Watonwan River Watershed Restoration and Protection Strategies

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MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Those with disabilities limiting their ability to access report information may contact the MPCA watershed project manager to provide alternate formats that suit their needs.

Contents

Glossary

Altered hydrology (USGS 2013): 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: A term typically used in feedlot regulatory language. One animal unit is roughly equivalent to 1,000 pounds of animal, but varies depending on the specific animal.

Assessment Unit Identifier (AUID): The unique water body 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 water body 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 TP, 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 aquatic macroinvertebrate (bug) IBI score.

Civic Engagement (CE): CE is a subset of 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 water body 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 geographic information system 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 Pomme de Terre River Watershed is assigned a HUC-8 of 07020002.

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 2013e)), 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 ID process, which is only done when a bio-impairment is identified (due to a low fish and/or macroinvertebrate 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.

Polychlorinated Biphenyls (PCBs): A group of toxic, man-made organic chemicals sometimes found as a pollutant in water bodies, formerly used in the U.S. in industrial and commercial applications. See EPA site for more information on PCBs.

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.

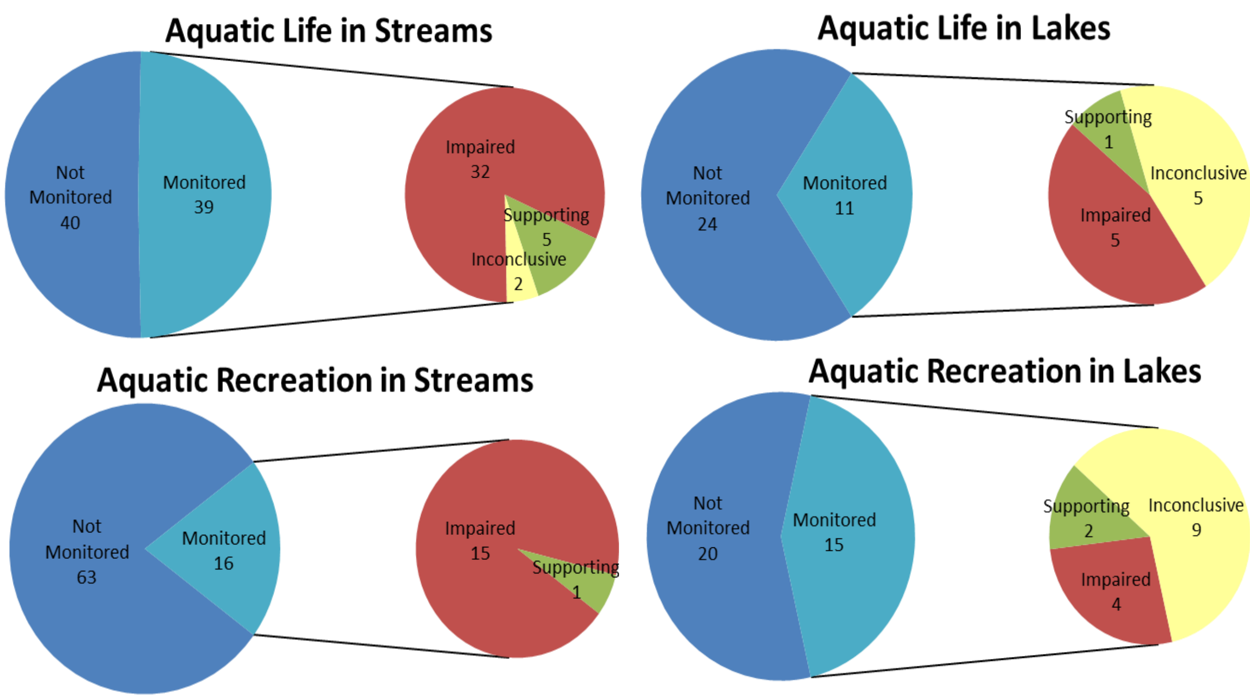
Total Maximum Daily Load (TMDL) is the maximum amount of a pollutant (or load capacity) a water body can receive without exceeding the water quality standard. In additional to calculating the load capacity, TMDL studies identify pollutant sources by allocating the load capacity between point sources (or wasteload) and nonpoint sources (or load). Finally, TMDLs calculate the necessary pollutant reductions necessary for a water body 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 Minnesota Pollution Control Agency's (MPCA) Watershed Approach work findings, addressing the fishable, swimmable status of surface waters in the Watonwan River Watershed. This work relied on a scientific approach by MPCA staff, but also developed and vetted results using a team of local watershed partners (Soil and Water Conservation Districts [SWCDs], counties, and other state agencies). Another important aspect of this work was a robust civic engagement process, which identified challenges, opportunities, and recommendations to achieve higher adoption of conservation practices within the watershed.

The majority of monitored stream reaches and lakes in the Watonwan River Watershed are not meeting water quality standards for aquatic life (fishing) and aquatic recreation (swimming), as illustrated in the pie charts below. Trend analysis indicates a long-term declining trend in P concentrations and a short-term declining trend in sediment concentrations. Other pollutants showed no trend.



Several water body pollutants and stressors were identified. A source assessment, goals, and 10-year targets were developed for each pollutant and stressor. The pollutants and stressors along with their goals and 10-year targets are summarized in the table on the following page.

Strategies to address the goals and 10-year targets were developed. Strategies Table A (Table 21, Page 70) provides a high-level narrative estimate of the total changes necessary for all waters to be restored and protected, and Strategies Table B (Table 22, Page 71) presents a suite of strategies and numeric adoption rates to meet the 10-year targets. With 87% of the watershed in cultivated crops, the largest opportunity for water quality improvement is from this land use. Identified strategies include improving soil health with cover crops and reduced tillage, improving manure and fertilizer application, and improving stream riparian habitat.

Parameters (Pollutant/ Stressors)	**Watershed-Wide Goal** (Average/surrogate for Watershed)	**Range of Subwatershed Goals** (Estimated only when TMDL or MSHA data are available)	**10-year Target** (for 2029)	**Years to Reach Goal** (from 2019)
Habitat	35% increase in MSHA habitat score	protect up to a 164% increase	12% ↑	75
Altered Hydrology	25% reduction in peak & annual stream flow	not estimated (TMDLs not completed on this parameter)	4% ↓	45
	increase dry season stream base flow where ID'd in SID by enough to support aquatic life		increase	15
Nitrogen	50% reduction in stream concentrations/loads	not estimated (TMDLs not completed on this parameter)	15% ↓	60
Sediment	20% reduction in stream concentrations/loads	protect up to a 94% reduction	4% ↓	45
Connectivity	Address human-caused issues (dams, culverts) as identified in SID and where practical/feasible	not estimated (TMDLs not completed on this parameter)	Replace 5% of culverts	45
Phosphorus/ Eutrophication	40% reduction in lake and stream concentrations/loads	protect up to a 47% reduction	Streams 5% ↓ Lakes 10% ↓	Streams 60 Lakes 35
Bacteria	65% reduction in stream concentrations/loads	10-84% reduction	12% ↓	65
Parameters that are impacted/addressed by the above pollutants and stressors				
F-IBI & M-IBI	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 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	60
DO				60

Priority areas to focus restoration and protection efforts were developed using multiple criteria and presented in a Priorities Table (Table 23, Page 73). Identified priorities include barely impaired waters, protecting supporting waters, drinking/ground water, and critical wildlife habitat.

The biophysical means to restore and protect the watershed (i.e. the strategies) are fairly well understood. However, the transition to these sustainable practices is limited by social-based challenges. Some social-based challenges like program inadequacies and undeveloped markets are outside the scope of local conservation staff influence, but other challenges can be addressed at this local level. The Watonwan River Watershed civic engagement process focused on producing leverage points to conservation adoption and solution strategies. This work (summary and links in Section 3.2) was integrated into the strategies table, but also independently serves as a representation of citizen recommended work and next steps for local conservation planning.

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, water body restoration and protection strategies and local plans are developed, and conservation practices are implemented. Watershed Approach assessment work started in the Watonwan River Watershed in 2013 (Figure 1).

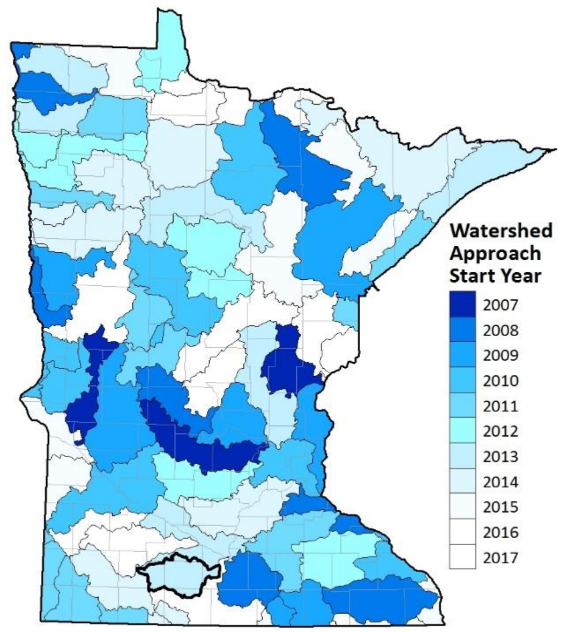


Figure 1: "Watershed Approach" work started in 2013 in the Watonwan River watershed (in bold). Watershed Approach work starts in approximately eight major watersheds each year.

Much of the information presented in this report was produced in earlier Watershed Approach work, prior to the development of the Watershed Restoration and Protection Strategy (WRAPS) report. However, the WRAPS report presents additional data and analyses. To ensure the WRAPS strategies and other analyses appropriately represent the Watonwan River Watershed, local and state natural resource and conservation professionals (referred to as the WRAPS Local Work Group; see group members listed on inside of front cover) were convened to inform the report and advise technical analyses.

Two key products of this WRAPS report are the strategies table and the priorities table, each developed with the WRAPS Local 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 waterbodies 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 4.4.

In summary, the ***purpose*** of the WRAPS report is to summarize work done in this first cycle of the Watershed Approach in the Watonwan River Watershed, which started in 2013. The ***scope*** of the report is surface water bodies and their aquatic life and aquatic recreation beneficial uses as currently assessed by the MPCA. 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 additional audiences.

This WRAPS is not a regulatory document, but is legislatively required per the Clean Water Legacy legislation on WRAPS (ROS 2016). This report is 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, through 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 Watonwan River Watershed (Hydrologic Unit Code (HUC)-8: 07020010 [USGS, 2014a]) drains approximately 562,000 acres of land into the Watonwan River, which eventually flows to the Minnesota River (Figure 2). This area includes 11 towns and cities (St. James, Madelia, Mountain Lake, etc.) and portions of 6 counties (Watonwan, Cottonwood, Blue Earth, Brown, Martin, and Jackson). Roughly 18,000 people live in the Watonwan River Watershed.

Land use in the Watonwan River Watershed is similar to other regions in Southern Minnesota: land use is dominated by warm-season, annual, cultivated, row crops (Figure 3). The most common crops are field corn and soybeans.

Topography in the Watonwan River Watershed (Figure 4) reflects the effects of glaciers and varies from nearly level to gently rolling hills. The western, southern, and eastern boundaries of the watershed contain hilly moraine ridges made by glacial movement and rock and sediment deposition. The remnants of a glacial lakebed is in the southeastern portion of the watershed, making this area particularly flat.

Just as the topography of the watershed reflects the effects of glacial activity, the soils in the Watonwan River Watershed are glacial deposits. These soils range from very poorly drained to moderately drained soils and tend to be a mixture of clay, silt, sand, and gravel. The area of the former glacial lakebed is dominated by poorly drained clay and silt soils.

More background information on the Watonwan River Watershed can be found at:

Rapid Watershed Assessment (NRCS 2015)

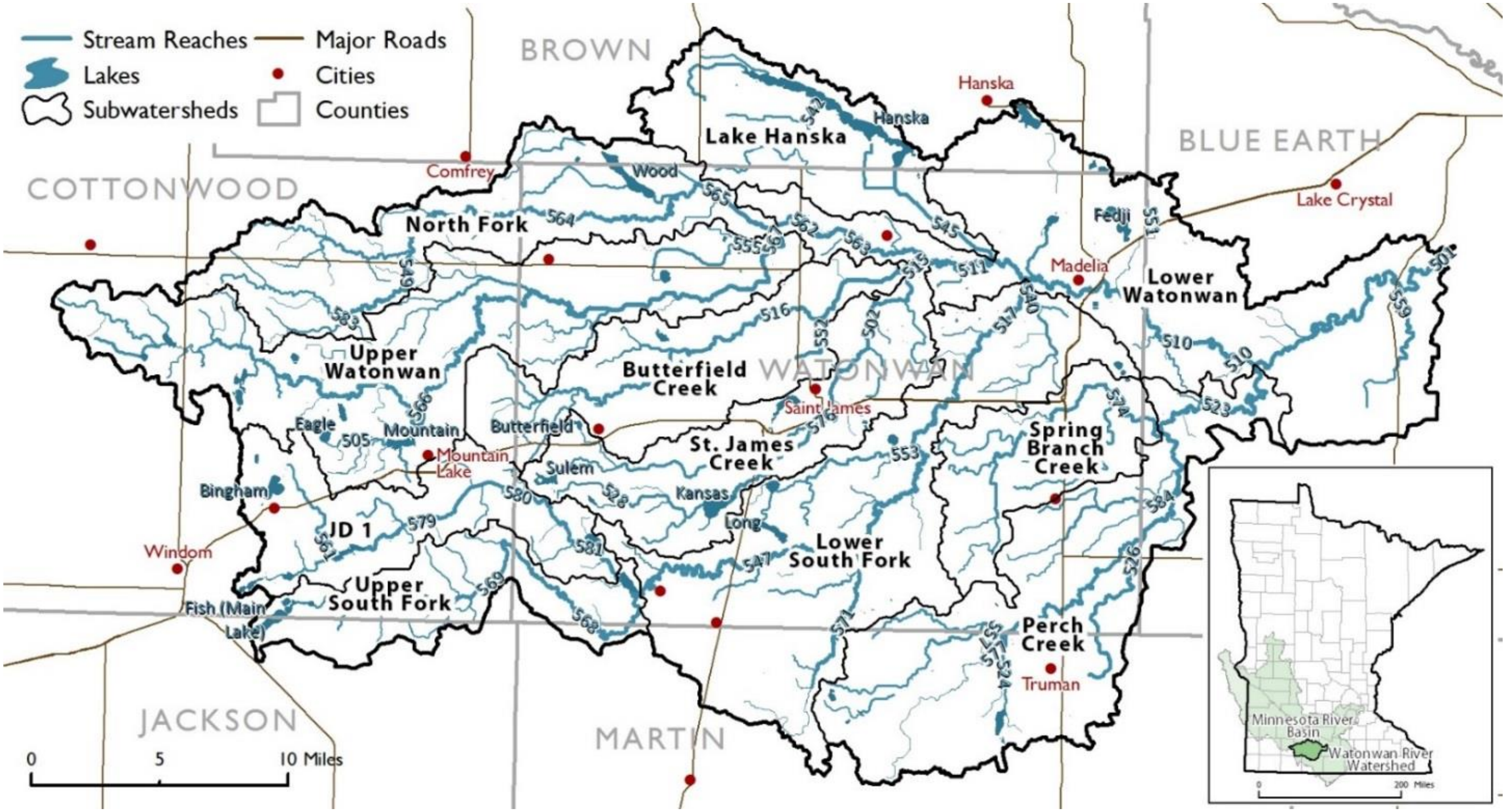


Figure 2: The Watonwan River Watershed drains approximately 562,000 acres from six different counties. The Watonwan River Watershed is one of 13 major watersheds that comprise the Minnesota River Basin. The streamline size in this image is used to indicate the estimated average stream flow, and stream reaches are labeled by the last three digits of the AUID (AUID-3).

1.3 Assessing Water Quality

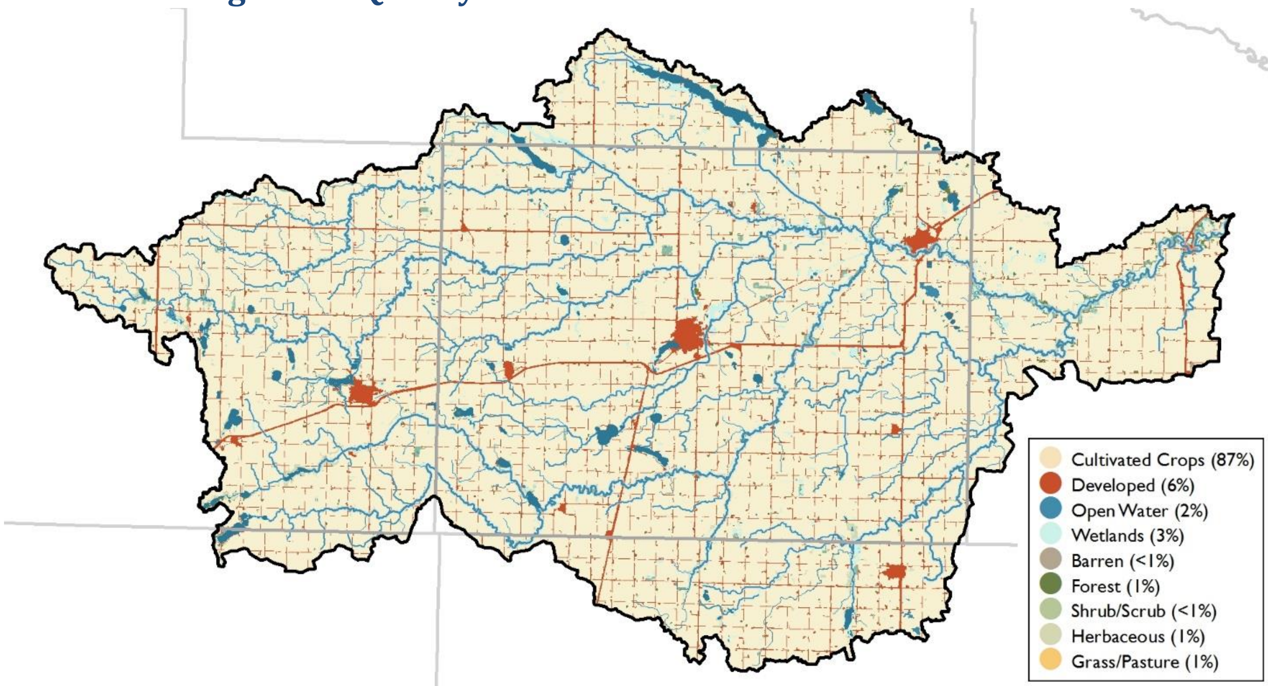


Figure 4: Land use in the Watonwan River Watershed is dominated by cultivated crops. Land use breakdowns are shown in the figure key.

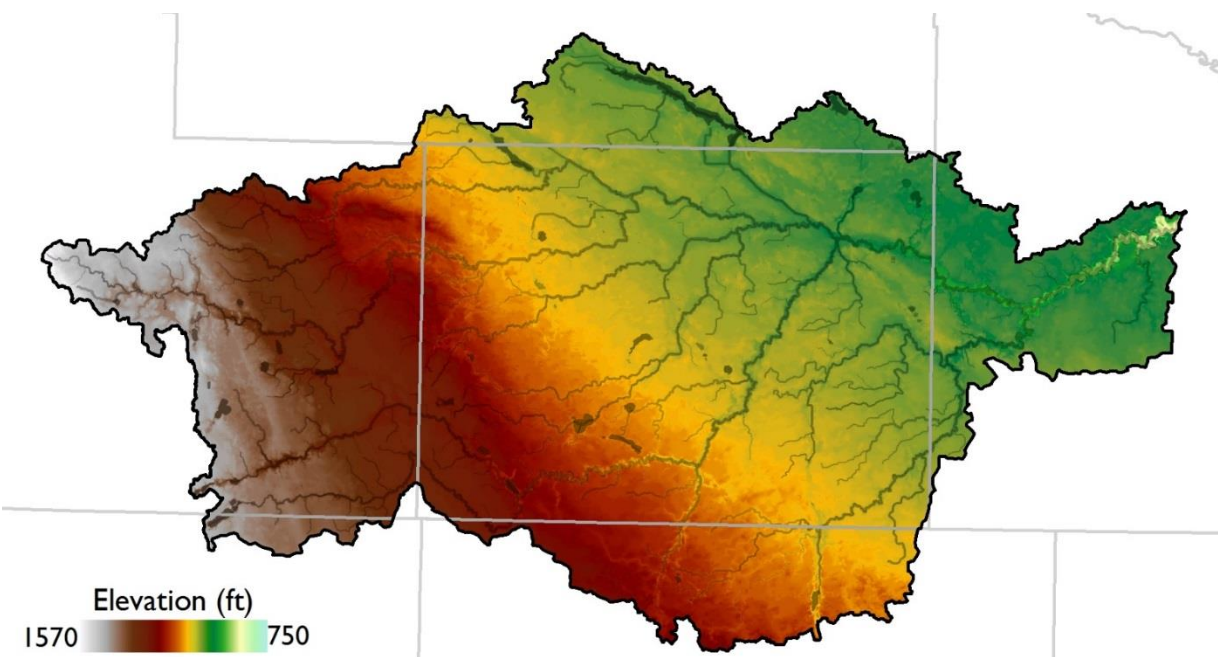


Figure 3: Elevation in the Watonwan River Watershed drops roughly 800 feet from its highest point in the west to its lowest point at the watershed's outlet to the Blue Earth River in the east.

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 some process steps is included below.

Water Quality Standards

Water quality is not expected to be as clean as it would be under undisturbed, "natural background" conditions. However, waterbodies are expected to support designated (or 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 designated uses, and include natural background conditions.

Water Quality Monitoring and Assessment

To determine if water quality is supporting its designated use, data on the water body are compared to relevant standards. Some commonly monitored parameters include nitrogen, P, Escherichia Coli (*E. coli*) bacteria, and aquatic life (fish and aquatic macroinvertebrates, referred to simply as bugs for the remainder of the report) populations. When parameters in a water body do not meet the water quality standard, the water body is considered impaired (MPCA 2011a). When parameters in a water body meet the water quality standard, the water body is considered supporting. If the monitoring data sample size is not robust enough to ensure that the data adequately represent the water body, or if monitoring results seem unclear regarding the condition of the water body, an assessment is delayed until further data are collected; this is referred to as an inconclusive or insufficient findings.

Several parameters are considered for the assessment of each designated use. For aquatic recreation assessment, streams are monitored for bacteria and lakes are monitored for clarity and algae-fueling P. For aquatic life assessment, streams are monitored for both aquatic life populations and pollutants that are harmful to these populations, and lakes are monitored for aquatic life (fish and aquatic bug populations). A water is considered impaired for aquatic life populations (referred to as "bio-impaired") when low or imbalanced fish or bug populations are found (as determined by the Index of Biological Integrity [IBI] score).

This WRAPS report summarizes the assessment results but the full report is available at *Watonwan River Watershed Monitoring and Assessment Report* (MPCA 2016c).

Stressor Identification

When streams are found to be bio-impaired, the cause of bio-impairment is studied and identified in a process called stressor identification (SID). SID identifies the parameters negatively impacting the aquatic life populations, referred to as "stressors". Stressors can be pollutants like nitrate or sediment or can be non-pollutants like degraded habitat or high flow. Stressors are identified using the EPA Caddis process. In short, stressors are identified based on the characteristics of the aquatic community in tandem with water quality information and other observations. This WRAPS reports summarizes the SID results but the full report is available at *Watonwan River Watershed Stressor ID* (MPCA 2018a).

Summary of Beneficial Uses, Pollutants, and Stressors

Pollutants and stressors both affect the beneficial uses and must be addressed to bring waters to a supporting status. However, they are identified in different ways: pollutants are compared to the water quality standards directly while stressors are identified based on the characteristics of the aquatic community in tandem with water quality information and other observations. 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. The difference between a pollutant and a stressor and a brief summary of how pollutants and stressors are identified is illustrated in Figure 5.

