutrient loss to surface runoff and groundwater. For example, 30% of crops treat/prevent 1/3rd of its runoff: 1/3*30%=10%

2% of watershed (66% of pastures) are pastures that are contributing nutrients, sediment, and bacteria

15% of watershed gets subsurface manure, 5% of watershed gets surface manure => 25% of cropland gets manure applied, and of applied manure: 75% is applied subsurface, 25% is surface-applied

When ag-wide control measure goes in, assume manured and non-manured have same adoption rate as do tiled and untiled (by % of land use)

source assessments presented in WRAPS report used in calculations with the following refinements of the identified sources:

2% of total watershed sediment load travels through open tile intakes (50% of total sediment load from sediment)

2% of stream bank erosion is from bank trampling in addition to other pasture sediment contributions

3% of phosphorus travels through open tile intakes

Except a few cases where noted, the estimated reduction per strategy adoption is:

The parameter reductions associated with the strategy assume a mixture of most and least effective BMPs per strategy (a mid-range reduction versus a high or low). So in addition to the inherent error estimating BMP reduction efficiencies, the estimated reductions could more significantly vary from actual reductions if the least effective or most effective BMPs within a strategy type are adopted. For instance, under the "reduce tillage" strategy type, if no-till is adopted exclusively (or contrarily the basic conservation tillage is adopted exclusively), the reduction from this strategy will likely be higher (contrary case: lower) than the estimated reduction.

Pollutant Reduction from a BMP at a watershed scale
=
(% of watershed to adopt)
X
(% reduction efficiency)
X
(% of load from source type)
/
(% watershed that has that source type)

the primary assumptions of this equation are:

the pollutant contributions of land types and efficiencies of BMPs are equivalent throughout the contributing areas

% reductions in pollutant loads from implementing a BMP result in the same pollutant loading reductions to water bodies (e.g. 50% less sediment lost from field x results in 50% less sediment contributed to water bodies by field x)

Tools for Prioritizing and Targeting

Electronic copy with live hyperlinks available by request.