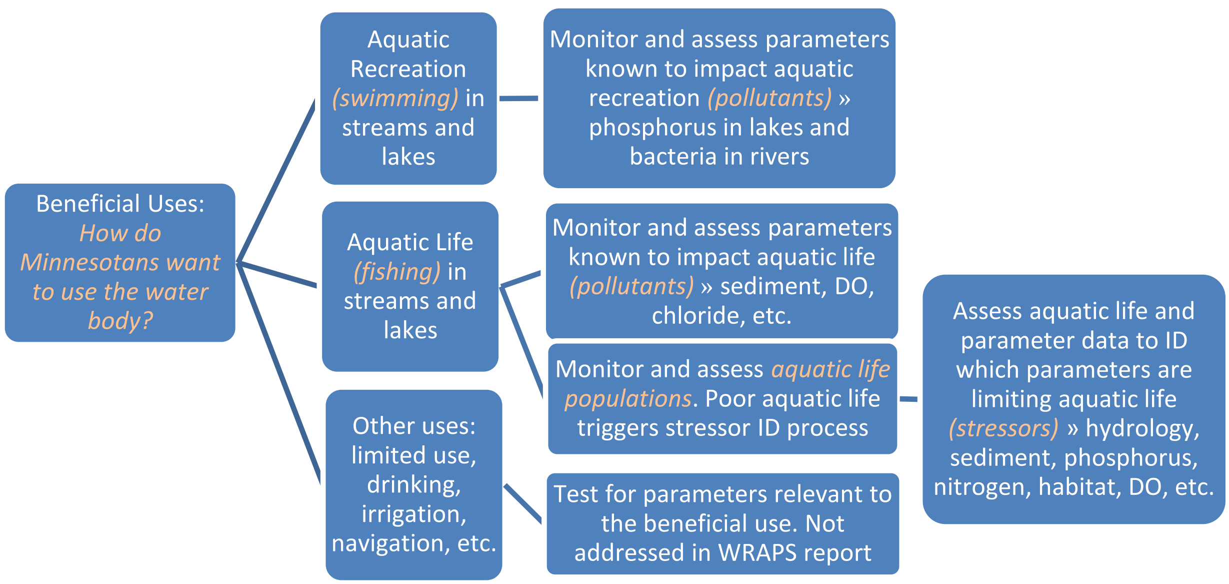


Figure 5: Pollutants and stressors are identified through different processes. Pollutants are parameters that are tested for directly, and the level of the parameter can be compared directly to a pre-developed numeric water quality standard. Stressors are parameters that are assessed only when aquatic life populations are monitored and assessed and found to be low or imbalanced (using the IBI score). Then, the SID 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.

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 Watonwan 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 watershed (Figure 6). The parameters collected at each monitoring site can vary. Local partners collect additional data to supplement 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 quality and aquatic life (fish and bug community) data at numerous stream and lake monitoring stations in 1 to 2 years, every 10 years. These sites include both Surface Water Assessment Grants (SWAG) and 10x sites. Monitoring sites are generally selected to provide comprehensive coverage of watersheds. This work is scheduled to start its second iteration in the Watonwan 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 Watonwan River Watershed, there is one annual site near the outlet and a seasonal site in each of the North Fork and Lower South Fork subwatersheds.

[Citizen Stream and Lake Monitoring Program](#) (MPCA 2015d) data provide a continuous record of water body transparency. This program relies on a network of volunteers who make approximately monthly lake and river measurements. Eight volunteer-monitored locations exist in the Watonwan River Watershed. Citizen data are not as rigorous but provide a long-term data set.

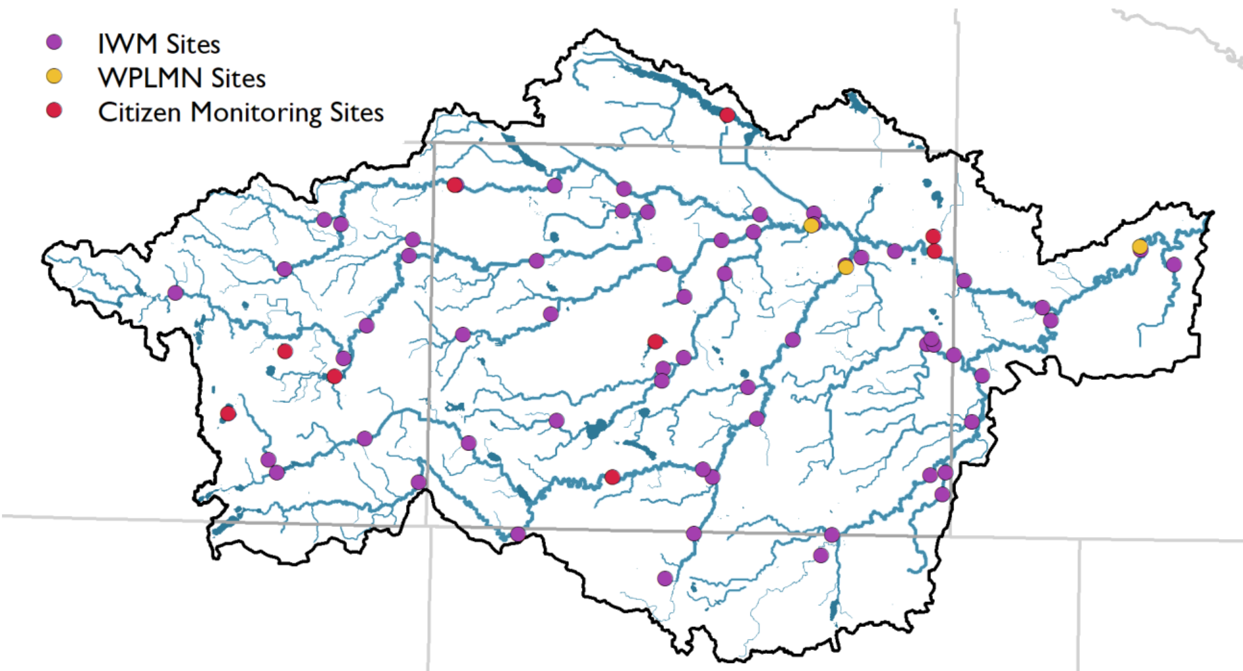


Figure 6: Three different programs collect water chemistry and/or aquatic life data at dozens of sites within the Watonwan River Watershed. These data are used to assess and track area-wide conditions.

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 2014c) explains the model's uses and development. Information on the HSPF development, calibration, and validation in the Watonwan River Watershed are available: *Watonwan River HPSF Model Summary* (MPCA 2017b), *Model Resegmentation and Extension for Minnesota River Watershed Model* (RESPEC 2014a), and *Hydrology and Water-Quality Calibration and Validation of Minnesota River* (RESPEC 2014b).

HSPF model output provide a reasonable estimate of pollutant concentrations across watersheds. The output can be used for source assessment, TMDL calculations, and prioritizing and targeting conservation efforts. However, these data are not used for impairment assessments since monitoring data are required for those assessments. Modeled pollutant concentration yields are presented in Section 2.2 within the Sources subsection for each pollutant; modeled yields are presented in Appendix 4.5 under HSPF Yield Maps, and modeled landscape and practice changes (referred to as scenarios) are summarized in Section 3.1 and detailed in Appendix 4.4 under Model Summary.

2 Water Quality Conditions

The "condition" refers to the water bodies' ability to support fishable and swimmable water quality standards. This section summarizes condition information including water quality data and associated impairments. For water bodies found not able to support fishable, swimmable standards, the reason for these poor conditions – the pollutants and/or stressors – are identified. This report covers only impairments to aquatic recreation and aquatic life. Several lakes and stream reaches are impaired for aquatic consumption with information available at the links below.

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.

More information on the conditions of the Watonwan River Watershed can be found at:
Watonwan River Watershed Monitoring and Assessment Report (MPCA 2016c)
Watonwan River Watershed Stressor ID (MPCA 2018a)
Watonwan River Watershed Hydrology, Connectivity, and Geomorphology Assessment (DNR 2014b)
Environmental Data Application (MPCA 2015e) *Watershed Health Assessment Framework* (DNR 2013)
State-wide Mercury TMDL (MPCA 2015f) *Fish Consumption Advice* (MDH 2019)

Status Overview

Of the 79 stream reaches in the Watonwan River Watershed, monitoring was conducted on 39 reaches for aquatic life (fish and bugs) and 16 reaches for aquatic recreation (swimming). Of the 35 assessable lakes, monitoring was conducted on 11 lakes for aquatic life and 15 lakes for aquatic recreation. A breakdown of the total number of water bodies, the monitored water bodies, and the assessment results are presented in Figure 7. See Appendix 4.1 for a comprehensive table of monitoring and assessment results by stream reach.

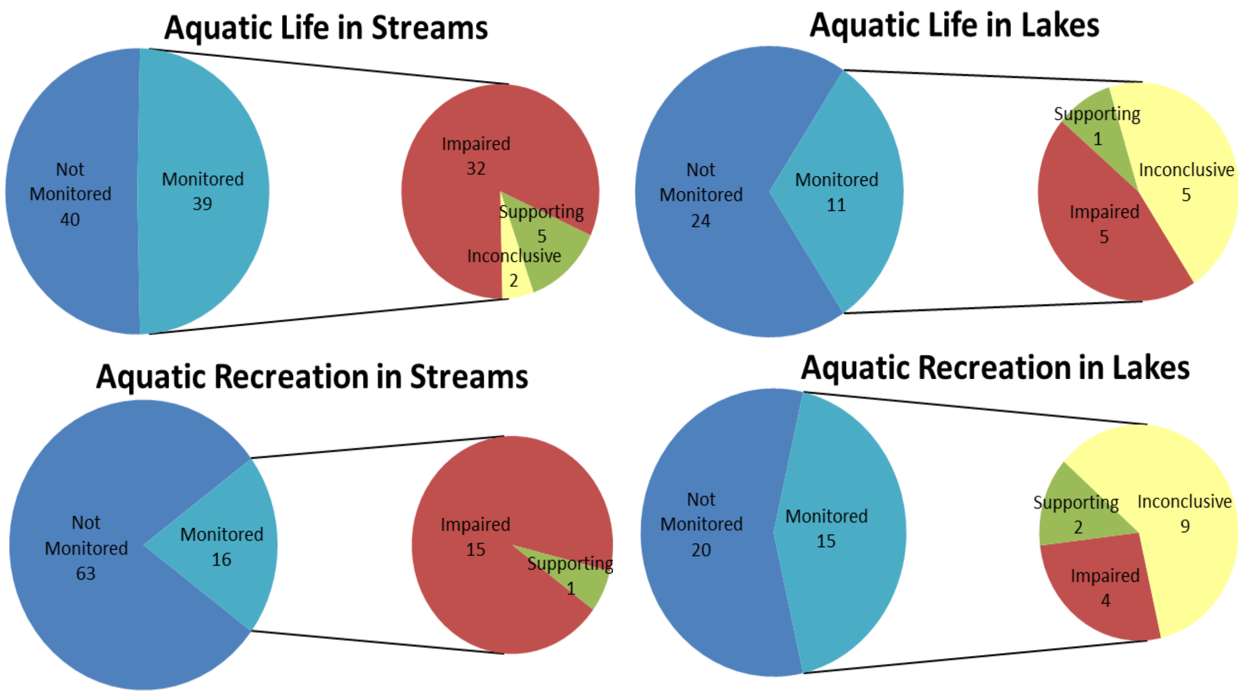


Figure 7: Of the 79 stream reaches in the Watonwan River Watershed, 39 were monitored to assess the designated use of aquatic life and 16 were monitored to assess the designated use of aquatic recreation. Of the 35 lakes over 100 acres, 11 were monitored to assess the designated use of aquatic life and 15 were monitored to assess the designated use of aquatic recreation. Generally, the number of water bodies impaired exceeded the number supporting for each designated use. However, several monitored lakes needed more data to make an assessment.

Many of the monitored stream reaches and lakes have impaired aquatic recreation and/or aquatic life as illustrated in Figure 8 (red). Only five stream reaches are supporting aquatic life; one stream reach is supporting aquatic recreation; one lake is supporting aquatic life; and two lakes are supporting aquatic recreation (Figure 8, green). Several reaches and lakes need more data to make a scientifically conclusive finding (Figure 8, yellow). The specific pollutants and/or stressors that are causing the impairments are discussed in Section 2.2.

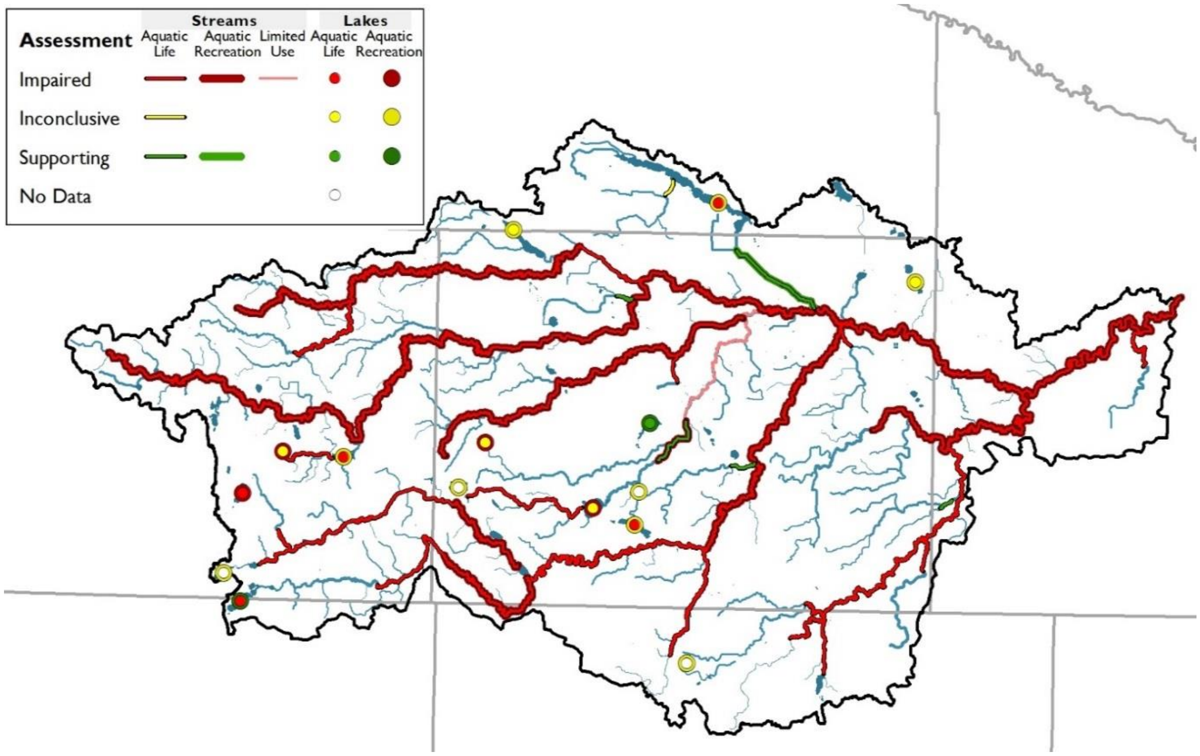


Figure 8: Impairments (shades of red) of the beneficial uses of aquatic life and aquatic recreation dominate the monitored streams and lakes across the Watonwan River Watershed. Only a handful of stream and lakes were found supporting (shades of green) these beneficial uses. In this image, the inside 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. These results are tabulated in Appendix 4.1.

Trends Overview

A substantial amount of change has occurred across the landscape in terms of land use, farming practices, human populations, etc. Trends observed in the Minnesota River Basin are discussed in the *Minnesota River Basin Trends Report* (MSU 2009a).

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. Despite these challenges, some trends have been observed in the Watonwan River Watershed.

Statistical trends in pollutant concentrations were observed in the Watonwan River as reported in the *Water Quality Trends for Minnesota Rivers and Streams at Milestone Sites* (MPCA 2014h; Table 1). Using the Seasonal Kendall test, longer-term trends in the Watonwan River Watershed showed a decrease in TP, while no trend was observed in nitrite/nitrate (NO_2/NO_3) and total suspended solids (TSS). Shorter-term trends show a decrease in sediment and no trend in TP and NO_2/NO_3. Trends are based on median summer (June through August) concentration (mg/L) values.

Table 1: TSS data indicate a short-term improvement in TSS concentrations, and TP data indicate long term improvement in TP concentrations.

River	Years with Data	Trend in Data		
		TSS	TP	NO_2/NO_3
Watonwan	1995-2009	-59%	No Trend	No Trend
	1969-2009	No Trend	-20%	No Trend

The annual flow in the Watonwan River has increased between 1977 and 2013 as illustrated by the blue trend line in Figure 9. This increase in flow has occurred despite a slight decrease in annual precipitation as illustrated by the orange trend line. While TSS and TP concentrations show some improvement as mentioned above, the total amount of water moving through the Watonwan River has increased.

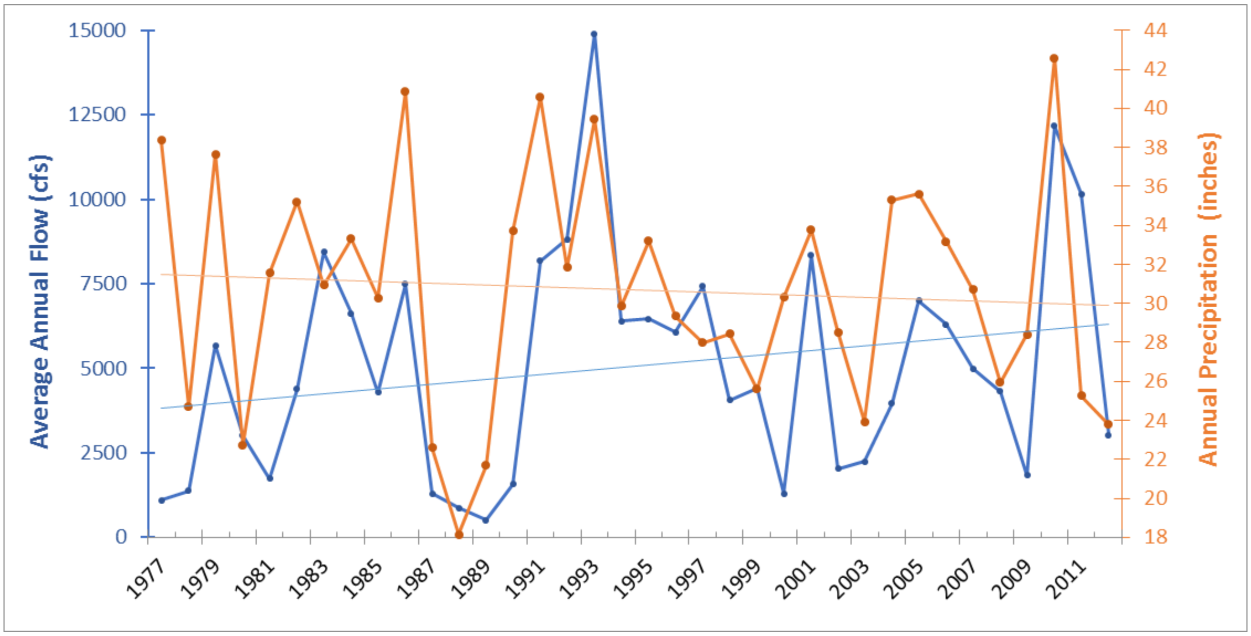


Figure 9: The annual flow of the Watonwan River has increased by roughly 50% over the last four decades despite a slight decrease in annual precipitation.

Because the total flow has increased and the pollutant load is the product of flow and concentration, the total pollutant load delivered by the river may have increased. At this time, there is not sufficient watershed load data to calculate load trends, but enough data may be available in coming years.

Clarity is measured at several lakes in the watershed. St. James Lake and Fish Lake show improving trends, while Lake Hanska shows a declining trend (Table 2). The other lakes in the watershed did not have ample data to calculate a trend or no trend was observed in the data. Clarity is also measured at over 30 river locations in the watershed. At this time, either the data does not indicate a trend or there is not enough data to calculate a trend.

Table 2: Three lakes in the Watonwan River Watershed have ample data to identify a trend. Lake Hanska shows a declining trend while Fish and St. James Lakes show an improving trend over the years with data.

Lake	Years with Data	Trend in Data	
		Transparency (ft/decade)	Min / Max Transparency
Hanska	1976-1980, 1991-2016	-0.49	-0.14 / -0.94
Fish (Main)	1981-2010	0.32	-0.05 / 0.86
St. James	1988-1991, 2008-2016	0.41	-0.38 / 0.91

Sources Overview

This section orients readers to the array of sources of pollutants and stressors in the Watonwan River Watershed. Sources of pollutants and stressors can be grouped into either point sources (NOAA 2008), which are discharge directly from a discrete point, and Land sources (EPA 2018), which are 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 so that 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 Watonwan 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 are regulated through National Pollutant Discharge Elimination System (NPDES; EPA 2014a) permits. 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; some are allowed to discharge under special circumstances or required to use best management practices (BMPs) to reduce pollutants.

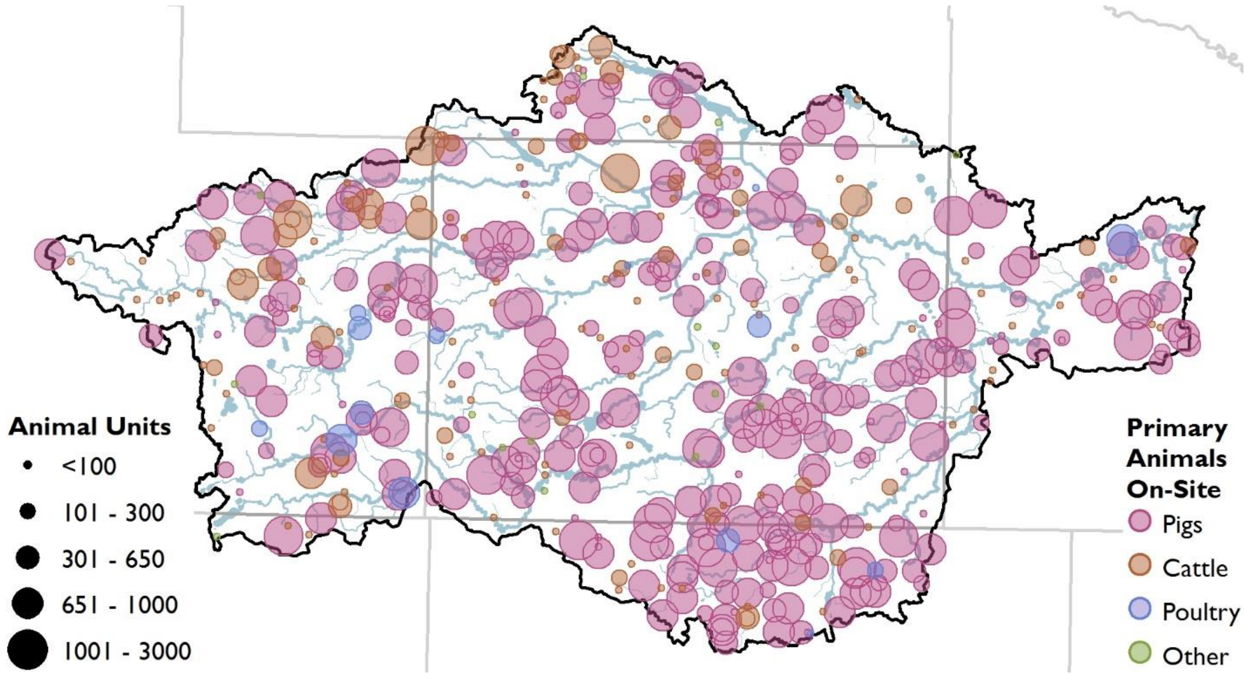
Municipal and Industrial Wastewater

Municipal and industrial wastewater point sources have discharge and monitoring requirements specified in the facility permits to ensure pollutant levels in their permitted discharge support water quality goals. The industrial and municipal facilities that discharge to water bodies are listed in Table 3. Because these systems often require discharge monitoring, their total contributions can be calculated. The estimated 2011 through 2015 contributions of these facilities to the total loads delivered by the

Table 3: Five industries and ten municipal wastewater treatment plants comprise the point sources that discharge into the Watonwan River watershed.

Industrial Facility	County
Erosion Control Plus Inc	Blue Earth
Mathiowetz Construction	Brown
Ethanol POET Biorefining	Cottonwood
Truman WTP	Martin
Bituminous Materials LLC	Watonwan

Municipal Facility	County
Delft Sanitary District WWTP	Cottonwood
Mountain Lake WWTP	Cottonwood
Neuhof Hutterian Brethren	Cottonwood
Truman WWTP	Martin
Butterfield WWTP	Watonwan
La Salle WWTP	Watonwan
Lewisville WWTP	Watonwan
Madelia WWTP	Watonwan
Odin-Ormsby WWTP	Watonwan
Saint James WWTP	Watonwan



	Pigs	Cattle	Poultry	Other
Total AUs	198,908	25,033	5,241	395
% of Total	87%	11%	2%	0.2%

Figure 10: Over 229,000 animal units are registered within the Watonwan River Watershed. See the Animal Unit Calculator (MPCA, 2016a) for conversions of animal numbers to units. The number of feedlot animal units per region, along with additional information, can indicate the likeliness that feedlot-produced manure is making substantial contributions of bacteria and nutrients to water bodies.

Nonpoint Sources

With a generally low input of pollutants/stressors from point sources, nonpoint sources are the dominant source of pollutants/stressors in the Watonwan River Watershed. Nonpoint sources of pollutants/stressors are products of the ways that land is used and how well human impacts are managed/mitigated with BMPs. This section summarizes the types of nonpoint sources.

Nonpoint sources of pollutants/stressors typically travel from the land and watershed around a water body into the water body in response to precipitation. 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). 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.

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 compared to many cultivated crop fields, urban developments, and over-grazed pastures. 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.

When land uses such as cultivated crops do not adhere to industry 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 Watonwan River Watershed is dominated by cultivated crop production (refer to 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. As demonstrated by sustainable agriculture (USC 2018), farming and clean water do not have to be mutually exclusive. 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, city stormwater systems can be designed and built for zero or minimal runoff depending on the size and intensity of the rain event.

While some agricultural and urban runoff has been reduced using sufficient BMPs, including a short term reduction in sediment and long term reduction in phosphorous (Table 1), substantial additional BMPs need to be adopted to achieve clean water. The new MPCA Healthier Watersheds Accountability Report (MPCA 2018a) shows that 633 BMPs have been installed in the Watonwan River Watershed since 2004. The Agricultural Water Quality Certification Program (MDA 2019) has certified 21 producers on 10,000 acres (<2%) as of April 2018. These farms are certified 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

In addition to surface runoff pathways, subsurface drainage pathways also deliver pollutants/stressors to water bodies. In urban settings, subsurface drainage occurs via storm sewers. Up to 6% of the Watonwan is serviced by storm sewers, based on the land use statistics. In farming settings, subsurface drainage occurs via subsurface tile drainage systems. Based on a Geographic Information System (GIS) analysis, up to 82% of the Watonwan River Watershed's area may be tile drained, with 40% of the area likely drained (Figure 11).

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.

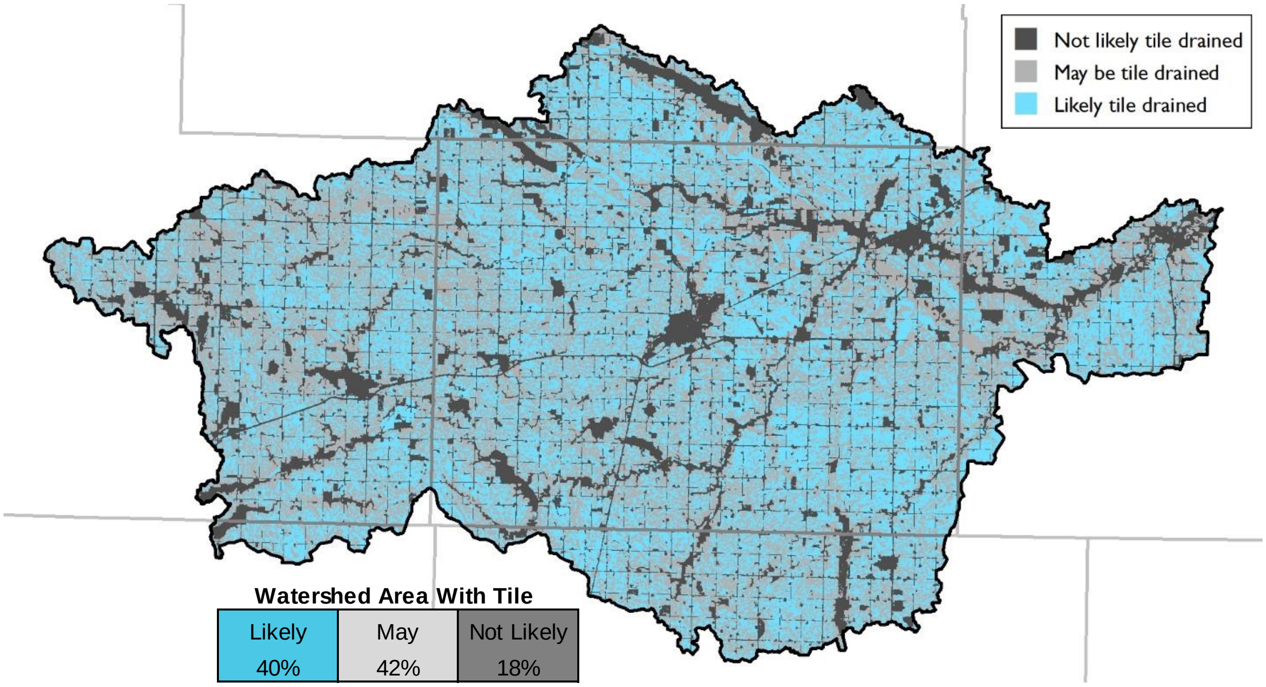


Figure 11: Relative to many parts of Southern Minnesota, a smaller portion of agricultural lands within the Watonwan River Watershed are tile drained. According to a GIS analysis, 40% of the area is likely to be tile drained, and up to another 42% may be tile drained.

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). 111,000 (48%) AUs in 316 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 nonregulated 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 Watonwan River Watershed, 5,800 (2%) AUs in 30 feedlots are near shoreland, one of which is a CAFO. Of the feedlots in shoreland, 3,500 (1.5%) AUs in 23 feedlots have access to open lots. Open lots can be particularly high risk because manure is not contained within a structure and may more readily run off.

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 67% of the AUs in the watershed is likely injected and incorporated manure (swine manure for facilities with more than 300). Fifteen percent 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 1%, 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 water body, 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 two to three failing septic systems Subsurface Treatment Systems (SSTS) per 1,000 acres in the Watonwan River Watershed (Figure 12). 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.

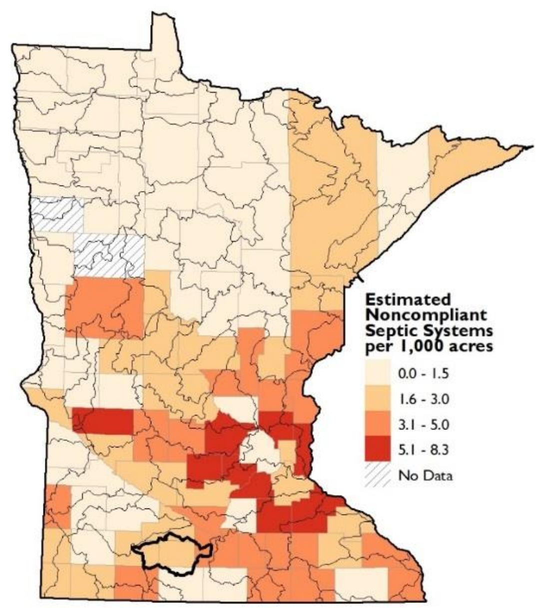


Figure 12: The Watonwan River Watershed has an estimated average of two to three failing septic systems per 1,000 acres as of 2016.

Unsewered or undersewered communities (MPCA 2019) 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 Watonwan River Watershed including Garden City, Long Lake, Grogan and South Branch.

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 water body can help capture pollutants/stressors, stabilize the streambank, and provide habitat to sensitive aquatic species. Other particularly sensitive areas include flood plains, high slope areas, and areas with highly erodible soils.

Historical Changes

Understanding landscape conditions prior to European settlement, and changes between then and today, provides context for today's water quality conditions and sources. The landscape in the Watonwan River Watershed has been highly manipulated since European settlement. Figure 13 compares the estimated streams, lakes, and wetlands of pre-European settlement to those of today. In 1855, portions of the Watonwan River Watershed were covered by prairie and dotted with prairie potholes (EPA 2015). 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 used for vegetative growth and to recharge shallow groundwater, which 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.

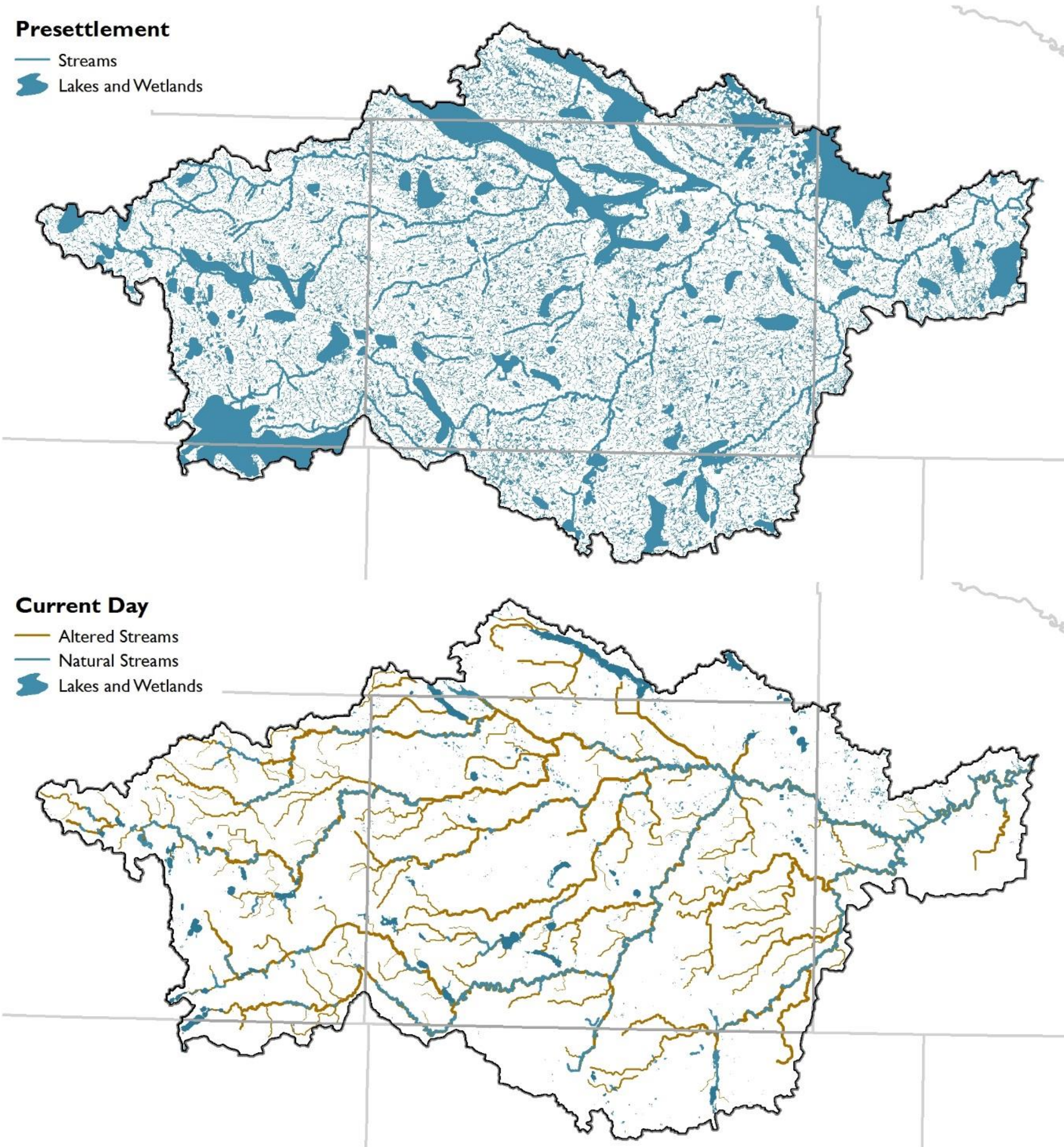


Figure 13: The areas covered by wetlands, lakes, and streams has changed substantially between the mid-19th century and today. The Watonwan River Watershed likely had substantial amounts of wetlands to hold, infiltrate, and evapotranspirate water. This image is for illustrative purposes only. See Appendix 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 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 14). 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 15), resulting in more precipitation entering rivers in spring and less entering in mid-summer.

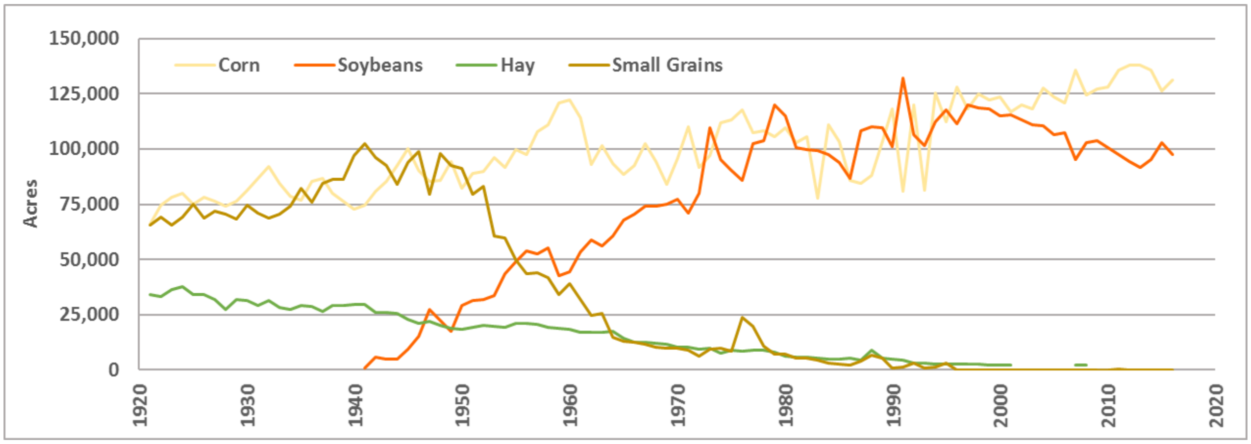


Figure 14: The harvested acres of corn, soybeans, hay, and small grains in Watonwan County illustrate how small grains and hay were replaced through time by soybeans and corn.

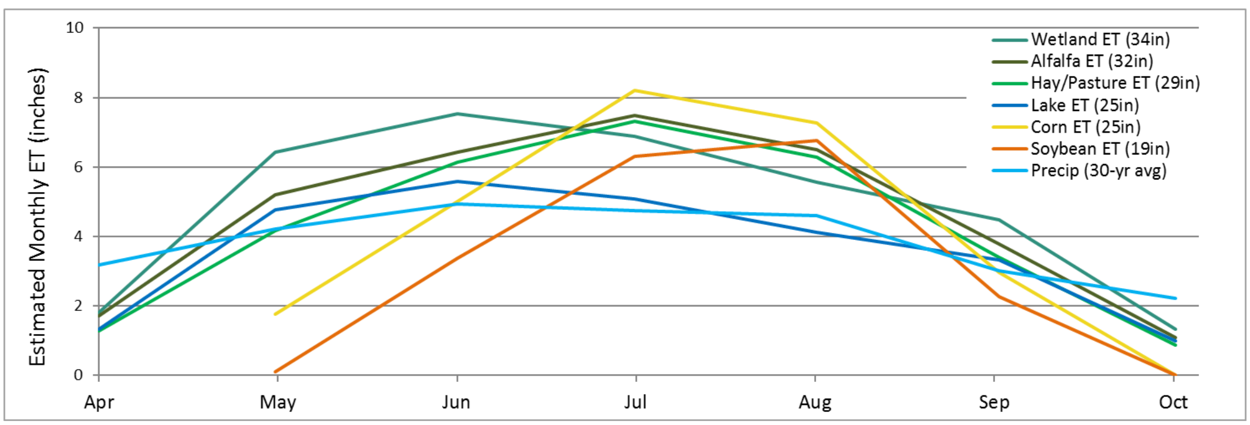


Figure 15: Since European settlement, prairies and wetlands were replaced first by diverse crops and then by corn and soybeans. The total annual ET rates (indicated in the figure legend) of these replacement crops are smaller and the timing of ET through the year has shifted. These changes affect the hydrology of the watershed. See Appendix 4.1 for data sources and calculations.

Goals & Targets Overview

Water quality goals are intended to help both water bodies within the watershed and waterbodies downstream of the watershed meet water quality goals. Goals for the Watonwan River Watershed (Table 4) were set after analyzing the WPLMN data, HSPF model output, *Total Maximum Daily Load* (TMDL; MPCA 2013f) studies, and statewide reduction goals (summarized in Appendix 0). The selected watershed-wide goals integrate multiple levels of goals into one watershed-wide goal. Subwatershed goals (for individual stream reaches and lakes) are presented for water bodies when TMDL data are available. The TMDL studies include the *Watonwan River Watershed TMDL* (developed concurrently with this WRAPS report; see MPCA Watonwan River webpage [MPCA 2018c]), draft *Minnesota River and Greater Blue Earth River Basin TMDL for TSS* (MPCA 2018c) and the *Blue Earth River Basin Fecal Coliform TMDL* (MPCA 2007).

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, dissolved oxygen [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 the IBI score threshold. 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 water body 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 bug 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” and a proposed “years to reach goal” were selected by consensus of the WRAPS Local Work Group. The 10-year targets allow opportunities to adaptively manage implementation efforts, while the years to reach the goals set reasonable timelines to meet water quality goals.

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 water body conditions reflected by new data or due to changes in standards, statewide goals, and calculation methods.

Table 4: 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 Local Work 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/surrogate for Watershed)	**Range of Subwatershed Goals** (Estimated only when TMDL or MSHA data are available)	**10-year Target** (for 2029)	**Years to Reach Goal** (from 2019)
Habitat	35% increase in MSHA habitat score	protect up to a 164% increase	12% ↑	75
Altered Hydrology	25% reduction in peak & annual stream flow	not estimated (TMDLs not completed on this parameter)	4% ↓	45
	increase dry season stream base flow where ID'd in SID by enough to support aquatic life		increase	15
Nitrogen	50% reduction in stream concentrations/loads	not estimated (TMDLs not completed on this parameter)	15% ↓	60
Sediment	20% reduction in stream concentrations/loads	protect up to a 94% reduction	4% ↓	45
Connectivity	Address human-caused issues (dams, culverts) as identified in SID and where practical/feasible	not estimated (TMDLs not completed on this parameter)	Replace 5% of culverts	45
Phosphorus/ Eutrophication	40% reduction in lake and stream concentrations/loads	protect up to a 47% reduction	Streams 5% ↓ Lakes 10% ↓	Streams 60 Lakes 35
Bacteria	65% reduction in stream concentrations/loads	10-84% reduction	12% ↓	65
Parameters that are impacted/addressed by the above pollutants and stressors				
F-IBI & M-IBI	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 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	60
DO				60

2.2 Identified Pollutants and Stressors

This section summarizes information by parameter, describing and/or illustrating:

- Status: the streams and lakes known to be impacted or not impacted by the pollutants/stressors
- Sources: a detailed source assessment for the watershed

- Goals: estimated reductions or improvements necessary to meet water quality goals in and downstream of the Watonwan River Watershed

Refer to the Conditions Overview Section 2.1 for a broad summary and methods relevant to multiple parameters. The map in Figure 8 provides a reference to impairments within the watershed. Refer to the Assessing Water Quality Section 1.3 for a summary of how water bodies are monitored and assessed, the SID process, and the difference between a pollutant and stressor.

Habitat

Habitat, as identified in this report, refers to the in- and adjacent-stream habitat. Important stream habitat components include stream size and channel dimensions, channel gradient (slope), channel substrate, habitat complexity, and in-stream and riparian zone vegetation. 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 30 bio-impaired stream reaches, degraded habitat was identified as a stressor in all 30-stream reaches. *MPCA Stream Habitat Assessment* (MSHA) scores in the Watonwan River Watershed range from 24 to 69 (Figure 17) with an average score of 50. The habitat assessment results are illustrated in Figure 16 and tabulated in Table 5. The 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 have a "good" MSHA score, SID 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.

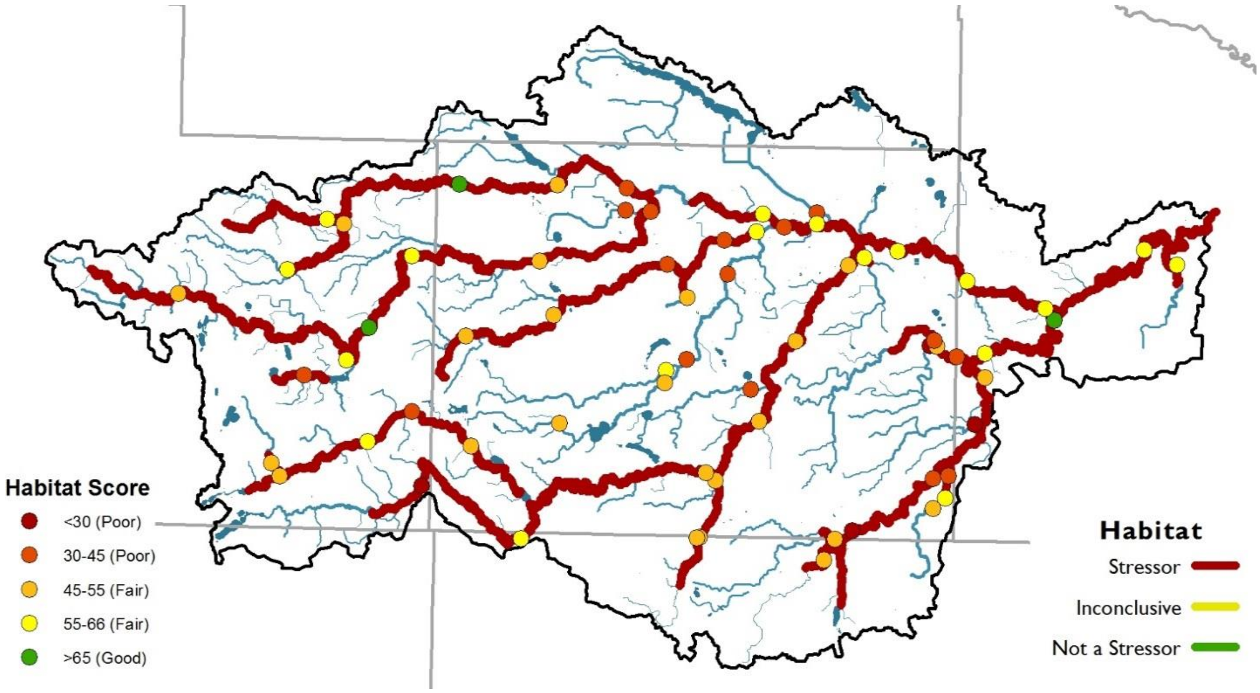


Figure 16: Degraded habitat was identified as a stressor in all of the bio-impaired stream reaches in the Watonwan River Watershed, as indicated by the red stream reaches. The habitat at point locations was scored using the MSHA habitat score; those scores are indicated by the colored dots. While a stream reach can be stressed by degraded habitat, point locations on that reach may have good habitat, as illustrated by three green dots on red stream reaches. However, most locations in the watershed scored poor to fair habitat.

Table 5: Assessment results for degraded habitat as a stressor in Watonwan River Watershed stream reaches

Stream	Reach (AUID-3)	Habitat Assessment	Stream	Reach (AUID-3)	Habitat Assessment	Stream	Reach (AUID-3)	Habitat Assessment
Watonwan River	501	x	Watonwan River	547	x	Watonwan River	567	x
Unnamed Creek	505	x	Unnamed Creek	549	x	Watonwan River	568	x
Watonwan River	510	x	Unnamed Creek	552	x	Watonwan River	569	x
Watonwan River	511	x	Unnamed Creek	557	x	Willow Creek	571	x
Butterfield Creek	516	x	County Ditch 78	559	x	Spring Branch Creek	574	x
Watonwan River	517	x	Unnamed Creek	561	x	Mink Creek	577	x
Perch Creek	523	x	Watonwan River	563	x	Judicial Ditch 1	579	x
Perch Creek	524	x	Watonwan River	564	x	Judicial Ditch 1	580	x
Unnamed Creek	526	x	Watonwan River	565	x	Judicial Ditch 1	581	x
Spring Brook	540	x	Watonwan River	566	x	Unnamed Creek	583	x

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

Sources

The sources of lack of habitat in the Watonwan River Watershed (Table 6) reflect complex, interconnected sources driven by three primary factors: altered hydrology, degraded riparian areas, and altered (channelized) streams. Within the confines of a channelized stream, the impacts of altered hydrology (excessive flow) are magnified because the stream cannot dissipate energy to the floodplain. Concurrently, degraded riparian vegetation lacks the strength to resist erosion and does not offer aquatic life adequate cover. The excessive streambank erosion in turn creates bedded sediment. All of these factors compromise or destroy critical habitat components.

Table 6: The specific sources of lack of habitat were assessed for the Watonwan River Watershed in the Stressor ID report. Excessive flow alteration (altered hydrology) and degraded riparian are two driving factors contributing to other sources.