Tool	Description	Example Uses	Notes for GIS Use	Link to Data/Info
National Hydrography Dataset (NHD) & Watershed Boundary Dataset (WBD)	The NHD is a vector GIS layer that contains features such as lakes, ponds, streams, rivers, canals, dams and stream gages, including flow paths. The WBD is a companion vector GIS layer that contains watershed delineations.	General mapping and analysis of surface-water systems. A specific application of the data set is to identify buffers around riparian areas.	GIS layers are available on the USGS website.	http://nhd.usgs.gov/
Impaired Waterbodies	Data indicates which stream reaches, lakes, and wetlands have been identified as impaired, or not meeting water quality standards. Attribute table includes information on the impairment parameters.	Examples of region/subwatershed prioritization includes: the number of impairments, specific impairment parameter, % of stream miles/lakes that are impaired, immediate subwatersheds of impaired rivers/lakes, identifying reaches with specific impairment parameters, etc. Field-scale targeting examples include: buffering impaired waters.	GIS layers are available on the PCA website.	http://www.pca.state.mn.us/index.php/data/spatial-data.html?show_descr=1
Hydrological Simulation Program – FORTRAN (HSPF)	Simulation of watershed hydrology and water quality. Incorporates point and non-point sources including pervious land surfaces, runoff and constituent loading from impervious land surfaces, and flow of water and transport/ transformation of chemical constituents in stream reaches. The model is typically calibrated with monitoring data to ensure accurate results.	Since the model produces data on a subwatershed scale, the model output can be particularly useful for identifying "priority" subwatersheds. The modeled pollutant or concentrations or total loads include TSS, TP, and TN. Point and non-point contributions can be extracted separately. Can be used to analyze different BMP "scenarios".	PCA models many major watersheds with HSPF. If completed, model data can be obtained from PCA and imported into GIS.	http://water.usgs.gov/software/HSPF/
HSPF - Scenario Application Manager (SAM)	Designed for those without HSPF training to visualize HSPF data and develop non-point and point source BMP scenarios "on the fly" without having to manually manipulate HSPF code	A local county government could develop HSPF scenarios in SAM that would demonstrate BMPs that would reach local WQ goals; this demonstration could then be used to secure funding for BMP placement. This would be done without having to contract out the scenarios with an engineering firm	Can export data from SAM as shapefile for use in GIS	http://www.respec.com/portfolio_project_view.php?project_id=15
1855 Land Survey Data	Data originally created by land surveyors in the mid-to-late 1800s. Surveys were conducted in one-mile grid and indicated the land cover at the time of the survey. This data has been georeferenced and is available for most of the state. This information has been digitized by PCA staff for the GRBERB.	This information could be used to prioritize areas based on changes in the landscape. This information is also helpful to understand landscape limitations (e.g. former lake beds may not be drain well).	Image data is available from MN Geo. Digitized rivers, lakes, and wetlands (in the GBERB only) are available from PCA staff.	http://www.mngeo.state.mn.us/glo/
Drinking Water Supply Management Areas	Drinking water supply management area (DWSMA) is the Minnesota Department of Health (MDH) approved surface and subsurface area surrounding a public water supply well that completely contains the scientifically calculated wellhead protection area and is managed by the entity identified in a wellhead protection plan. The boundaries of the drinking water supply management area are delineated by identifiable physical features, landmarks or political and administrative boundaries.	This dataset was developed with the intention of protecting the public drinking water supply and complies with the federal Safe Drinking Water Act	Contact Minnesota Department Of Health Source Water Protection Unit with questions.	ftp://ftp.gisdata.mn.gov/pub/gdrs/data/pub/us_mn_state_health/water_drinking_water_supply/metadata/drinking_water_supply_management_areas.html
Drinking Water Supply Management Area Vulnerability	Drinking water supply management area (DWSMA) vulnerability is an assessment of the likelihood for a potential contaminant source within the drinking water supply management area to contaminate a public water supply well based on the aquifer's inherent geologic sensitivity; and the chemical and isotopic composition of the groundwater.	This dataset was developed with the intention of protecting the public drinking water supply and complies with the federal Safe Drinking Water Act	Contact Minnesota Department Of Health Source Water Protection Unit with questions.	ftp://ftp.gisdata.mn.gov/pub/gdrs/data/pub/us_mn_state_health/water_drinking_water_supply/metadata/drinking_water_supply_management_area_vulnerability.html
Restorable Depressional Wetland Inventory	A GIS layer representing drained, potentially restorable wetlands in agricultural landscapes. Created primarily through photo-interpretation of 1:40,000 scale color infrared photographs acquired in April and May, 1991 and 1992.	Identify restorable wetland areas with an emphasis on: wildlife habitat, surface and ground water quality, reducing flood damage risk. To see a comprehensive map of restorable wetlands, must display this dataset in conjunction with the USGS National Wetlands Inventory (NWI) polygons that have a 'd' modifier in their NWI classification code	GIS layer is available on the DNR Data Deli website also available from Ducks Unlimited.	http://deli.dnr.state.mn.us/metadata.html?id=L390002730201 ; http://prairie.ducks.org/index.cfm?&page=minnesota/restorablewetlands/home.htm#downfile