Stream	AUID	Flow Alteration	Degraded Riparian	Altered Channel	Bedded Sediment	Streambank Erosion	Lack of Cover	Stream	AUID	Flow Alteration	Degraded Riparian	Altered Channel	Bedded Sediment	Streambank Erosion	Lack of Cover
Watonwan River	501				x	x	?	Unnamed Creek	561	x	x	?	x	x	x
Unnamed Creek	505		x	x	x		x	Watonwan Creek	563				x	x	
Watonwan River	510		x		x	x	x	Watonwan Creek	564	x	x	x	x	x	
Watonwan River	511				x	x	x	Watonwan Creek	565	x		x		x	
Butterfield Creek	516	x	x	x	x	x	x	Watonwan Creek	566	x	x		x	x	
Watonwan River	517	x	x		x	x	x	Watonwan Creek	567	x	x	x	x	x	x
Perch Creek	523				?	x	x	Watonwan Creek	568	x	x		x	x	
Perch Creek	524		x		x	x	x	Watonwan Creek	569	x	x	x	x	x	x
Unnamed Creek	526	x	x	x	x	?	x	Willow Creek	571	x	x		x	x	x
Spring Brook	540			x	x	?		Spring Branch Creek	574	x	x	x	x	x	x
Watonwan River	547	x			x	x		Mink Creek	577	x	x	x	x	x	
Unnamed Creek	549	x	x	x		x	x	Judicial Ditch 1	579	x	x	x	x	x	x
Unnamed Creek	552		x	x	?		x	Judicial Ditch 1	580	x		x	x		x
Unnamed Creek	557	x		x	x	x		Judicial Ditch 1	581	x	x	x	?	x	x
County Ditch 78	559		x	x		x	x	Unnamed Creek	583	x	x	x	x	x	x

x = likely source or driver ? = unknown effect <blank> = not likely source or driver

Goal & 10-year Target

The watershed-wide goal for habitat in the Watonwan River Watershed (Figure 17) is a 35% increase in the watershed average MSHA score, from 50 to 66 or greater. Subwatershed goals range based on the steam class: Class 2 stream reaches should have “good” habitat (MSHA score >66) and for Class 2 modified (ditches) and Class 7 (limited use) stream reaches should have “fair” habitat (MSHA score >45). Goals at point locations are illustrated by a gray circle; point locations meeting/exceeding the goal need “protection” and are illustrated with a white star.

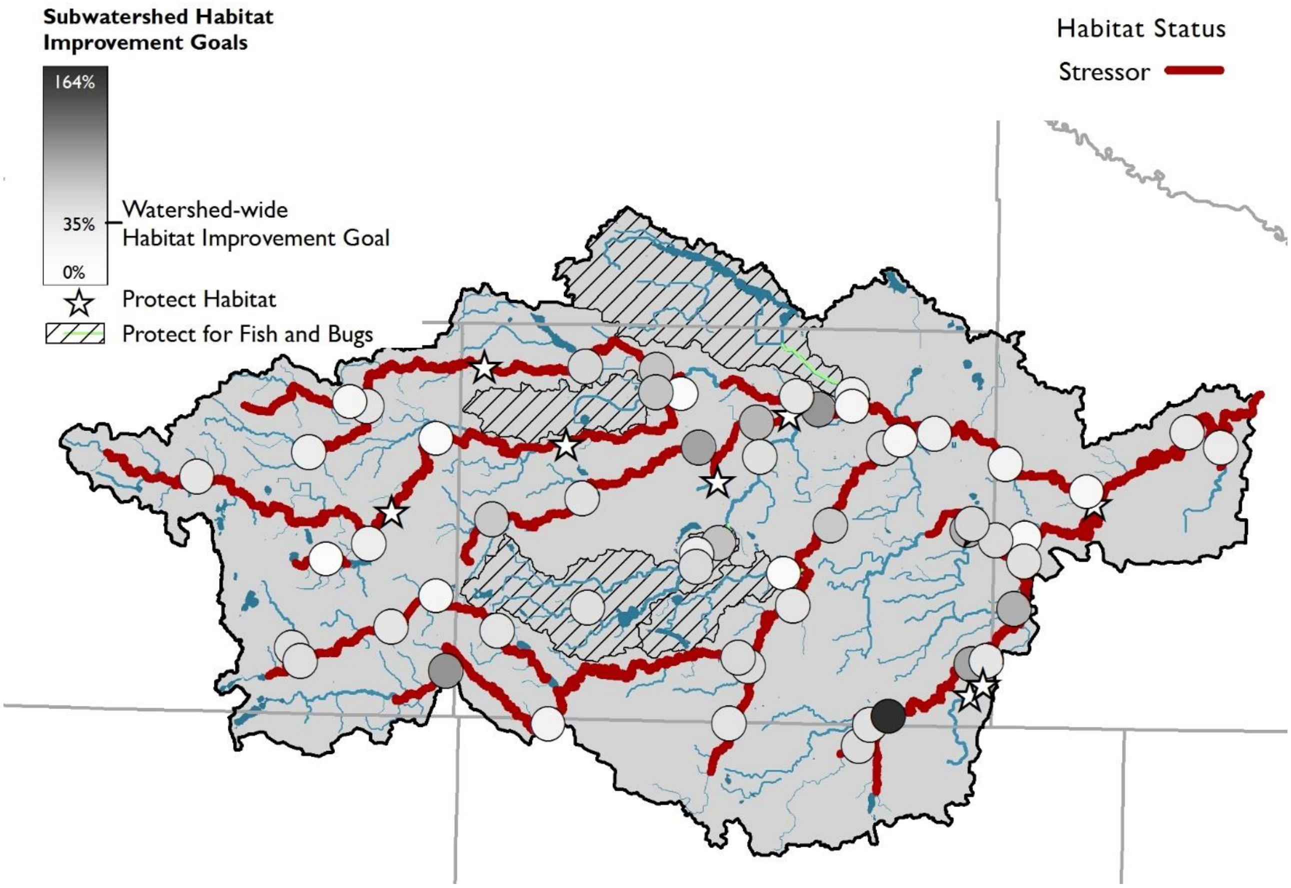


Figure 17: The watershed-wide habitat goal for the Watonwan River Watershed is to increase the average MSHA score in the watershed from the current score of 50 (fair) to a score of >66 (good), a 35% increase. The relative amount of change needed at a point location is illustrated by the color of the dot: the darker the dot, the more improvement needed. Locations with good habitat scores, illustrated with stars, should be protected.

The 10-year target selected by the WRAPS Local Work Group is a 12% increase in the MSHA scores. Since low habitat scores are mostly due to degraded riparian vegetation, channel instability, and excess sediment (the latter being accelerated by altered hydrology), these factors should be the focus of restoration and protection efforts to meet the goal and 10-year target. Strategies and methods to prioritize regions to address habitat are summarized in Section 3.

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 can also indirectly harm 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

Of the 30 bio-impaired stream reaches, altered hydrology was identified as a stressor in 21 and inconclusive in 9. The altered hydrology assessment results are illustrated in Figure 18 and tabulated in Table 7.

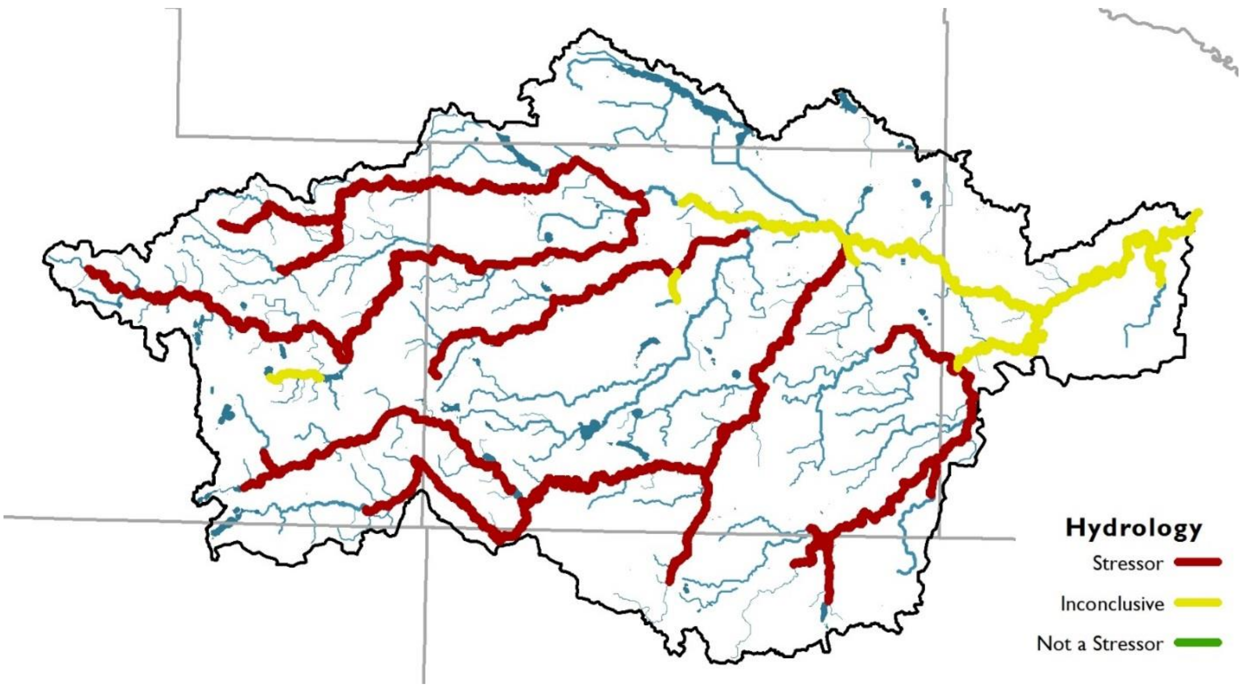


Figure 18: Altered hydrology was identified as a stressor throughout the Watonwan River Watershed. Red indicates a stressor (altered hydrology is problematic in that reach), and yellow indicates that more data is needed to assess altered hydrology as a stressor. Altered hydrology as a stressor was not ruled out in any stream reach.

Data from the WPLMN indicate that the average volume of water leaving the Watonwan River Watershed from 2007 through 2015 was 302,000 acre-feet.

Table 7: Assessment results for altered hydrology as a stressor in Watonwan River Watershed stream reaches.

Stream	Reach (AUID-3)	Hydrology Assessment	Stream	Reach (AUID-3)	Hydrology Assessment	Stream	Reach (AUID-3)	Hydrology Assessment
Watonwan River	501	?	Watonwan River	547	x	Watonwan River	567	x
Unnamed Creek	505	?	Unnamed Creek	549	x	Watonwan River	568	x
Watonwan River	510	?	Unnamed Creek	552	?	Watonwan River	569	x
Watonwan River	511	?	Unnamed Creek	557	x	Willow Creek	571	x
Butterfield Creek	516	x	County Ditch 78	559	?	Spring Branch Creek	574	x
Watonwan River	517	x	Unnamed Creek	561	x	Mink Creek	577	x
Perch Creek	523	?	Watonwan River	563	?	Judicial Ditch 1	579	x
Perch Creek	524	x	Watonwan River	564	x	Judicial Ditch 1	580	x
Unnamed Creek	526	x	Watonwan River	565	x	Judicial Ditch 1	581	x
Spring Brook	540	?	Watonwan River	566	x	Unnamed Creek	583	x

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

Sources

There are several causes of altered hydrology in the Watonwan River Watershed. These causes range from landscape and climate changes, to crop and vegetative changes, to soil and drainage changes. While understanding what has caused altered hydrology is important to develop restoration strategies, numeric source assessment work focused on the land use and pathway that water travels after being received as precipitation. By understanding the relative magnitude of water coming from various land uses and pathways, the land uses most critical to mitigating altered hydrology are identified.

While most precipitation is returned to the atmosphere by ET, the remaining water travels to water bodies via different pathways. Pathways for water to travel to water bodies include surface runoff, groundwater flow, and artificial subsurface drainage such as drainage tile or storm sewer networks. Numeric estimates of the Watonwan River Watershed land uses' contributions of water to waterbodies were estimated using a water portioning calculator (Appendix 4.2) and vetted by the WRAPS Local Work Group (Figure 19).

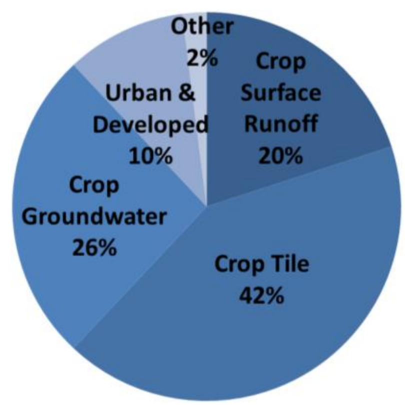


Figure 19: Precipitation falls on the landscape and is eventually delivered from the varying land uses through surface or subsurface (groundwater or artificial drainage) pathways. An estimated 88% of water that enters waterbodies in the Watonwan River Watershed is delivered from cultivated crops through surface runoff, tile drainage, or groundwater pathways.

Stressor identifion analyzed the specific altered hydrology issues of stressed stream reaches in the Watonwan River Watershed. Of the 21 stream reaches stressed by altered hydrology, only one showed issues with water withdrawal while the rest showed issues resulting from land use/tile drainage or channelization (Table 8).

Table 8: The specific sources of altered hydrology were assessed for the Watonwan River Watershed in the Stressor ID report. Tile drainage and channelized (altered) streams were the two most commonly identified issues.

Stream	AUID	Water Withdrawal	Altered Channel	Tile Drainage/ Landuse
Butterfield Creek	516		x	x
Watonwan River	517			x
Perch Creek	524			x
Unnamed Creek	526		x	x
Watonwan River	547			x
Unnamed Creek	549		x	x
Unnamed Creek	557		x	x
Unnamed Creek	561		x	x
Watonwan River	564		x	x
Watonwan River	565	x	x	x

Stream	AUID	Water Withdrawal	Altered Channel	Tile Drainage/ Landuse
Watonwan River	566		x	x
Watonwan River	567		x	x
Watonwan River	568			x
Watonwan River	569		x	x
Willow Creek	571			x
Spring Branch Creek	574		x	x
Mink Creek	577		x	x
Judicial Ditch 1	579		x	x
Judicial Ditch 1	580		x	x
Judicial Ditch 1	581		x	x
Unnamed Creek	583		x	x

x = likely source or driver ? = unknown effect <blank> = not likely source or driver

Areas of the watershed with higher levels of hydrologic alteration were estimated using GIS (Figure 20). Hydrologic factors considered in the presented analysis include the estimated percentage of land area that is tile drained, the percentage of stream length that is channelized/artificially straightened, the percentage of wetlands that were drained, the percentage of land in nonperennial vegetation, the percentage of land covered in impervious surfaces, and the number of road crossings per stream length. See Appendix 4.5 for maps of the individual hydrologic factors and weights.

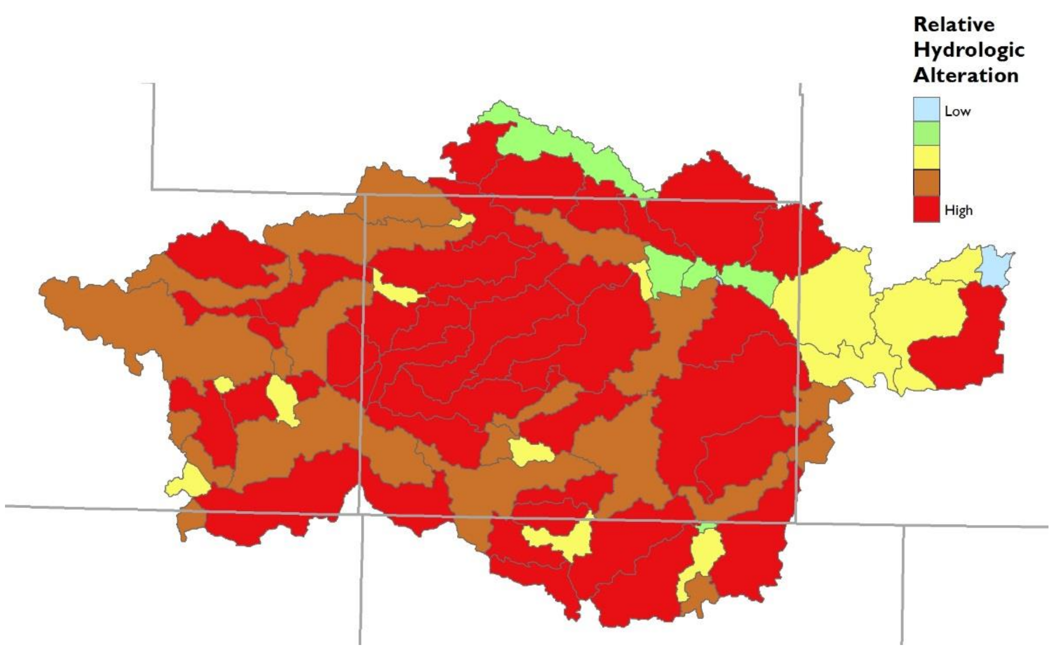


Figure 20: GIS analysis of the watershed estimates where more changes to the natural hydrology of the watershed have occurred. Refer to Appendix 4.5 for more information on this analysis and maps of the individual hydrologic parameters used.

Goal & 10-year Target

The watershed-wide goals for altered hydrology in the Watonwan River Watershed are a 25% decrease in average annual flow (from 302,000 to 226,000 acre-feet) and in peak river flow, and an increase in dry season base flow sufficient to support aquatic life (**Figure 21**). This goal considered multiple lines of evidence including the observed increase in river flow since 1977 (refer to the Trends Overview section), the Sediment Reduction Strategy for the Minnesota River Basin (MPCA 2015h), and data and goals for altered hydrology from other southwestern Minnesota watersheds. This goal is revisable and will be revisited in the next iteration of the Watershed Approach.

The 10-year target selected by the WRAPS Local Work Group is a 4% decrease in annual and peak river flow and an increase in dry season base flow. Decreases in the total annual flow should focus on decreasing peak flows, shifting flow timing to the dry season, 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.

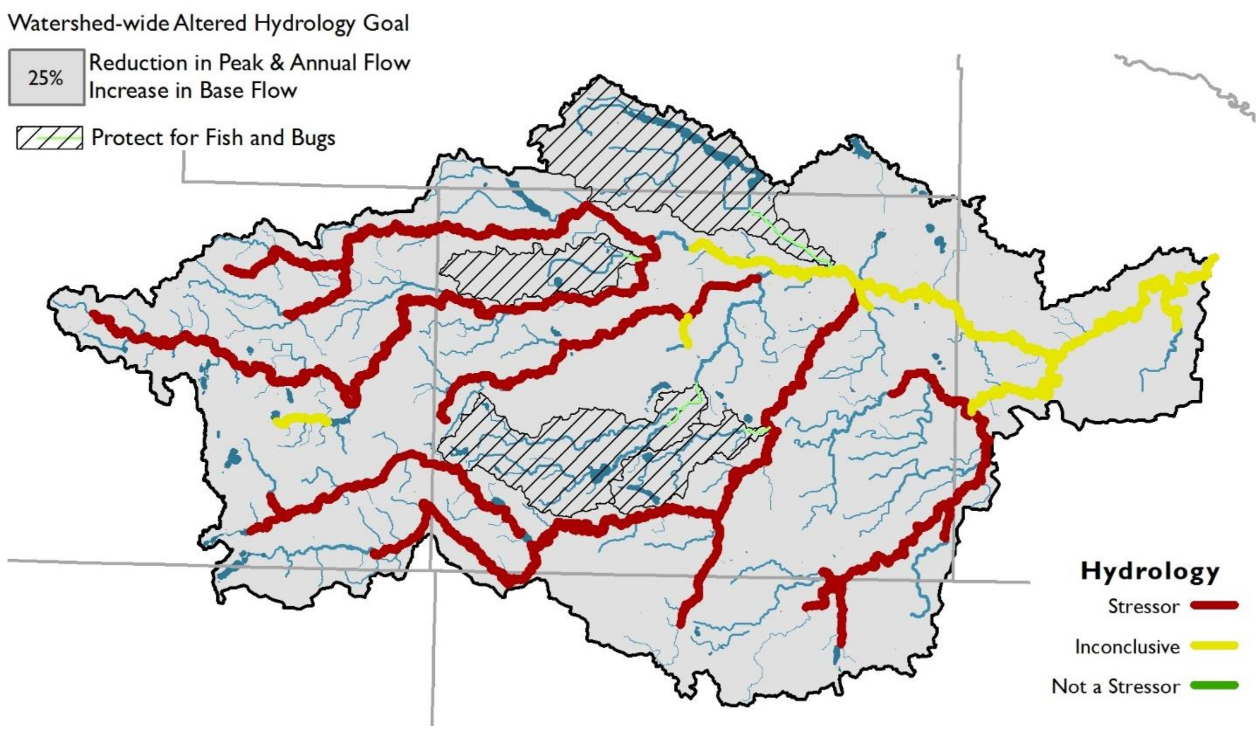


Figure 21: The watershed-wide hydrology goal is a 25% reduction in peak and annual flow and in increase in dry season base flow where needed as identified in the Stressor ID report.

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 (Britanica 2019). Nitrate is typically the nitrogen form of concern in water. However, all nitrogen forms are connected, and all forms pose risks. Therefore, 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; even at small concentrations, nitrogen 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 human health concern, as excessive nitrate consumption via drinking water causes blue baby syndrome (WHO 2018). Due to this health risk, excessive nitrogen in drinking water can necessitate expensive treatments.

Status

Of the bio-impaired stream reaches, nitrogen as a stressor was identified in 15, ruled out in three, and inconclusive in 12. Figure 22 illustrates the stream reaches assessed for nitrogen, and Table 9 tabulates those results. Nitrogen in groundwater, while outside the scope of the WRAPS report, is a related concern as nitrogen in groundwater originates from surface waters.

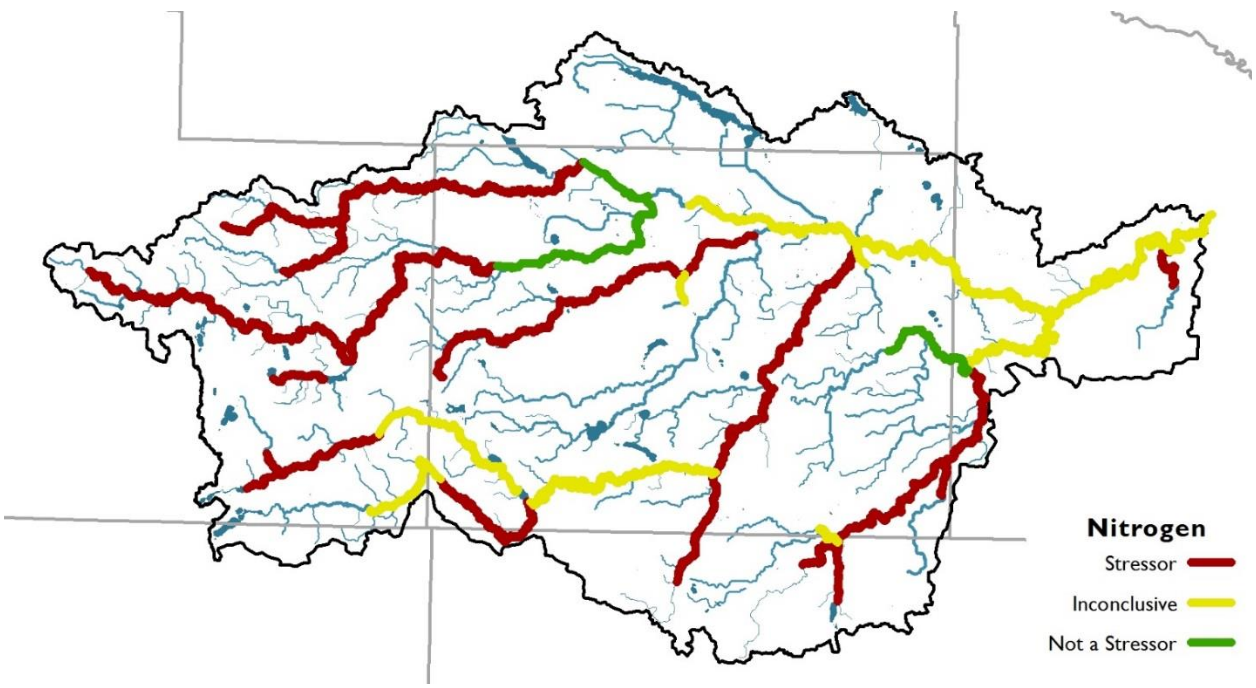


Figure 22: Nitrogen as a stressor is common in the Watonwan River Watershed. Stream reaches assessed for nitrogen and the assessment results are indicated by color. Red indicates TN was identified as a stressor (TN is problematic in that reach), and green indicates TN is not a stressor (TN is not problematic in that reach).

Table 9: Assessment results for nitrate as a stressor in Watonwan River Watershed stream reaches.

Stream	Reach (AUID-3)	Nitrate as a Stressor	Stream	Reach (AUID-3)	Nitrate as a Stressor	Stream	Reach (AUID-3)	Nitrate as a Stressor
Watonwan River	501	?	Watonwan River	547	?	Watonwan River	567	+
Unnamed Creek	505	x	Unnamed Creek	549	x	Watonwan River	568	x
Watonwan River	510	?	Unnamed Creek	552	?	Watonwan River	569	?
Watonwan River	511	?	Unnamed Creek	557	?	Willow Creek	571	x
Butterfield Creek	516	x	County Ditch 78	559	x	Spring Branch Creek	574	+
Watonwan River	517	x	Unnamed Creek	561	X	Mink Creek	577	x
Perch Creek	523	?	Watonwan River	563	?	Judicial Ditch 1	579	x
Perch Creek	524	x	Watonwan River	564	x	Judicial Ditch 1	580	?
Unnamed Creek	526	x	Watonwan River	565	+	Judicial Ditch 1	581	?
Spring Brook	540	?	Watonwan River	566	x	Unnamed Creek	583	x

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

From a statewide perspective, the Watonwan River Watershed has a high yield and flow-weighted mean concentration (FWMC) of nitrogen (Figure 23). From 2007 through 2015, the FWMC of nitrogen in the Watonwan was 11 mg/L.

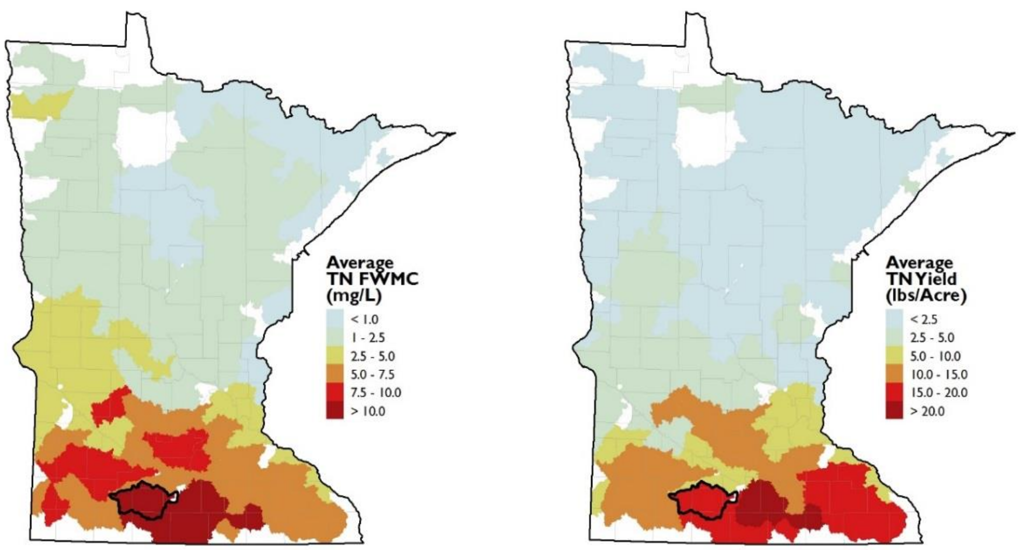


Figure 23: The Watonwan River Watershed has a high flow-weighted FWMC and yield of TN compared to the rest of the state. Data are from the WPLMN.

An HSPF model was developed for the Watonwan River Watershed. The models estimated FWMCs for the years 1996 through 2012 are illustrated in Figure 24. This model output can be used to estimate conditions in stream reaches that have not been monitored.

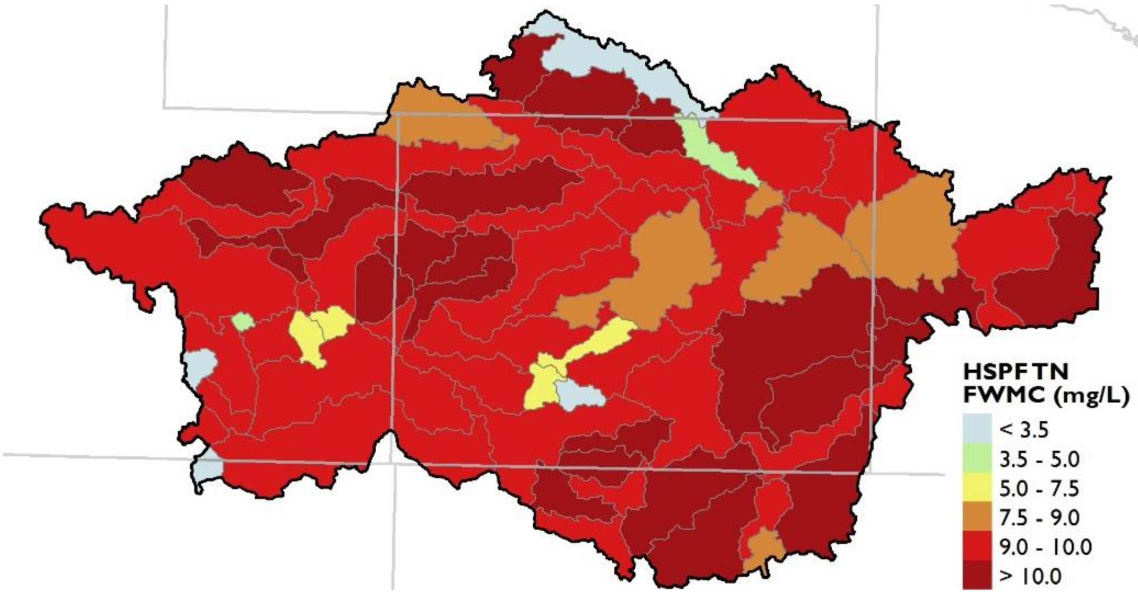


Figure 24: HSPF model output indicate that the FWMC nitrogen concentrations are roughly similar through much of the watershed. The presented model output represent years 1996-2012.

Nitrogen from the Watonwan River Watershed is contributing to groundwater nitrogen issues within the Watonwan Watershed and to downstream nitrogen issues in the Blue Earth Watershed.

The city of Mankato operates two Ranney wells that extract water from an aquifer with a direct connection to surface water. One of those wells is influenced by the Blue Earth River, to which the Watonwan River contributes stream flow and pollutants. Nitrate concentrations in the Mankato Ranney wells often exceed the drinking water standard of 10 mg/L, requiring costly treatment or dilution with other sources. More details on the city's drinking water are in the Appendix 4.4.

The city of Darfur also uses a groundwater source that is subject to nitrate contamination. While nitrate concentrations have not yet exceeded the drinking water standard, data suggests that aquifer concentrations are approaching 10 mg/L and are likely to exceed the standard in the near future. Dilution of water from the city's primary well with another nonimpacted water source is not possible for Darfur.

Sources

In the Watonwan River Watershed, most nitrogen that reaches water bodies is from nonpoint sources. Point source contributions for the years of 2011 through 2015 are estimated to total less than 1.3% of the Watonwan River Watershed's nitrogen load (Appendix 4.2). A numeric estimate of the Watonwan River Watershed's nitrogen sources (land use and pathways) is presented in Figure 25; refer to the Sources Overview in Section 0 for more details.

Crop drainage and crop groundwater dominate nitrogen contributions to water bodies. Nitrogen contributions from cropland originate from fertilizers, manure, plant mater decomposition (referred to as mineralization), and legumes. Nitrogen from these sources then travels to water bodies through multiple pathways: surface runoff, groundwater, or tile drainage. Over-application of fertilizer and manure increases the potential nitrogen loss from cropland.

The SID report provides information on the sources for the nitrogen-stressed stream reaches (Table 10). SID source assessment results indicate cropland use and tile drainage are contributing nitrogen in all of the assessed reaches and that point sources are contributing nitrogen in four reaches.

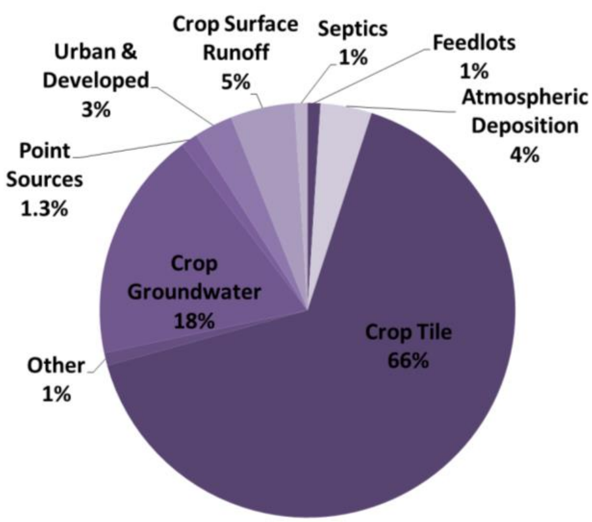


Figure 25: Source assessment in the Watonwan River Watershed estimates that crop drainage and crop groundwater dominate nitrogen contributions. The nitrogen leaving crops is from applied fertilizer, manure, plant material decomposition, and legumes.

Table 10: The specific sources of nitrogen were assessed for the Watonwan River Watershed's bio-impaired stream reaches in the SID report. Tile drainage and cropland use were the most commonly identified issues, with four reaches receiving some nitrogen from point sources.

Stream	AUID	Tile Drainage/ Land Use	Point Sources
Unnamed Creek	505	x	
Butterfield Creek	516	x	x
Watonwan River	517	x	
Perch Creek	524	x	
Unnamed Creek	526	x	x
Unnamed Creek	549	x	
County Ditch 78	559	x	
Unnamed Creek	561	x	
Watonwan River	564	x	
Watonwan River	566	x	x
Watonwan River	568	x	
Willow Creek	571	x	
Mink Creek	577	x	
Judicial Ditch 1	579	x	x
Unnamed Creek	583	x	

x = likely source or driver

<blank> = not likely source or driver

Goal & 10-year Target

The watershed-wide goal for nitrogen is a 50% reduction of nitrogen (Figure 26) to a FWMC of 5 mg/L. Two nitrogen goals were considered to set the watershed-wide reduction goal: the proposed aquatic life toxicity standard (MPCA 2010b; 4.9 mg/L) and the *Minnesota Nutrient Reduction Strategy* (MPCA 2014f), which calls for a 45% reduction (with an interim 20% reduction by 2025) from the Minnesota portion of the Mississippi River Basin as a whole. The reaches not stressed by nitrogen have a protection goal.

The 10-year target selected by the WRAPS Local Work Group is a 15% decrease in nitrogen. 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.

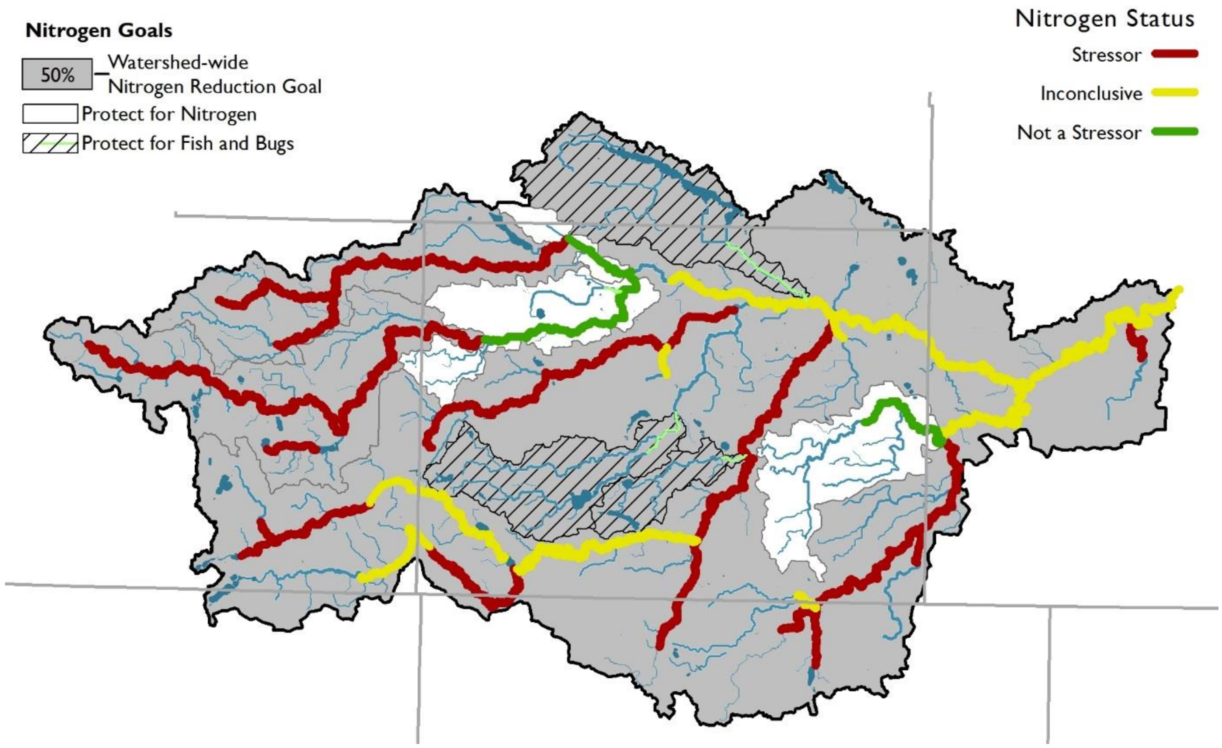


Figure 26: The watershed-wide nitrogen goal for the Watonwan River Watershed is a 50% reduction. Stream reaches where nitrogen was not a stressor have a protection goal.

Connectivity

Connectivity, as identified in this report, refers to the longitudinal connectivity of a stream, or the upstream to downstream connectedness of a stream. A lack of connectivity is typically due to dams, waterfalls, perched culverts, and improperly sized bridges and culverts. A lack of connectivity can obstruct the movement of migratory fish and bugs, causing a negative change in the population and community structure.

Status

Lack of connectivity as a stressor was identified in 6, ruled out in 13, and inconclusive in 11 stream reaches. Figure 27 illustrates the stream reaches assessed for connectivity and Table 11 tabulates those results.

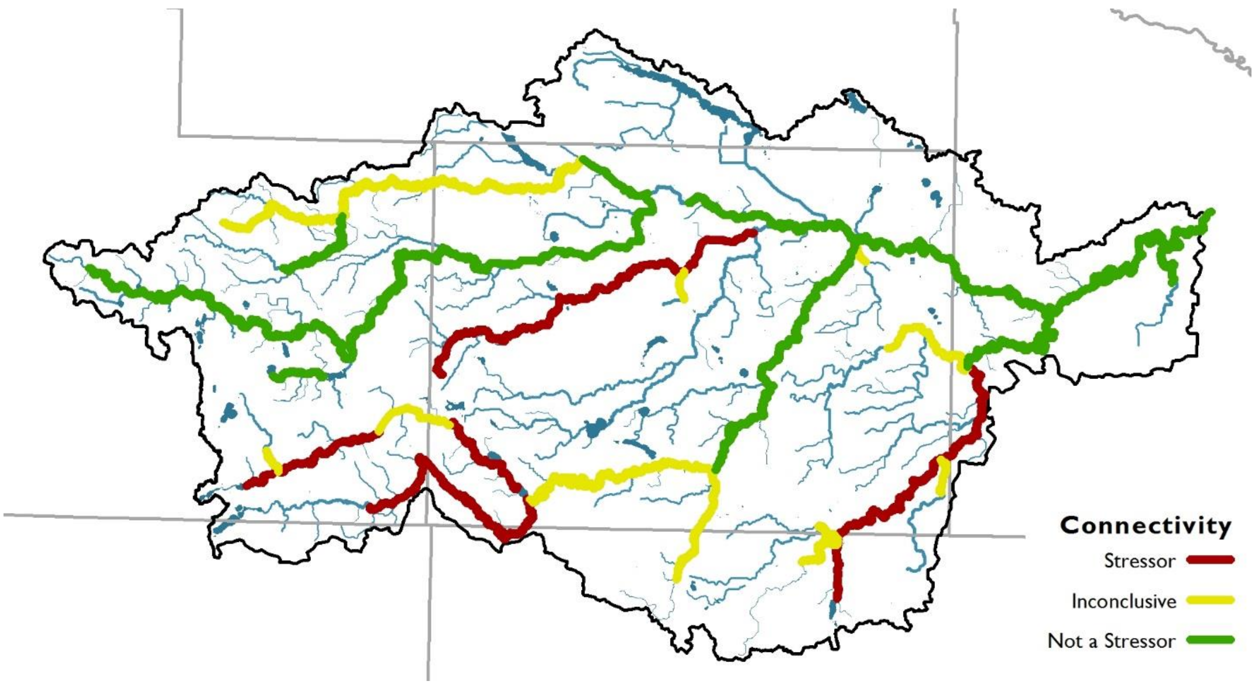


Figure 27: Assessment results show that lack of connectivity is stressing roughly one third of the Watonwan River Watershed's bio-impaired streams. Red indicates lack of connectivity is a stressor (connectivity is problematic in that reach), green indicates connectivity is not a stressor (connectivity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

Table 11: Assessment results for lack of connectivity as a stressor in Watonwan River Watershed stream reaches

Stream	Reach (AUID-3)	Connectivity Assessment	Stream	Reach (AUID-3)	Connectivity Assessment	Stream	Reach (AUID-3)	Connectivity Assessment
Watonwan River	501	+	Watonwan River	547	?	Watonwan River	567	+
Unnamed Creek	505	+	Unnamed Creek	549	+	Watonwan River	568	x
Watonwan River	510	+	Unnamed Creek	552	?	Watonwan River	569	x
Watonwan River	511	+	Unnamed Creek	557	?	Willow Creek	571	?
Butterfield Creek	516	x	County Ditch 78	559	+	Spring Branch Creek	574	?
Watonwan River	517	+	Unnamed Creek	561	?	Mink Creek	577	?
Perch Creek	523	+	Watonwan River	563	+	Judicial Ditch 1	579	x
Perch Creek	524	x	Watonwan River	564	?	Judicial Ditch 1	580	?
Unnamed Creek	526	?	Watonwan River	565	+	Judicial Ditch 1	581	x
Spring Brook	540	?	Watonwan River	566	+	Unnamed Creek	583	+

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

Sources

Of the six stream reaches stressed by lack of connectivity, two are impacted by a dam and one is impacted by a culvert (Table 12). Three reaches may be impacted by a culvert, but more investigatory work is needed.

Table 12: The specific sources of connectivity issues were assessed for the Watonwan River Watershed in the SID report. The only issues identified were dams and road crossings.

Stream	AUID	Dam	Culvert
Butterfield Creek	516		?
Perch Creek	524		?
Watonwan River	568	x	?
Watonwan River	569		?
Judicial Ditch 1	579	x	?
Judicial Ditch 1	581		x

x = likely source or driver
? = unknown effect
<blank> = not likely source or driver

Goal & 10-year Target

The goal for connectivity for the Watonwan River Watershed is to mitigate or remove connectivity issues where relevant and feasible. The 10-year target selected by the WRAPS Local Work Group is to replace 5% of culverts that are stressing aquatic life. Connectivity issues should be assessed to determine if they are the main stressor to the reach prior to investing in upgrades. Upgrades or mitigation may not be cost effective if other stressors (altered hydrology, nutrients, habitat, etc.) are having larger impacts on the aquatic communities.

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.

Sediment

TSS are materials suspended in the water. These materials are often primarily sediment but also includes algae and other solids. Suspended sediment and streambed sediment are closely related because they have many of the same sources. 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 due to P (eutrophication) and are addressed in that section of this report.

TSS directly affects aquatic life by reducing visibility, which reduces feeding; clogging gills, which reduces respiration; and smothering substrate, which limits reproduction. Excessive TSS indirectly affects aquatic life by reducing the penetration of sunlight, limiting plant growth, and increasing water temperatures.

Status

Of the stream reaches monitored to assess if TSS is a pollutant 13 were impaired, 2 were supporting, and 4 were inconclusive. Of the bio-impaired stream reaches, TSS as a stressor was identified in 13, ruled out in 3, and inconclusive in 14. Figure 28 illustrates the stream reaches that were assessed for TSS and Table 13 tabulates those results.

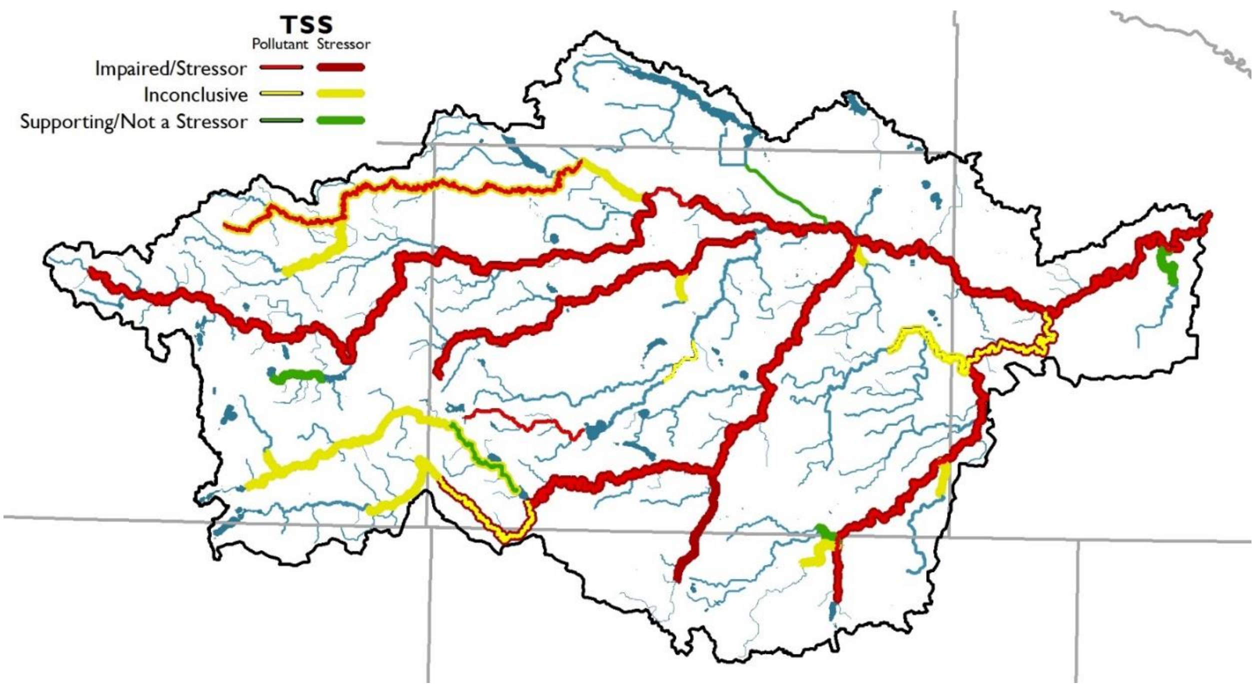


Figure 28: The majority of bio-impaired and assessed stream reaches show issues with TSS, as indicated by color. Red indicates an impairment or a stressor (TSS is problematic in that reach), green indicates TSS is supporting the standard or not a stressor (TSS is not problematic in that reach), and yellow indicates more data is needed. The results for the pollutant assessment overlay the results for the stressor assessment, with the pollutant results in the inside and stressor results showing around the outside.

Table 13: Assessment results for TSS as a pollutant and/or stressor in Watonwan River Watershed stream reaches.

Stream	Reach (AUID-3)	TSS as a Stressor	TSS as a Pollutant	Stream	Reach (AUID-3)	TSS as a Stressor	TSS as a Pollutant	Stream	Reach (AUID-3)	TSS as a Stressor	TSS as a Pollutant
Watonwan River	501	x	x	Watonwan River	547	x	x	Watonwan River	567	x	x
Unnamed Creek	505	+		Unnamed Creek	549	?		Watonwan River	568	x	?
Watonwan River	510	x	x	Unnamed Creek	552	?		Watonwan River	569	?	
Watonwan River	511	x	x	Unnamed Creek	557	+		Willow Creek	571	x	
Butterfield Creek	516	x	x	County Ditch 78	559	+		Spring Branch Creek	574	?	?
Watonwan River	517	x	x	Unnamed Creek	561	?		St James Creek	576		?
Perch Creek	523	x	?	Watonwan River	562		x	Mink Creek	577	?	
Perch Creek	524	x	x	Watonwan River	563	x	x	Judicial Ditch 1	579	?	
Unnamed Creek	526	?		Watonwan River	564	?	x	Judicial Ditch 1	580	?	
St James Creek	528		x	Watonwan River	565	?		Judicial Ditch 1	581	?	+
Spring Brook	540	?		Watonwan River	566	x	x	Unnamed Creek	583	?	
Unnamed Ditch	545		+								

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

From a statewide perspective, the Watonwan River Watershed has a high yield and FWMC of TSS (Figure 29). From 2007 through 2015, the FWMC of TSS in the Watonwan River Watershed was 82 mg/L.