"Altered Hydrology" (PCA Analysis)	GIS layers (results of GIS analysis) of hydrology-influencing parameters indicating the amount of change (since European settlement) including: % tiled, % wetland loss, % stream channelized, % increase in waterway length, % not perennial vegetation, % impervious. Analysis done at the same subwatershed scale as the HSPF modeling was completed to facilitate subwatershed prioritization. Analysis was completed using available GIS data layers.	These 6 layers could be used individually or in combination (using raster calculator) to prioritize subwatersheds to target conservation practices intended to mitigate altered hydrology.	GIS layers are available from PCA staff.	
Altered Watercourse Dataset (Channelized Streams)	Statewide data layer that identifies portions of the National Hydrography Dataset (NHD) that have been visually determined to be hydrologically modified (i.e., ditches, channelized streams and impoundments).	Identifies streams with highly modified stream channels for conservation prioritization. Subwatersheds with high levels of channelized streams may be prioritized for specific conservation practices.	GIS layers are available on the MN Geo website.	http://www.mngeo.state.mn.us/ProjectServices/awat/
Tile Drainage (PCA Analysis)	Data created as an estimate of whether a pixel is tiled or not. Assumes tiled if: row crop, <3% slope, poorly drained soil type	Can be useful for prioritizing highly drained areas to implement BMPs that address altered hydrology.	Data can be obtained from PCA staff	
Light Detection and Ranging (LiDAR)	Elevation data in a digital elevation model (DEM) GIS layer. Created from remote sensing technology that uses laser light to detect and measure surface features on the earth.	General mapping and analysis of elevation/terrain. These data have been used for: erosion analysis, water storage and flow analysis, siting and design of BMPs, wetland mapping, and flood control mapping. A specific application of the data set is to delineate small catchments.	The layers are available on the MN Geospatial Information website for most counties.	http://www.mngeo.state.mn.us/chouse/elevation/lidar.html
Stream Power Index (SPI)	SPI, a calculation based on a LiDAR file, describes potential flow erosion at the given point of the topographic surface. As catchment area and slope gradient increase, the amount of water contributed by upslope areas and the velocity of water flow increase. Varying SPI analyses have been done with different resulting qualities depending on the amount of hydrologic conditioning that has been done.	Useful for identifying areas of concentrated flows which can be helpful for targeting practices such as grassed waterways or WASCOBs. Again, the usefulness may depend on the level of hydrologic conditioning that has been done.	This layer has been created by PCA staff with little hydroconditioning for the GBERB and can be obtained from PCA staff.	http://iflorinsky.narod.ru/si.htm
Compound Topographic Index (CTI)	CTI, a calculation based on a LiDAR file, is a steady state wetness index. The CTI is a function of both the slope and the upstream contributing area per unit width orthogonal to the flow direction. CTI was designed for hillslope catenas. Accumulation numbers in flat areas will be very large and CTI will not be a relevant variable.	Identifies likely locations of soil saturation which can be useful for targeting certain practices.	Can be downloaded from ESRI	http://arcscripts.esri.com/details.asp?dbid=11863
NRCS Engineering Toolbox	The free, python based toolsets for ArcGIS 9.3 and 10.0 allow for user friendly use of Lidar Data for field office applications, Hydro-Conditioning, Watershed Delineation, conservation planning and more.	Many uses including siting and preliminary design of BMPs.	Toolbox and training materials available on the MnGeo site.	http://www.mngeo.state.mn.us/chouse/elevation/lidar.html
RUSLE2	RUSLE2 estimates rates of rill and interrill soil erosion caused by rainfall and its associated overland flow. Several data layers and mathematical calculations are used to estimate this erosion.	Estimating erosion to target field sediment controlling practices.		http://www.ars.usda.gov/Research/docs.htm?docid=6016
Crop Land - National Agricultural Statistics Service (NASS)	Data on the crop type for a specific year. Multiple years data sets available.	Identify crop types, including perennial or annual crops and look at crop rotations/changes from year to year. A specific example of a use is to identify locations with a short season crop to target cover crops practice.	Data available for download from the USDA or use the online mapping tool.	http://www.nass.usda.gov/research/Cropland/SARS1a.htm
National Land Cover Database (NLCD) from the MRLC	Data on land use and characteristics of the land surface such as thematic class (urban, agriculture, and forest), percent impervious surface, and percent tree canopy cover.	Identify land uses and target practices based on land use. One example may be to target a residential rain garden/barrel program to an areas with high levels of impervious surfaces.	Data available for download from the MRLC website	http://www.mrlc.gov/
CRP land (2008)	Data on which areas were enrolled in the USDA Conservation Reserve Program. This data is no longer available but may exist at the county level.	Potential uses include targeting areas to create habitat corridors or targeting areas coming out of CRP to implement specific BMPs.		http://www.fsa.usda.gov/FSA/webapp?area=home&subject=copr&topic=crp
Soils Data (SSURGO)	Data indicates soil type and properties.	Soil types can be used to determine the acceptableness of a practice based on properties such as permeability or erosvity.	Data can be downloaded or online viewers are available on the NRCS website.	http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053627

Feedlot Locations	Data indicates the location of existing feedlots. Some data in this data layer is not accurate and feedlot locations could be mapped at the owner's address or in the center of the quarter quarter.	May be helpful prioritizing areas to implement strategies that address E. coli or nutrients.	Data available on PCA website	ftp://files.pca.state.mn.us/pub/spatialdata/ see "mpca_feedlots_ac.zip"
Land Ownership/ Property Boundaries	Data indicates the owner and property boundary. This data is kept at the county level.	May be helpful for targeting efforts, particularly when a proactive approach is taken (e.g. if areas are targeted for specific practices and land owners are contacted to gauge their interest in a specific practice).	Some data available on the MN Geo website. Not all areas may have data in GIS format. Contact specific counties for more details/information.	http://www.mngeo.state.mn.us/chouse/land_own_property.html
Installed Practices	Data exists in a limited extent at this time. Agencies like BWSR, the NRCS, or County SWCDs may be able to provide some information.	Knowing which areas have had multiple practices installed could indicate more interested landowners or help identify areas to anticipate water quality improvements.	Contact listed agencies to inquire if any data is available.	
Watershed Health Assessment Framework (WHAF)	An online spatial program that displays information at the major and subwatershed scaled. Information includes: hydrology, biology, and water quality.	The online program is helpful for quick viewing and could be used to prioritize subwatersheds based on parameters or criteria in the WHAF.	Online only	http://arcgis.dnr.state.mn.us/ewr/whaf/Explore/
Agricultural Conservation Planning Framework (ACPF; Tomer et al.)	An outlined methodology uses several data layers and established analyses to identify specific locations to target several different BMPs. A "toolbox" is being created to facilitate the use of this methodology in MN.	Targeting specific BMPs (see link).	see demo: https://usdanrcs.adobeconnect.com/p6v40eme1cz/	http://northcentralwater.org/acpf/
Ecological Ranking Tool (Environmental Benefit Index - EBI)	Three GIS layers containing: soil erosion risk, water quality risk, and habitat quality. Locations on each layer are assigned a score from 0-100. The sum of all three layer scores (max of 300) is the EBI score; the higher the score, the higher the value in applying restoration or protection.	Any one of the three layers can be used separately or the sum of the layers (EBI) can be used to identify areas that are in line with local priorities. Raster calculator allows a user to make their own sum of the layers to better reflect local values or to target specific conservation practices.	GIS layers are available on the BWSR website.	http://www.bwsr.state.mn.us/ecological_ranking/
MN Natural Heritage Information System (Rare Features Data)	NHIS contains information about the location and identities of Minnesota's endangered, threatened, special concern, watch list, and species of greatest conservation need (state and federally listed), as well as records of rare native plant communities, Animal aggregations, and geologic features. It is classed as protected data under MN Statute, section 84.0872	This data can be used to prioritize areas for restoration and conservation protection.		http://www.dnr.state.mn.us/nhnrp/nhis.html
MNDNR Native Plant Communities	Classification of Minnesota's remnant land cover types. They are classified by considering vegetation, hydrology, landforms, soils, and natural regimes.	This data can be used to prioritize areas for restoration and conservation protection.		http://www.dnr.state.mn.us/npc/index.html
Protected Lands and Easements	This data is pulled from multiple GIS layers and summarizes fee title and easement lands held by MNDNR, TNC, BWSR, USDA, USFWS, and USFS	This data can be used to prioritize areas for restoration and conservation protection. It gives connection points in the landscape for creating larger blocks of habitat that serve to preserve our diversity.		https://gisdata.mn.gov/
Lakes of Phosphorus Sensitivity Significance	A ranked priority list for Minnesota's unimpaired lakes based on sensitivity to additional phosphorus loading. The most sensitive lakes will likely see substantial declines in water clarity with increased nutrient pollution loading.	Dataset valuable to local governments and state agencies tasked with prioritizing unimpaired lakes for protection efforts.	GIS layer available from Minnesota Geospatial Information Office.	https://gisdata.mn.gov/dataset/env-lakes-phosphorus-sensitivity
Zonation	A values-based framework and software for large-scale spatial conservation prioritization. Allows balancing of alternative land uses, landscape condition and retention, and feature-specific connectivity responses. Produces a hierarchical prioritization of the landscape based on the occurrence levels of features in sites/grid cells. It iteratively removes the least valuable remaining cell, accounting for connectivity and generalized complementarity in the process.	Surveys are created and given to targeted audiences to identity their priorities. These survey priorities are then used by the program. The output of Zonation can be used to identify areas that align with the conservation values of the survey respondents.	Zonation results can be exported to GIS. Paul Radomski (DNR) and colleagues have expertise with Zonation.	http://cbig.it.helsinki.fi/software/zonation/