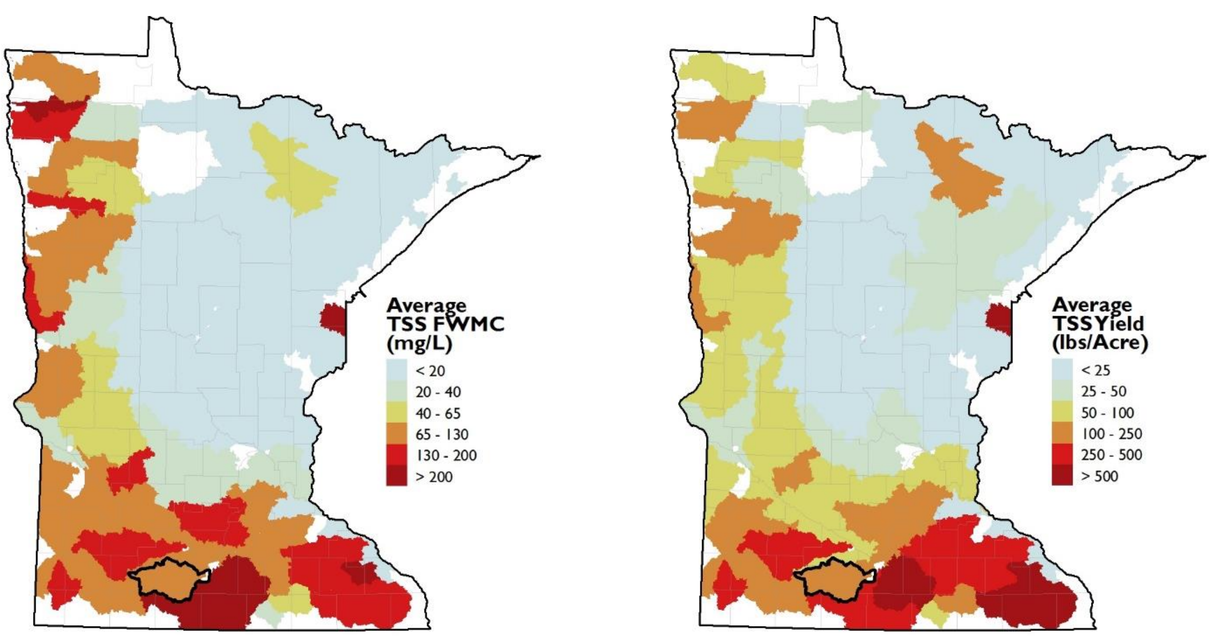


Figure 29: The Watonwan River Watershed has a high annual sediment yield (the total amount leaving the watershed), losing over 100 pounds per acre on average. The in-stream FWMC of TSS over the same period was 82 mg/L.

An HSPF model was developed for the Watonwan River Watershed. The models estimated FWMCs for the years 1996 through 2012 are illustrated in Figure 30. This model output can be used to estimate conditions in stream reaches that have not been monitored.

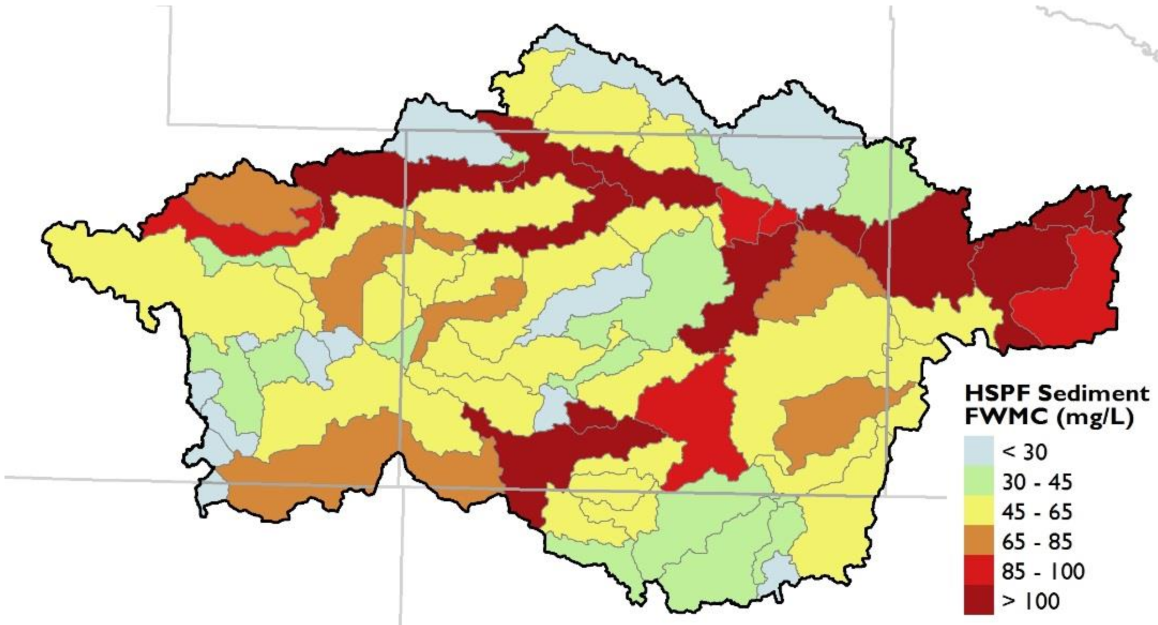


Figure 30: HSPF model output indicate that the FWMC sediment concentrations vary through the watershed. The highest modeled concentrations were found in the North Fork, South Fork, and the outlet of the Watonwan River. The presented model output represent years 1996-2012.

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 be about 0.1% of the Watonwan River Watershed's sediment load (data and calculations in Appendix 4.2).

Upland erosion includes farm field surface and gully erosion, sediment that is washed away from roads and developed areas, and surface erosion from other areas. Upland sediment contributions typically happen when bare soils erode during rains or snowmelt.

Channel sediment contributions are dominated by streambank, ditch bank, and bluff erosion, but also include channel bed and other material in or directly adjacent to the water body. While some amount of channel migration and associated bank/bluff erosion is natural, altered hydrology has 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. In the Watonwan River Watershed, a more rapid elevation change occurs near the outlet, making ravines more common in this area of the watershed. While some erosion of ravines is natural, the natural erosion rate is greatly accelerated when the land use above the ravine delivers more water than a natural condition, including when drainage waters from farms and cities are routed down the 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 Watonwan River Watershed as discussed in the *Watonwan River Watershed Hydrology, Connectivity, and Geomorphology Assessment* (DNR 2014b). According to this report, stream instability can occur from degraded riparian vegetation and 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 and intact floodplain areas appeared more resilent than those without dense, deep-rooted vegetation.

A numeric estimate of the Watonwan River Watershed's sediment sources is presented in Figure 31; refer to the Sources Overview in Section 0 for more details. Cultivated crop surface runoff and streambank erosion are the dominant sources of sediment throughout the Watonwan River Watershed.

SID provides information on the sources for the TSS-stressed stream reaches (Table 14). All of the 13 TSS-stressed reaches likely receive excess sediment from streambank erosion. Most of these stream reaches are impacted by altered hydrology, including flow alteration and altered channels.

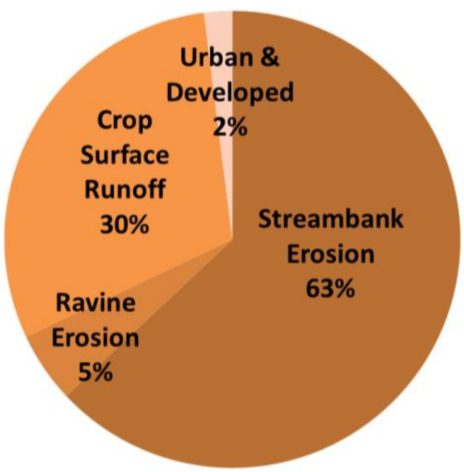


Figure 31: The TSS source assessment in the Watonwan River Watershed estimates that the largest sources of sediment are from streambank erosion and crop surface runoff.

Table 14: TSS contributions were assessed for sediment-stressed stream reaches in the Watonwan River Watershed in the SID report. Flow alteration and streambank erosion were the two most commonly identified issues.

Stream	AUID	Flow Alteration	Streambank Erosion	Altered Channel	Local Land Use or Pasture
Watonwan River	501		x		
Watonwan River	510		x	x	
Watonwan River	511		x	x	
Butterfield Creek	516	x	x	x	
Watonwan River	517	x	x		x
Perch Creek	523		x		
Perch Creek	524	x	x		
Watonwan River	547	x	x		
Watonwan River	563		x		
Watonwan River	566	x	x		
Watonwan River	567	x	x	x	
Watonwan River	568	x	x		x
Willow Creek	571	x	x		x

x = likely source or driver

<blank> = not likely source or driver

Goal & 10-year Target

The watershed-wide sediment goal for the Watonwan River Watershed (Figure 32) is a 20% reduction in stream TSS FWMC to reach a FWMC of 65 mg/L. Subwatershed goals were calculated where TMDL data are available and range from a 94% reduction goal for the upstream reach of St. James Creek to a protection goal in several reaches. Subwatershed goals are illustrated below and are tabulated in Appendix 4.3. The selected watershed-wide goal provides consistency with the *Sediment Reduction Strategy...* (MPCA 2015h), which identifies a baseline 2000 to 2010 FWMC of 116 mg/L and calls for a 25% reduction by 2020, 50% reduction by 2030, and 80% reduction by 2040 from the Minnesota River.

The 10-year target selected by the WRAPS Local Work Group is a 4% reduction in TSS. 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.

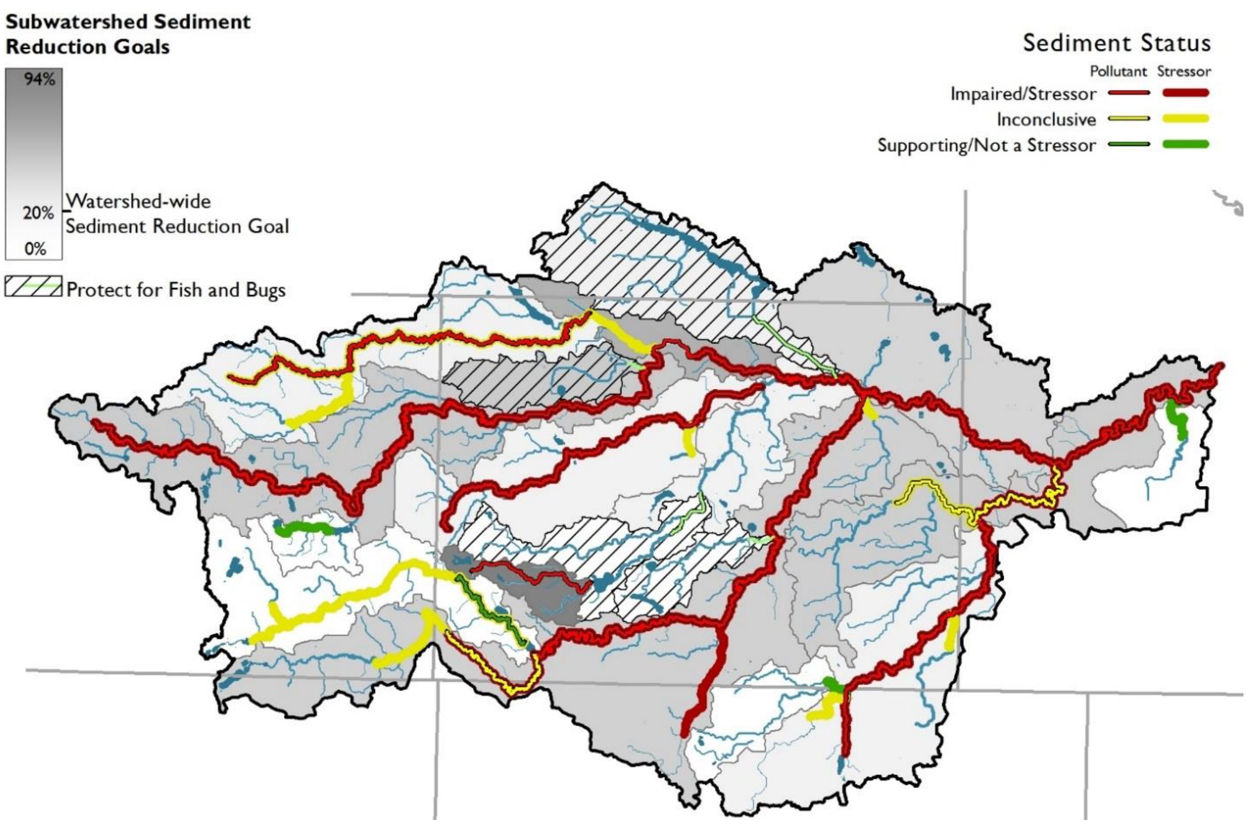


Figure 32: The watershed-wide sediment goal for the Watonwan River Watershed is a 20% reduction. Subwatershed goals range from protect to a 94% reduction.

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 concentrations impact aquatic life by limiting respiration, which contributes to stress and disease and can result in reduced growth or death.

Status

Of the stream reaches monitored to assess if DO meets standards, none were impaired, 13 were supporting, and four were inconclusive. Of the bio-impaired stream reaches, DO as a stressor was identified in 1, ruled out in 8, and inconclusive in 21. Figure 33 illustrates the stream reaches assessed for DO and Table 15 tabulates those results.

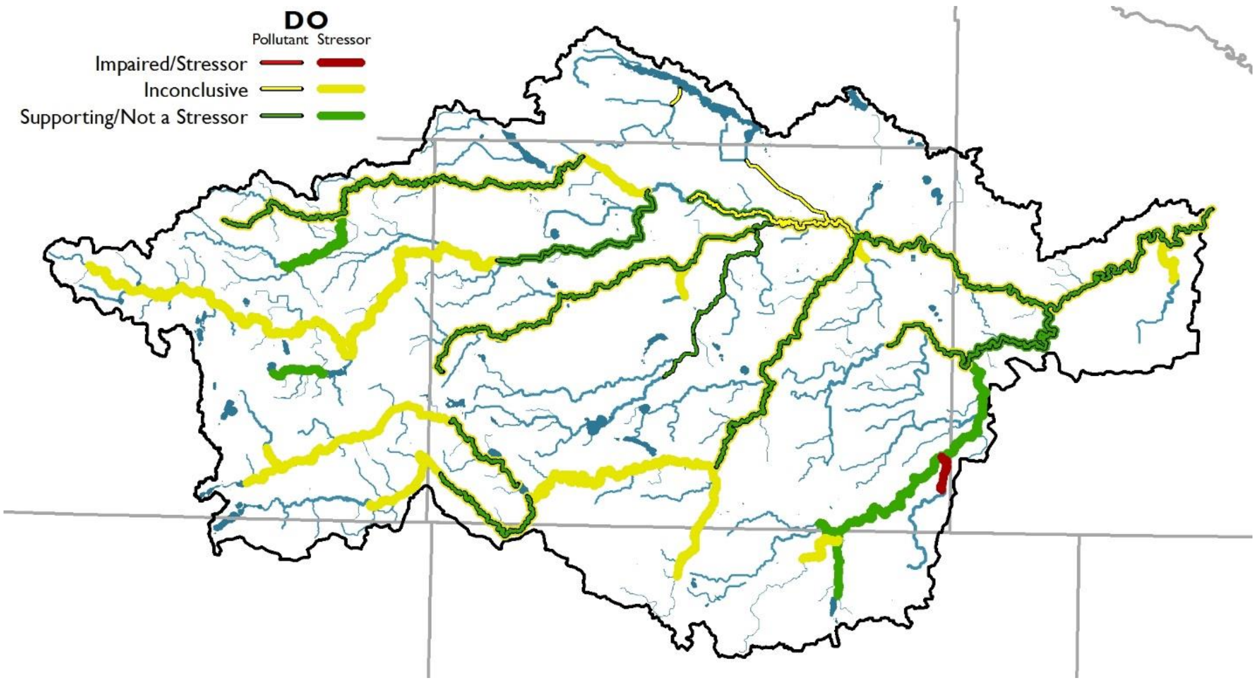


Figure 33: Stream reaches in the Watonwan River Watershed tend to be inconclusive or supporting DO standards. Stream reaches assessed for low DO and the assessment results are indicated by color. Red indicates an impairment or a stressor (low DO is problematic in that reach), and green indicates DO is supporting the standard or not a stressor (DO is not problematic in that reach). The results for the pollutant assessment overlay the results for the stressor assessment, with the pollutant results showing in the inside and stressor results showing around the outside.

Table 15: Assessment results for DO as a pollutant and/or stressor in Watonwan River Watershed stream reaches.

Stream	Reach (AUID-3)	DO as a Stressor	DO as a Pollutant (Class 2)	DO as a Pollutant (Class 7)
Watonwan River	501	?	+	
St James Creek	502			+
Unnamed Creek	505	+		
Watonwan River	510	?	+	
Watonwan River	511	?	?	
St James Creek	515			+
Butterfield Creek	516	?	+	
Watonwan River	517	?	+	
Perch Creek	523	+	+	
Perch Creek	524	+		
Unnamed Creek	526	x		
Spring Brook	540	?		

Stream	Reach (AUID-3)	DO as a Stressor	DO as a Pollutant (Class 2)
Judicial Ditch 5	542		?
Unnamed Ditch	545		?
Watonwan River	547	?	
Unnamed Creek	549	+	
Unnamed Creek	552	?	
Unnamed Creek	557	+	
County Ditch 78	559	?	
Unnamed Creek	561	?	
Watonwan River	563	+	?
Watonwan River	564	?	+
Watonwan River	565	?	
Watonwan River	566	?	

Stream	Reach (AUID-3)	DO as a Stressor	DO as a Pollutant (Class 2)
Watonwan River	567	+	+
Watonwan River	568	?	+
Watonwan River	569	?	
Willow Creek	571	?	
Spring Branch Creek	574	?	+
St James Creek	576		+
Mink Creek	577	?	
Judicial Ditch 1	579	?	
Judicial Ditch 1	580	?	
Judicial Ditch 1	581	?	+
Unnamed Creek	583	+	

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

Sources

Low DO in water bodies is caused by: 1) excessive oxygen use, which is often caused by the decomposition of algae and plants, whose growth is fueled by excess P and/or 2) too little re-oxygenation, which is often caused by minimal turbulence due to low flow or high water temperatures. Low DO levels can be exacerbated in over-widened channels because these streams move more slowly and have more direct sun warming. Likewise, channels with degraded riparian vegetation lack cover and are susceptible to excessive warming.

Goal & 10-year Target

Because DO is primarily a response to other stressors, the effective watershed-wide goal and 10-year target for DO are to meet the altered hydrology, P, and habitat goals. The reach-specific goal for DO is to reach the minimum standard of 5 mg/L and for diurnal DO flux to be less than 4.5 mg/L. 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, P, and habitat are summarized in Section 3.

Phosphorus

P is a nutrient that fuels algae and plant growth. While not directly harmful to aquatic life, excess P can lead to excessive algae growth and eutrophication (Nature 2013). These responses to excess P affect aquatic life by changing food chain dynamics, affecting fish growth and development, and decreasing DO when algae/plant growth decomposes. P also affects 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 P as a pollutant or stressor, eutrophic conditions must be observed in addition to high P concentrations. Furthermore, a high P concentration does not always result in eutrophic conditions. While a watershed with high P concentrations may not have eutrophic response, a downstream receiving water body may show a eutrophic response. Therefore, regardless of whether eutrophication is present, high P concentrations are concerning.

Status

Of the lakes that were monitored to determine if P is a pollutant, four were impaired, two were supporting, and nine were inconclusive. Of the bio-impaired stream reaches, P as a stressor was identified in 1 and inconclusive in 29. Figure 34 illustrates the stream reaches and lakes that were assessed for P. Table 17 tabulates lake status results along with lake transparency trends, and Table 16 tabulates stream status results.

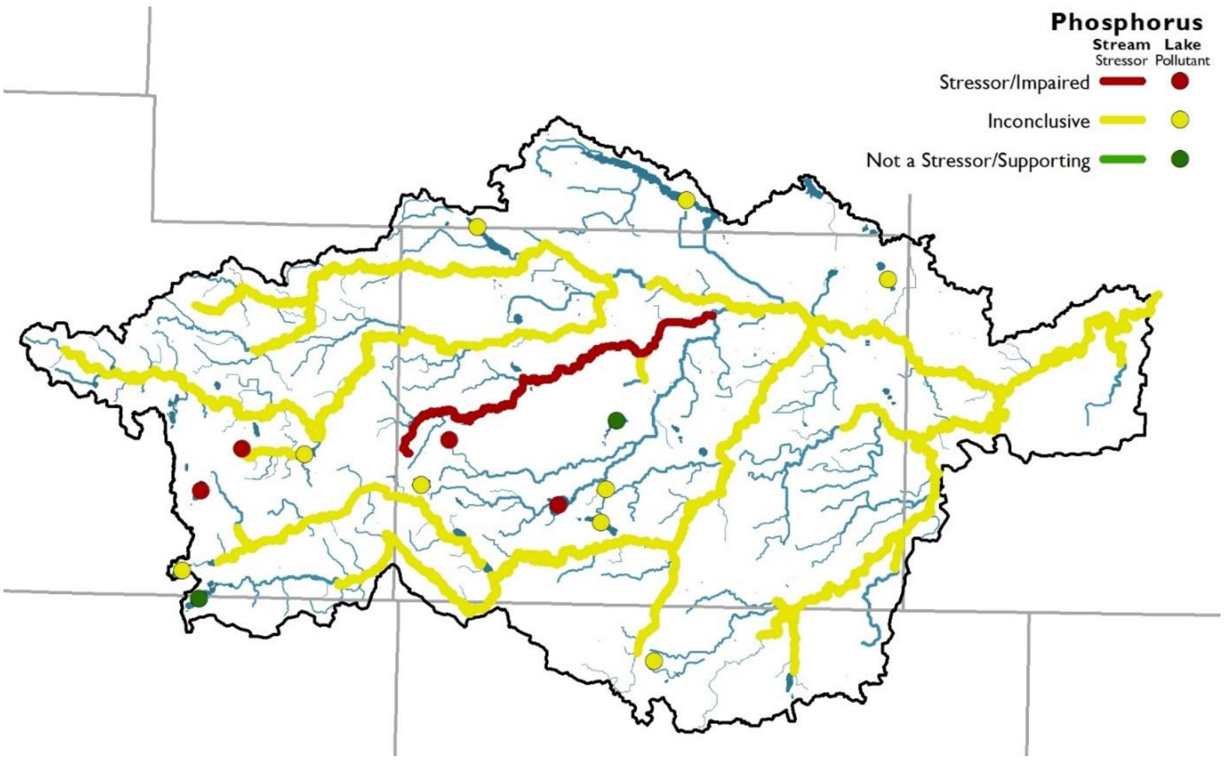


Figure 34: Eutrophic conditions have only been observed in four lakes in the watershed, resulting in four impairments for eutrophication/TP. Streams and lakes assessed for eutrophication/TP and the assessment results are indicated by color. Red indicates an impairment or a stressor (TP is problematic in that reach/lake), and green indicates TP is supporting the standard or not a stressor (TP is not problematic in that reach).

Table 17: Assessment results for eutrophication/P as a pollutant and transparency trends in Watonwan River Watershed lakes.

Lake Name	Lake ID	Eutroph/Phos Assessment	Transparency Trend	Lake Name	Lake ID	Eutroph/Phos Assessment	Transparency Trend	Lake Name	Lake ID	Eutroph/Phos Assessment	Transparency Trend
Hanska	08-0026-00	?	x	Fish (Main)	32-0018-03	+	+	Long	83-0040-00	?	-
Mountain	17-0003-00	?	-	Round	46-0084-00	?	?	St. James	83-0043-00	+	+
Bingham	17-0007-00	x	-	Fedji	83-0021-00	?	?	Sulem	83-0051-00	?	?
Three	17-0012-00	?	?	Mary	83-0035-00	?	?	Butterfield	83-0056-00	x	?
Eagle	17-0020-00	x	?	Kansas	83-0036-00	x	?	Wood	83-0060-00	?	?

+ = supporting/not a stressor/improving trend
? = inconclusive (need more data)
x = impaired/stressor/declining trend
- = no trend detected

Table 16: Assessment results for eutrophication/P as a stressor in Watonwan River Watershed stream reaches.

Stream	Reach (AUID-3)	Eutroph/Phos Assessment	Stream	Reach (AUID-3)	Eutroph/Phos Assessment	Stream	Reach (AUID-3)	Eutroph/Phos Assessment
Watonwan River	501	?	Watonwan River	547	?	Watonwan River	567	?
Unnamed Creek	505	?	Unnamed Creek	549	?	Watonwan River	568	?
Watonwan River	510	?	Unnamed Creek	552	?	Watonwan River	569	?
Watonwan River	511	?	Unnamed Creek	557	?	Willow Creek	571	?
Butterfield Creek	516	x	County Ditch 78	559	?	Spring Branch Creek	574	?
Watonwan River	517	?	Unnamed Creek	561	?	Mink Creek	577	?
Perch Creek	523	?	Watonwan River	563	?	Judicial Ditch 1	579	?
Perch Creek	524	?	Watonwan River	564	?	Judicial Ditch 1	580	?
Unnamed Creek	526	?	Watonwan River	565	?	Judicial Ditch 1	581	?
Spring Brook	540	?	Watonwan River	566	?	Unnamed Creek	583	?

From a statewide perspective, the Watonwan River Watershed's P concentrations and yields are high (Figure 36). From 2007 through 2015, the FWMC of TP in the Watonwan River was 0.25 mg/L. Despite a lack of eutrophic conditions (as represented in the conditions discussed above), the Watonwan River is supplying excessive P to downstream waters that are impaired (e.g. Lake Pepin).