Restorable Wetland Prioritization Tool	The base layer is a restorable wetlands inventory that predicts restorable wetland locations across the landscape. There are also three decision layers including a stress, viability, and benefits layer. The stress and viability decision layers can be weighted differently depending on the users interest in nitrogen and phosphorus reductions and habitat improvement. Lastly, there is a modifying layer with aerial imagery and other supplemental environmental data.	This tool enables one to prioritize wetland restoration by nitrogen or phosphorus removal and/or by habitat. Additional uses include: locating areas most in need of water quality or habitat improvement; prioritizing areas that already are or are most likely to result in high functioning sustainable wetlands; refining prioritizations with aerial imagery and available environmental data.		https://beaver.nrri.umn.edu/MPCAWLPri/
Lakes of Biological Significance	Lakes were identified and classified by DNR subject matter experts on objective criteria for four community types (aquatic plants, fish, amphibians, birds).	Lakes with higher biological signaifcance can be prioritized for restroation and protection.		https://gisdata.mn.gov/dataset/env-lakes-of-biological-signific
National Fish Habitat Partnership Data System	Supports coordinated efforts of scientific assessment and data exchange among the partners and stakeholders of the aquatic habitat community. The system provides data access and visualization tools for authoritative NFHP data products and contributed data from partners. Data sets available include: anthropogenic barrier dataset,			http://ecosystems.usgs.gov/fishhabitat/
Indicators of Hydrologic Alteration (IHA)	The Indicators of Hydrologic Alteration (IHA) is a software program that provides useful information for those trying to understand the hydrologic impacts of human activities or trying to develop environmental flow recommendations for water managers. assess how rivers, lakes and groundwater basins have been affected by human activities over time – or to evaluate future water management scenarios. Assess how rivers, lakes and groundwater basins have been affected by human activities over time – or to evaluate future water management scenarios.	The software program assesses 67 ecologically-relevant statistics derived from daily hydrologic data. For instance, the IHA software can calculate the timing and maximum flow of each year's largest flood or lowest flows, then calculates the mean and variance of these values over some period of time. Comparative analysis can then help statistically describe how these patterns have changed for a particular river or lake, due to abrupt impacts such as dam construction or more gradual trends associated with land- and water-use changes.		https://www.conservationgateway.org/ConservationPractices/Freshwater/EnvironmentalFlows/MethodsandTools/IndicatorsofHydrologicAlteration/Pages/indicators-hydrologic-alt.aspx
InVEST	InVEST is a suite of software models used to map and value the goods and services from nature that sustain and fulfill human life. InVEST enables decision makers to assess quantified tradeoffs associated with alternative management choices and to identify areas where investment in natural capital can enhance human development and conservation.	InVEST models can be run independently, or as script tools in the ArcGIS Arc Toolbox environment. You will need a mapping software such as QGIS or ArcGIS to view your results. Running InVEST effectively does not require knowledge of Python programming, but it does require basic to intermediate skills in ArcGIS.		http://www.naturalcapitalproject.org/InVEST.html
RIOS	RIOS provides a standardized, science-based approach to watershed management in contexts throughout the world. It combines biophysical, social, and economic data to help users identify the best locations for protection and restoration activities in order to maximize the			http://www.naturalcapitalproject.org/RIOS.html
The Missouri Clipper	This tool will generate a ZIP file containing support files needed for SNMP, MMP and RUSLE2. These support files include aerial photo and topographic map images, soil and watershed shape files, a digital elevation model raster file, and a RUSLE2 GDB file. Soil data is obtained from the NRCS Web Soil Survey and may be limited by availability (see Status Map). To get your data, locate your farm on a map using Google			http://clipper.missouri.edu/index.asp?t=county&state=Minnesota
Map Window GIS + MMP Tools	Map Window GIS + MMP Tools is a free GIS that can be used for the following: 1.As a front-end to MMP when creating nutrient management plans. 2.As a front-end to Irris Scheduler when doing irrigation and nitrogen scheduling. 3.For designing research plots (randomized			http://www.purdue.edu/agsoftware/mapwindow/
Objective Model Custom Weight Tool	A decision support tool designed for USFWS resource managers the ability to make thoughtful and strategic choices about where to spend its limited management resources. This tool makes the processes used to prioritize these management units more transparent, improving the defensibility of management decisions. Originally created for the Morris Wetland Management District (WMD)			http://www.umesc.usgs.gov/management/dss/morris_wmd.html
WARPT: Wetlands-At-Risk Protection Tool	The Wetlands-At-Risk Protection Tool, or WARPT, is a process for local governments and watershed groups that acknowledges the role of wetlands as an important part of their community infrastructure, and is used to develop a plan for protecting at-risk wetlands and their			http://www.wetlandprotection.org/

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