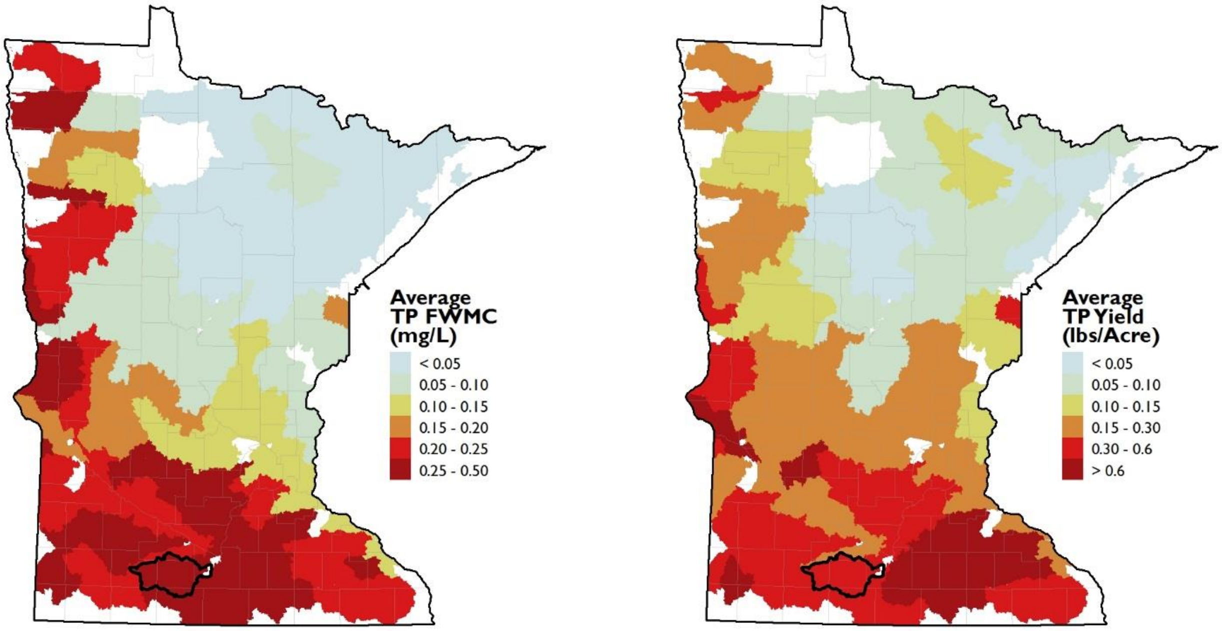


Figure 36: The Watonwan River Watershed has a high FWMC and yield of TP compared to the rest of the state. Data are from the WPLMN.

The HSPF models estimated TP FWMCs for the years 1996 through 2012 are illustrated in Figure 35. This model output can be used to estimate conditions in stream reaches that have not been monitored.

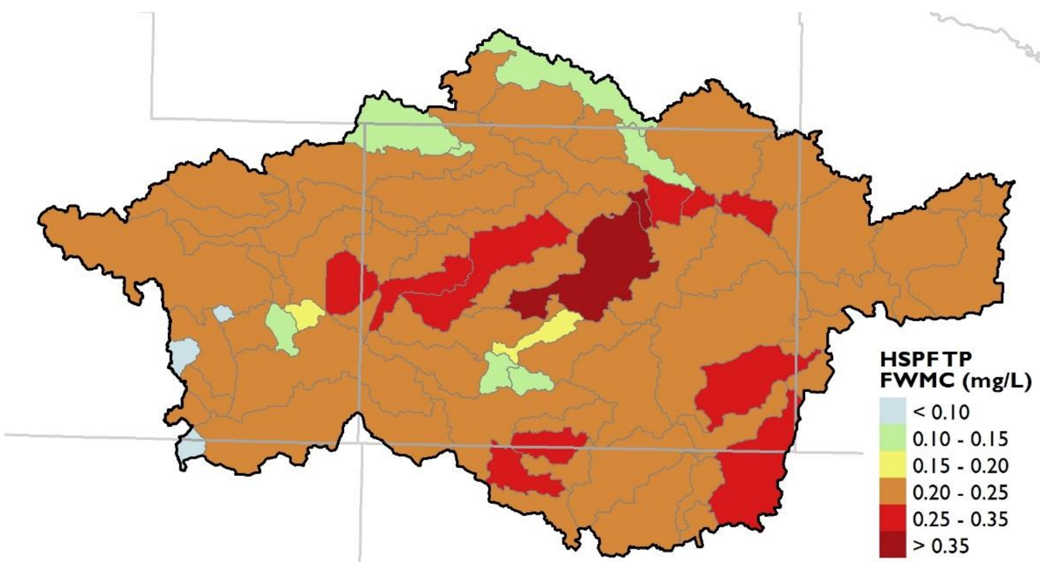


Figure 35: HSPF model output indicate that the FWMC P concentrations are roughly similar through much of the watershed, with notable exceptions. The highest modeled concentrations were found in St. James Creek. The presented model output are from years 1996-2012.

Sources

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

A numeric estimate of the Watonwan River Watershed's P sources is presented in Figure 37; refer to the Sources Overview in Section 0 for more details. Crop surface runoff and drainage tile were estimated to be the largest sources of P. Most of the P leaving agricultural fields is likely due to agricultural activities that include fertilizer and manure application (calculations in Appendix 4.2).

Internal lake P loads are not explicitly accounted for in the source assessment. Internal lake loads are a product of excessive, legacy P 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 in developing the specific strategies to address the impairment. Planners should consult the TMDL or additional lake modeling or studies to estimate the internal load accordingly.

According to the SID analysis, the only stream reach stressed by eutrophic conditions (Butterfield Creek) experiences classic P-driven conditions, resulting in excess algae (Table 18).

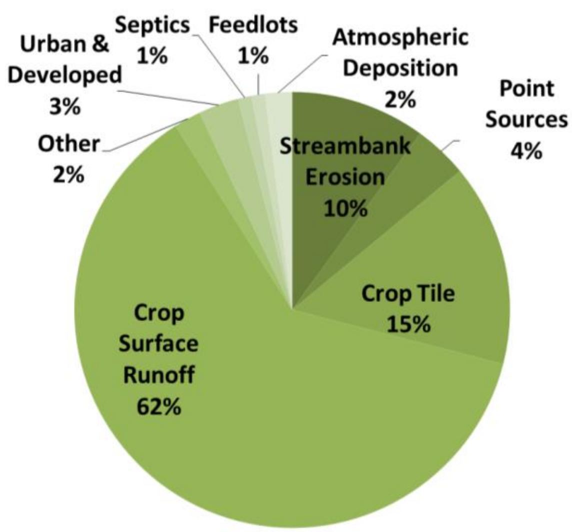


Figure 37: The P source assessment for the Watonwan River Watershed estimates that crop surface runoff is the largest contributor of P, although many sources are present. The P leaving crops is mostly from applied fertilizer or manure.

Table 18: Excess P was identified as the driver of eutrophication in Butterfield Creek in the SID report.

Stream	AUID	Excess Phosphorous	Algae/ Plant Shift
Butterfield Creek	516	x	x

x = likely source or driver

Goal & 10-year Target

The watershed-wide goal for P in the Watonwan River Watershed is a 40% reduction (**Figure 38**). The watershed-wide goal was set after reviewing P data from lakes and streams in the watershed, TMDL information, model output, and the *Minnesota Nutrient Reduction Strategy* (MPCA 2013c) goals. Streams should achieve a maximum FWMC of 0.15 mg/L, and lakes should achieve a maximum summer mean of 0.09 mg/L. Lake P reduction goals were calculated where TMDL data were available and vary from a 47% reduction to a protection goal in Fish and St. James lakes. Refer to the TMDL summary in Appendix 0 for a tabulated summary of lake reduction goals.

The 10-year target selected by the WRAPS Local Work Group is a 5% P reduction in streams and a 10% P reduction in lakes. Strategies to meet the goals and 10-year targets and methods to prioritize regions for P reductions are summarized in Section 3. These goals are revisable and will be revisited in the next iteration of the Watershed Approach.

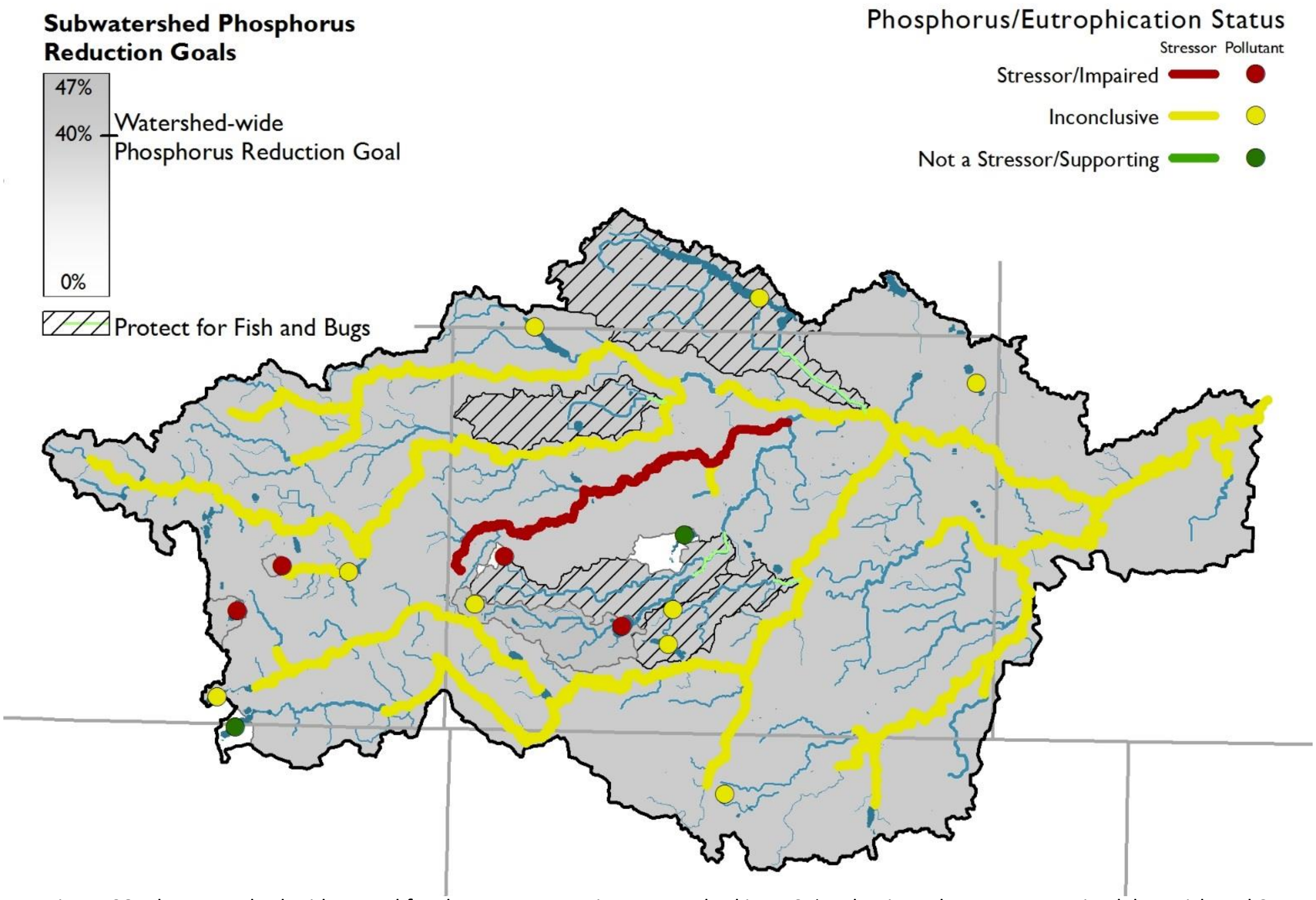


Figure 38: The watershed-wide **P** goal for the Watonwan River Watershed is a 40% reduction. The two supporting lakes, Fish and St. James, have protection goals, illustrated by their white subwatersheds.

Fecal Bacteria

Fecal coliform and *E. coli*, referred to in this report as bacteria, are indicators of animal or human fecal matter, which may contain pathogens. Fecal matter can make aquatic recreation unsafe because contact with fecal matter can lead to potentially severe illnesses. Fecal bacteria are living organisms unlike most other water quality parameters. Because bacteria can reproduce or die-off in the environment, this parameter's dynamics can be more challenging to understand.

Status

Of the 18 stream reaches monitored to assess if bacteria is a pollutant, 17 were impaired and 1 was supporting. Figure 39 illustrates the stream reaches assessed for bacteria, and Table 19 tabulates those results.

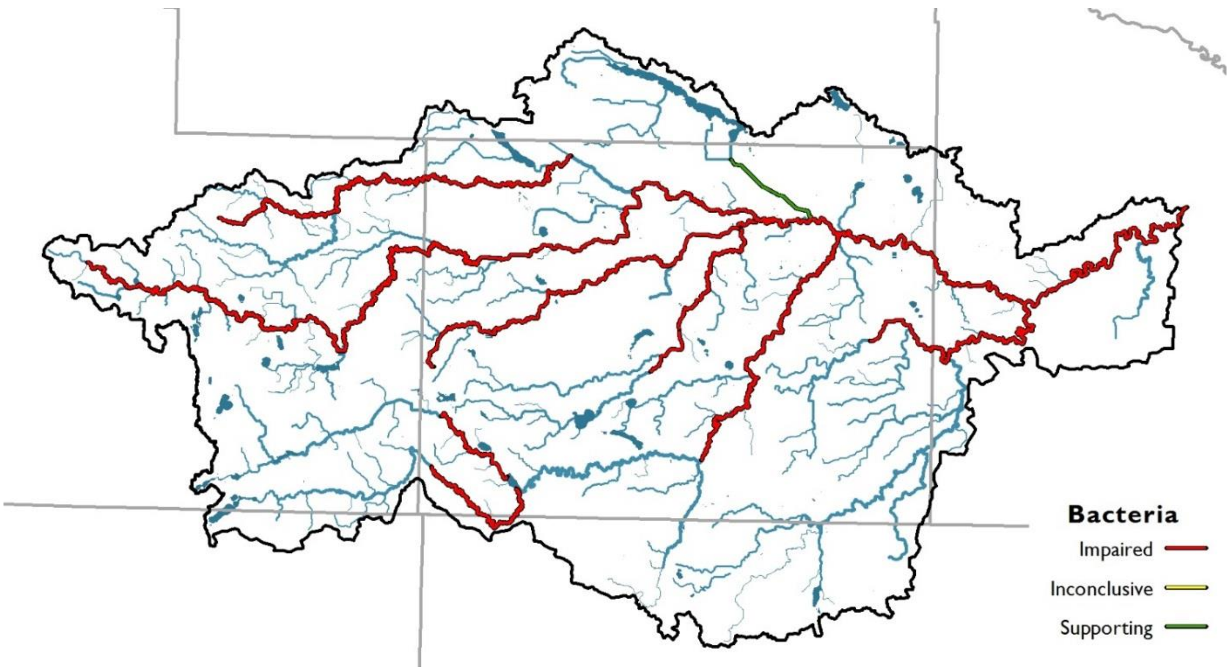


Figure 39: Stream reaches assessed for fecal bacteria and the assessment results are indicated by color. Red indicates an impairment (bacteria is problematic in that reach), and green indicates bacteria is supporting the standard (bacteria is not problematic in that reach).

Table 19: Assessment results for bacteria as a pollutant in Watonwan River Watershed stream reaches.

Stream	Reach (AUID-3)	Bacteria Class 2 Assessment	Bacteria Class 7 Assessment	Stream	Reach (AUID-3)	Bacteria Class 2 Assessment	Stream	Reach (AUID-3)	Bacteria Class 2 Assessment
Watonwan River	501	x		Watonwan River	517	x	Watonwan River	566	x
St James Creek	502		x	Perch Creek	523	x	Watonwan River	567	x
Watonwan River	510	x		Unnamed Ditch	545	+	Watonwan River	568	x
Watonwan River	511	x		Watonwan River	562	x	Spring Branch Creek	574	x
St James Creek	515		x	Watonwan River	563	x	St James Creek	576	x
Butterfield Creek	516	x		Watonwan River	564	x	Judicial Ditch 1	581	x

+ = supporting
x = impaired

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.

Sources

Specific source assessment of fecal bacteria is difficult due to the dynamic and living attributes of bacteria. Emmons & Olivier Resources (2009) conducted a *Literature Summary of Bacteria* for the MPCA. The literature review summarized factors that have either a strong or a weak positive relationship to fecal bacterial contamination in streams (Table 20).

Table 20: 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

Bacteria are able to survive and reproduce in streams as reported in Chandrasekaran et al., 2015. This study traced substantial numbers of bacteria to cattle sources, while no samples could be traced to human sources. The authors postulated that bacteria could be reproducing in the study region, but the amount of sampled bacteria that was from in-stream reproduction versus recent bacteria contamination was not determined. In order to acknowledge this source type, but without certainty, the Local Work Group assigned 10% of the watershed's bacteria population to environmental propagation; however, it should be noted that this value is currently not well-understood.

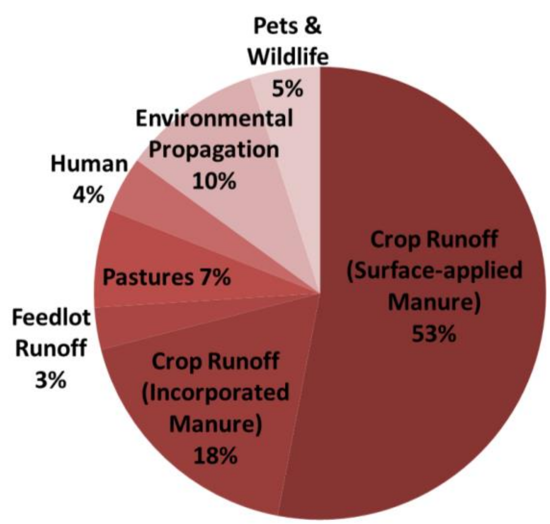


Figure 40: Source assessment work estimates that runoff from crops where manure is applied is the largest bacteria source in the Watonwan River Watershed.

A numeric estimate of the Watonwan River Watershed's fecal bacteria sources are presented in Figure 40. This source assessment was estimated by the WRAPS Local Work Group with the use of a bacteria calculator (Appendix 4.2). The single largest fecal bacteria source is from crop runoff from surface-applied manure.

Most of the manure that is applied to fields originates from feedlot operations. Refer to the Sources Overview in Section 0 for more information on feedlots in the Watonwan River Watershed.

Goal & 10-year Target

The watershed-wide goal for bacteria in the Watonwan River Watershed is 65% reduction (Figure 41), to a mean monthly geomean of 126 cfu/mL in stream bacteria. The 10-year target selected by the WRAPS Local Work Group is a 10% reduction in stream bacteria. The subwatershed goals range from protection in the Lake Hanska Watershed to an 84% reduction in the South Fork Watonwan River and St. James Creek. Refer to the TMDL summary in Appendix 4.3 for a table of subwatershed reductions goals.

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.

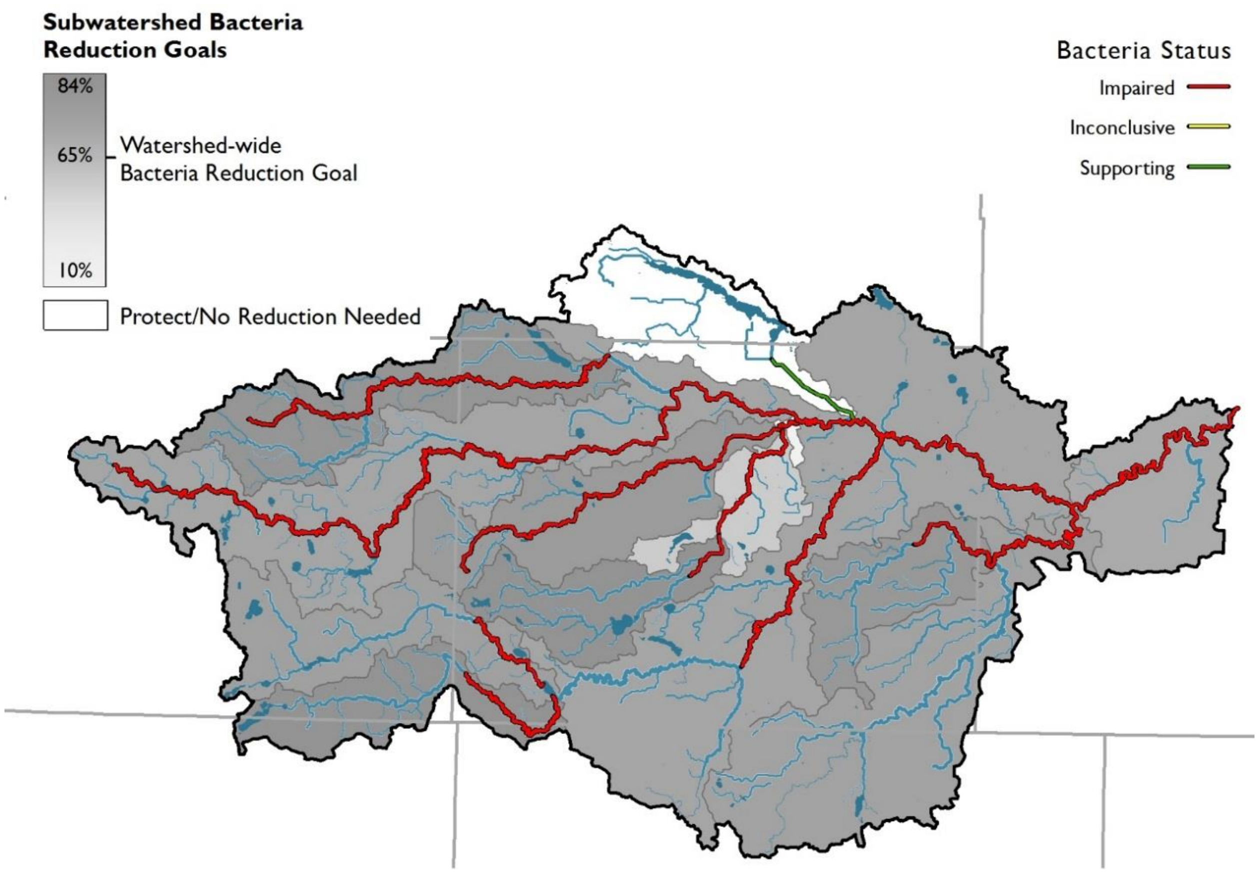


Figure 41: The watershed-wide reduction goal in the Watonwan River Watershed is a 65% reduction. The Lake Hanska subwatershed was meeting standards and should be protected.

3 Restoration and Protection

This section presents a summary of scientifically and socially supported strategies to restore and protect waters, “Strategies Tables”, and a “Priorities Table”. The content in these tables was primarily developed by the WRAPS Local Work Group. The Strategies Tables provide high-level information on the changes necessary to restore and protect waters within the Watonwan River Watershed. The Priorities Table provides subwatersheds that are high priority using various water quality and multiple benefits prioritizing criteria. These two high-level tools, along with civic engagement project findings, should provide a launching board for local water resource planning.

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. Supplementary and detailed information relevant to this section is included in Appendix 4.4.

To address the widespread water quality impairments, comprehensive and layered BMP suites are likely necessary. This comprehensive and layered BMP adoption represents a paradigm shift in land management, particularly in the agricultural lands that dominate the Watonwan River Watershed. However, these same principles should be applied to all land uses.

A conceptual model displaying this layered approach is presented by Tomer et al. (2013; Figure 42). 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.

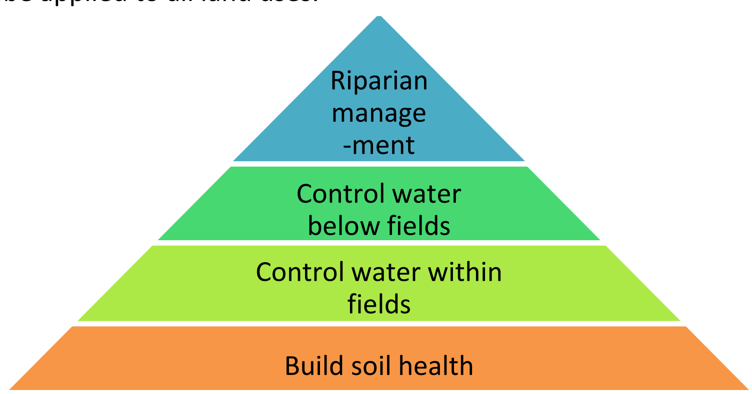


Figure 42: This conceptual model to address water quality in agricultural watersheds uses 1) soil health principles as a base: nutrient management, reduced tillage, crop rotation, etc., then 2) in-field water control: grassed waterways, controlled drainage, filter strips, etc., then 3) below-field water controls: wetlands, impounds, etc., and then 4) riparian management: buffers, stabilization, restoration, etc.

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.

Agricultural BMPs

Since the Watonwan River Watershed land use and pollutant sources are generally dominated by agriculture, reducing pollutant/stressor contributions from agricultural sources is critical to water resources restoration. A comprehensive resource for agricultural BMPs is the *Agricultural BMP Handbook for Minnesota* (MDA 2017b). Hundreds of field studies of agricultural BMPs are summarized in the handbook. 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 0.

Urban and Residential BMPs

The *Minnesota Stormwater Manual* (MPCA 2014b) is a comprehensive resource for urban and residential BMPs. This resource is in electronic format and includes links to studies, calculators, special considerations for Minnesota, and links regarding industrial and stormwater programs. In addition to Stormwater, failing and unmaintained septic systems can pollute waters. Information and BMPs for Septic Systems is provided by EPA (2014b).

Stream and Ravine Erosion Control

By-and-large, wide-scale stabilization of eroding streambanks and ravines is cost-prohibitive. Instead, first addressing altered hydrology (e.g. excessive, concentrated 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 *Minnesota River Basin Sediment Reduction Strategy* (MPCA 2015h). Improving activities directly adjacent the stream/ravine (e.g. buffers) can also decrease erosion as summarized in *The River Restoration Toolbox* (IA DNR 2018). In some cases, however, high value property may need to be protected, or a ravine/streambank may be experiencing such severe erosion that stabilizing the streambank or ravine is deemed necessary.

Lake Watershed Improvement

Strategies to protect and restore lakes include both strategies to minimize pollutant contributions from the watershed and strategies to implement adjacent and in the lake (refer to summary in Appendix 0). 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 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, HSPF, and other scenarios are summarized in the Model Summary Table in Appendix 0.

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.

3.2 Social Dimension of Restoration and Protection

Most of the changes that must occur to improve and protect water resources are voluntary; therefore, communities and individuals ultimately hold the power to restore and protect waters in the Watonwan 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 water body 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. With these factors in mind, a comprehensive civic engagement plan was developed, implemented, and reported for use in follow-up planning and implementation work.

Project Development

The broad goal of the Watonwan River Watershed Civic Engagement Project was to better understand connections and concerns around water, the drivers of and constraints to conservation adoption, and develop locally-identified solutions to facilitate higher conservation adoption. The Water Resources Center, Minnesota State University, Mankato (MSUM) worked with the Greater Blue Earth River Basin Alliance (GBERBA) and local conservation partners to create a network of citizens and conservation staff that provided solutions to improve conservation delivery and watershed health. The insights and strategies from this group should be used to shape conservation planning and delivery.

A planning team of MSUM and MPCA staff met frequently at the outset of the project to frame the approach. The team met with local County, SWCD, and State conservation professionals to support and build upon existing local efforts and gauge interest in participation with project activities. Subsequent meetings helped to refine the approach and discuss current public participation efforts, ideas for engaging citizens, and learn about the community leaders, connections, and networks in the watershed. Training opportunities were developed by the University of Minnesota (U of M) Forestry Resources on social science methods for interviews and focus groups. Additional meetings with local staff provided opportunities for updates, brainstorming, improving interview work, story building, and prioritizing areas of interest.

Activities

Several activities were undertaken to achieve the goals of the project. Existing partnerships and community initiatives were leveraged to optimize resources. Activities are summarized below.

Citizen Interviews

One-on-one interviews of watershed citizens helped to understand, frame, and communicate resource issues from a landowner's perspective. The planning team developed an interview template with assistance from U of M. The primary interview audience was farmers and landowners, and the primary interview content was their cultural outlook and values. Interview transcripts were analyzed and coded to distill key themes to help frame and focus citizen outreach efforts. The information was compiled, analyzed, and summarized to gather key points and help to better understand community assets, informal and formal networks, and individual and collective interests in order to build community readiness for future planning and implementation work.

Local Leader Interview Videos

Project staff interviewed and videoed watershed landowners who successfully completed conservation projects or who manage land with water resource protection goals. The goal of the videos was to share locally identified practices to improve water quality and provide peer-to-peer learning. Interviewees included farmers, business owners, a SWCD supervisor, a crop advisor, and local conservation staff.

City Staff Meetings

Two meetings were held with staff and elected officials from watershed cities. Meetings focused on identifying shared concerns in water management and infrastructure and to learn from effective regional case studies. Additionally, phone interviews of city staff were done to better understand their challenges related to water and infrastructure. A follow-up meeting focused on funding opportunities for rural infrastructure and water improvements and bringing city staff and elected officials from across the watershed together.

Sportsmen's Focus Groups

A focus group was targeted to the Madelia Sportsmen Group, which was identified as an active and effective conservation/recreation group in the watershed. The initial focus group interview gathered input on their perception of the river and conservation adoption challenges. Follow-up meetings were arranged to solicit advice about how to gain citizen interest in conservation work.

Groundwater Meeting

Through the interview process, groundwater was identified as a high priority concern in the watershed. Based on this, additional meetings were provided to better understand concerns, provide data, and brainstorm solutions. The meeting identified information gaps and next steps citizens could take to protect groundwater in the region.

Community Conversations

Community members and conservation partners from across the watershed were convened in a series of meetings to discuss water quality concerns and conservation adoption solutions. Research information was shared with the group, including landowner interview results and watershed scientific investigations. The group identified numerous innovative ideas that could help to "move the needle" towards more conservation adoption.

Open House Meetings

Open house meetings were held in the cities of Madelia, St. James, Mountain Lake, Lewisville, and Darfur. The goal of these meetings was to share the ideas developed throughout the project with other interested community members from across the watershed. Citizens had the opportunity to learn more about the health of area rivers and lakes, learn about the results of interviews and focus groups, and hear and discuss the strategies developed in the community conversations.

Soil Health Events

Two soil health education events occurred in the watershed. Natural Resources Conservation Service (NRCS) organized a "Cover Crop and Soil Health Field Day" near Bingham Lake. The agenda included economics of soil health, producer perspectives in the Watonwan River Watershed, a rainfall simulator, a producer panel discussion, and an overview of the Watershed Approach and water quality issues in the watershed. Producers from the region shared about the opportunities and challenges associated with soil health practices. A "Soil Health Information Day" was arranged at the St. James American Legion. The half-day session included an overview of the program "Profit Zone Manager" and a local farmer panel discussing cover crops, reduced tillage, and soil health practices. Event partners included local SWCDs, NRCS, Pheasants Forever and the Water Resources Center.

Results and Conclusions

The Watonwan River Watershed Civic Engagement Project used social science principles and several different activities to identify how citizens across the Watonwan River Watershed connect with water, perceive water problems, and prioritize water issues. Several summary documents were created to share more broadly with community members and local decision makers for use in future watershed planning. Products developed include summaries of interviews, focus groups and public meetings, interactive story maps, videos, animations, and infographics and are available at the Watonwan River Watershed Network website (WRC 2018). The summary reports include Land Management Practices Leverage Points for Conservation Adoption, and Conservation Challenges and Solution Strategies. A high-level summary of the recommendations from these reports is as follows:

More Conservation Outreach: Create a "Traveling Conservation Circus." The vision is to have a trailer that has a rainfall simulator, soil-testing equipment and other BMP and watershed information. Conservation partners would travel across the watershed and host events in big and small towns and on farms.

Promote Soil Health: Form Soil Health Team (like that of Freeborn County).

Leverage Ditch Improvement Projects: Map and identify upcoming ditch improvement projects and see if it is possible to get more water storage as part of the improvement process.

Target Conservation with GIS Mapping: Use a more systematic approach to target conservation and identify high priority areas. Use GIS mapping programs like the Agricultural Conservation Planning Framework (ACPF) to create targeted maps at field and/or subwatershed scale.

Focus on Marginal Lands: Use Profit Zone Manager or another program to help identify long-term economics of farming marginal ground. What will it take to set these lands aside? Get the message out: "Don't farm lands that don't pay; square off the fields."

Clarify Barriers to Conservation Adoption: Explain local partner needs and barriers. The group identified the lack of engineering services available, the need for staff stability and funds for staff training. Inform local, state, and federal partners about barriers to conservation adoption. Share information and documents with local government, state and federal legislators.

Clarify Economics: Explain the economics of BMPs and clarify costs for landowners. Explain that conservation practices can make farming easier and less stressful.

3.3 Restoration and Protection Strategies

The presented strategies tables show the types of practices and associated adoption rates estimated to meet: A) the full water quality goals (Table 21) and B) 10-year water quality targets (Table 22) for the Watonwan River Watershed. The strategies need to be refined in local planning processes to determine specific locations and means to get these types of strategies "on the ground".

Strategies Table A (Table 21) summarizes the water quality conditions, goals, and high-level strategies and adoption rates at the watershed scale. The basis for these goals was derived from the Model Summary presented in Appendix 4.4 and best professional judgement. Recommending specific suites of practices capable of cumulatively achieving all water quality goals is not practical. Challenges including the vast amount of change needed to meet water quality goals and the needed changes in technologies, programs, markets, and other whole-scale drivers will likely result in this work taking decades. Instead, high-level, narrative strategies and adoption rates were deemed more practical.

Strategies Table B (Table 22) presents specific strategies and numeric adoption rates estimated to meet the 10-year water quality targets along with the responsible parties. This strategies table is intended to be more helpful for local planning efforts, which typically work on a 10-year revision schedule. These strategies were proposed and ranked (highest to lowest adoption) by the WRAPS Local Workgroup. The numeric adoption rates were then calculated to meet the 10-year water quality targets, using the developed source assessment, with a spreadsheet tool (notes and assumptions in Appendix 4.4) and reviewed to ensure consistency with computer model information (Model Summary in Appendix 4.4).

The presented strategies need to be implemented across the watershed, in all subwatersheds with impaired water bodies or supporting water bodies with declining trends (any area shown in gray in the goals maps presented in Section 2.2). However, the adoption rates in any one region will not necessarily match the watershed-wide adoption rates due to regional differences. Furthermore, not all strategies are appropriate for all locations. The strategies and regional adoption rates need to be customized during local planning efforts.

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 in Table 21 and Table 22, set at the major watershed scale, are intended to not only restore, but also protect waters in the Watonwan 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 Watonwan River Watershed include:

- Mitigate alterations to hydrology by adding storage, infiltration, and ET. Effectively, this means improving soil health so that there is more organic matter in the soil to hold water; mitigating on-site when possible like adding a wetland/pond to intercept and infiltrate water from a new tile drainage project; and adding more living vegetation to the landscape in early summer and late fall by using cover crops, diversifying crops, 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.
- Maintain perennial vegetation on the landscape, especially adjacent water bodies, in areas with high slopes, and in areas with highly-erodible soils.

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 Watonwan River Watershed is groundwater – either from private wells, community wells, or a rural water supplier.

The communities of Darfur, LaSalle, St. James, and Mountain Lake have vulnerable drinking water systems that indicate a connection and influence from surface water in the watershed. Red Rock Rural Water's Lake Augusta wellfield is also highly vulnerable but is on the edge of the Watonwan River Watershed, therefore only encompassing a small portion of that drinking water supply area in the Watonwan River Watershed. Contaminants on the surface can move into the drinking water aquifers more quickly in these areas. The communities of Madelia and Truman 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.

3.4 Priority Areas

Conservation implementation plans (i.e. *One Watershed, One Plan* [1W1P; BWSR 2014b] or EPA CWA Section 319 work plans, etc.) that are developed subsequent to the WRAPS report should ***prioritize*** and ***target*** the strategies and set ***measurable*** goals. Figure 43 (BWSR 2014a) represents the prioritized, targeted, and measurable concepts. A broad list of tools for prioritizing and targeting work is in Appendix 4.4.

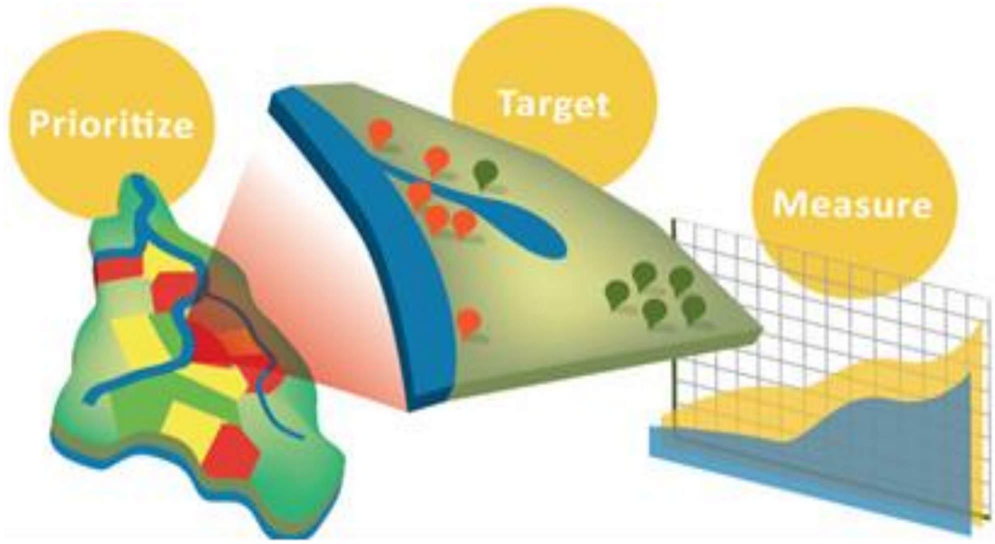


Figure 43: "Prioritized, targeted, and measurable" plans are more likely to improve water quality and have a better chance to be funded compared to those that are less strategic.

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 throughout, such as the goals maps, the HSPF model maps, and the GIS estimated altered hydrology maps. These and additional priority areas are summarized in Table 23. These priorities were developed in conjunction with the WRAPS Local Work 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.

Table 21, Strategies Table A: This portion of the strategies table summarizes the conditions, goals, 10-year targets, proposed years to reach the goals, and the strategies and estimated adoption rates needed to achieve the goals. 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 in the Watonwan River Watershed, and the SID and Geomorphology/Hydrology reports. Strategies, practices, specific adoption rates, and responsibilities to meet the 10-year targets are identified in Table 23.

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 24 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.
Habitat	▪30 stream reaches stressed ▪Likely stressor of lake aquatic life	Aquatic life populations are not stressed by lack of habitat.	35% increase in MSHA habitat score	12% ↑	75	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. Altered hydrology and sediment are addressed.
Altered Hydrology	▪20 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 creating problems with other parameters (habitat, sediment, nitrogen, phosphorus, etc.).	25% reduction in peak & annual river flow	4% ↓	45	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	15	
Nitrogen	▪15 stream reaches stressed/impaired ▪3 stream reaches not stressed ▪Nitrogen reductions needed to meet downstream needs	Aquatic life populations are not stressed by nitrogen. Support statewide and downstream reduction goals.	70% reduction in river concentrations/loads	15% ↓	65	All croplands improve soil health by decreasing/improving 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.
Sediment	▪16 stream reaches stressed/impaired ▪5 stream reaches not stressed/supporting ▪Sediment reductions needed to meet downstream needs	90% of stream concentrations are below 65 mg/L. Aquatic life populations are not stressed by sediment.	20% reduction	4% ↓	45	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.
Connect-ivity	▪6 stream reaches stressed ▪13 stream reaches not stressed	Aquatic life populations are not stressed by human-caused connectivity barriers.	Address human-caused barriers as identified in SID and where practical	Replace 5% of culverts	45	Fish barriers are addressed.
Phosphorus / Eutrophication	▪ 1 stream reach and 4 lakes stressed/impaired ▪ 2 lakes supporting ▪Phosphorus reductions needed to meet downstream needs	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.	40% reduction in lake and stream concentrations/loads	Streams 5% ↓ Lakes 10% ↓	Streams 60 Lakes 35	All croplands improve soil health by decreasing/improving 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.
Bacteria	▪17 stream reaches impaired	Average monthly geomean of stream samples is below 126 cfu/100mL.	65% reduction in river concentrations/loads	12% ↓	65	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.
Parameters that are impacted/addressed by the above pollutants and stressors						
F-IBI & M-IBI	▪30 stream reaches impaired ▪5 stream reaches supporting	Aquatic life populations are measured and numerically 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	60	The above strategies are implemented.
DO	▪1 stream reach stressed/impaired ▪19 stream reaches not stressed/supporting	Stream concentrations are above 5 mg/L and DO flux is not excessive.				

Table 22, Strategies Table B (page 1 of 2): This table presents a suite of strategies and practices that are cumulatively capable of meeting the 10-year targets for the Watonwan 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 Table 24 for information on practices and relevant NRCS practice codes.

Land use/Source Type	**Watonwan 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/improve fertilizer use:** nutrient management, eliminate fall anhydrous application	25%	140,500			x	-				√		√			√		√					√		√	√		√	√		
	Add cover crops for living cover in fall/spring: cover crops on corn/beans, cover crops on early-harvest (canning) crops	10%	56,200	x	x	**X**	**X**	x	-		√		√			√		√							√	√		√	√		
	Decrease tillage: conservation tillage, no-till, strip till, ridge till	5%	28,100	-	-	-	**X**	x			√		√			√		√							√	√		√	√		
	Replace open tile intakes*: blind, rock, sand filter, perforated pipe riser, etc. intakes	2%	11,200	**X**			**X**				√		√		√	√	√	√							√				√		
	Diversify crops: conversion to pasture, small grains, perennial crops	1%	5,600	x	x	**X**	x	x	-		√		√			√		√							√	√		√	√		
	Reduce and treat cropland surface runoff*: water and sediment control basins, grade stabilizations, terraces, grassed waterways	1%	5,600	x	-	-	**X**	x			√		√			√		√						√	√	√		√	√		
	Reduce and treat cropland tile drainage*: Treatment wetlands, saturated buffers, bioreactors, controlled drainage	2%	11,200		-	**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%	2,800	**X**	**X**	**X**	**X**	**X**	**X**		√	√	√					√							√				√		
	Mitigate new ag drainage projects by adding sufficent practices to mitgate flow changes †	All new projects		n/a							√		√			√	√	√					√		√	√		√	√		
	Maintain existing BMPs, CRP, RIM, etc. †	All current BMPs		n/a							√		√			√		√					√	√	√	√			√	√	
	Targeted audience outreach (on specific topics): canning crop fields and manured fields (cover crops), landowners on proposed ditch improvement (integrating water storage/mitigating drainage projects), younger farmers (soil health, precision ag, other), all farmers (economics of nutrient management, cover crop support group), farmers with economically marginal and high-risk land (diversify crops/conversion to critical habitat, mitigating conservation practices), tools for farmers to estimate their fields impact/results of practice adoption	sufficient to achieve the physical strategies listed above		n/a							√		√			√	√	√			√		√	√	√	√	√	√	√	√	
	Available/paid staff time: to do targeting (identification of the above mentioned landscape opportunities and audience members) and outreach work																√	√			√		√	√	√	√	√		√	√	
	Market development: second crop, small grains, perrenials												√	√							√								√		
Feedlots	**Optimize manure storage**: rainwater diversion (prevent from entering manure storage system) to water source, feedlot manure storage addition, add farm infrastructure to achieve storage/runoff reduction goals (machinery, buildings, roads)	sufficient to reduce current contributions by 50%				√	√	√			√		√			√		√		√			√		√	√			√		
	Integrate livestock onto the landscape: transition confined livestock to pasture systems, smaller family operations					√	√	√			√		√	√		√		√		√			√		√	√			√		
	Reduce/treat feedlot runoff: feedlot runoff (vegetative) treatment					√	√	√			√		√			√		√		√			√		√	√			√		
	Optimize feedlot siting: increase distance between livestock and water, move feedlots out of sensitive areas					√	√	√			√		√			√		√		√			√		√	√			√		
	Education, outreach and build social norms to encourage producers to graze livestock, use one-on-one conservation consultant, educate neighbors/community	sufficient to achieve the physical strategies listed above		n/a							√		√	√		√		√		√	√		√		√	√	√		√		
	Target feedlot siting: Site feedlots based on manure application history/available non-manured land										√		√	√		√		√		√	√		√		√	√			√		
Manure Application	**Improve manure application and in-field utilization**: use cover crops on manured fields, manure sampling and ample land for proper application rates, impove placement/setbacks, equipment upgrades	1%	5,600		-	x	x	**X**			√		√			√	√	√		√			√	√	√	√		√	√	√	
	Education: educate producers and appliers on proper stockpiling, manure nutrient accounting, manure application timing and placement, how to use MDA runoff risk tool; educate neighbors/community	sufficient to achieve the physical strategies listed above		n/a							√		√			√		√		√	√		√		√			√	√		
Pastures	**Improve pasture/grazing management**: managed/rotational grazing, graze cover crops, remote watering facilities and fencing	0.1%	600	**X**			**X**	**X**			√		√					√		√				√	√				√	√	
	Restrict livestock access to water bodies: exclusions/fencing, watering facilities	0.1%	600	**X**			**X**	**X**			√		√					√		√				√	√				√	√	
	Marketing to consumers: grazed/free range meat, direct marketing using pastures	sufficient to achieve the physical strategies listed above		n/a									√	√		√							√	√					√	√	
	Education: on grazing and soil health practices										√		√			√		√		√	√		√		√			√	√		

* = 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" affect 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 22, Strategies Table B (page 2 of 2): This table presents a suite of strategies and practices that are cumulatively capable of meeting the 10-year targets for the Watonwan 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 Table 24 for information on practices and relevant NRCS practice codes.

Land use/Source Type	**Watonwan 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**: 16ft, 50ft, 100ft buffers and/or riparian tree planting on public water and public ditches	100% of stream/ditches have req'd buffer and 5% have wider	√	√	√	√	√	√		√	√	√		√	√	√	√	√					√	√			√	√		
	Reduce ditch impacts: reduce ditch clean-outs, install side-inlets, ditch improvements add water storage	100% of ditches reduce cleanouts. 100% of improvements include some water storage. Install erosion control projects where high priority.	√			√	√	√		√				√		√	√						√	√						
	Improve stream/ditch channels, banks, and habitat: re-meander channelized stream reaches, re-connect/restore flood plains, stream habitat improvement and management, streambank stabilization (where infrastructure is threatened)	On 60 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	5% of culverts replaced							√								√				√		√							√
	Collaborative targeting and planning: project and drainage improvement mapping/tracking, collaborative prioritizing, targeting, and planning stream restoration and subwatershed-scale plans	sufficient to achieve the physical strategies listed above																		√	√	√	√	√				√	√	√
	Education and outreach: demo and benefits of reducing ditch clean-outs targeting County Board, education on landuse change impact on flow change											√				√	√	√		√		√	√	√			√	√	√	√
	Staff time and resources: paid and available staff time for outreach work, more resources for drainage entity											√				√	√	√		√	√	√	√	√				√	√	
Lakes, wetlands, & shoreland	**Restore/protect shoreland**: stabilize/restore shoreline with vegetation, increase distance (buffer) between waterbody and impacts	On 4 lakes (~10%): assess and address shoreland and in-lake management where needed				√		√		√	√	√		√		√	√				√	√	√	√					√	√
	Manage in-lake: Drawdowns, internal load controls (dredging, alum, rough fish control) based on collaborative planning with fisheries					√		√			√	√					√					√	√	√			√		√	
	Regulations/zoning: enforce shoreland ordinance, develop shoreland ordinance in protection watersheds, educate variance decision-makers	sufficient to achieve the physical strategies listed above												√			√	√		√			√							
	Collaoartively develop lake restoration plans: including internal load studies, in-lake, shoreland, and upland needs										√	√		√		√	√	√		√			√						√	
	Education: landowners on shoreland practices, AIS prevention										√	√		√		√	√	√		√			√						√	
	Associations/networks: Support lake associations and watershed networks, work to involve farmer neighbors																			√	√	√	√	√				√	√	√
Urban and residential	**City/neighborhood-scale water management:** retention and infiltration areas, runoff diversions, stormwater ponds, swales, rain gardens, wetlands	sufficient adoption to reduce current contributions by 20%	√	√	√	√	√				√	√	√	√				√		√	√				√		√			√
	Improve soil health: reduce fertilizer use, diversify lawns, add native trees/shrubs/prairie/forest, no-till and cover crop gardens		√	√	√	√	√				√	√	√	√			√	√		√					√		√			
	Decrease road salt use: strategic and decreased salt use		√	√	√	√	√				√	√	√	√				√		√	√	√					√			
	Resident-scale water management: rain gardens, 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 systems	sufficient adoption to reduce current contributions by 20%			√	√	√				√		√	√	√			√				√	√	√	√		√			
	Eliminate IPHT systems: systems discharging to streams/land surfaces				√	√	√				√			√				√				√								
	Improved septic solids application: increase buffers, application rates				√	√	√											√				√								
	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" affect 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: Priority areas to restore and protect surface water quality are summarized below. The first six rows of this table are priority areas directly from the WRAPS report and focus on water quality restoration or protection. The bottom three rows of this table are multiple benefit or locally driven priority areas not strictly associated with the WRAPS, but these areas would offer benefits to water quality. Priority areas should be further customized and focused during local planning efforts using additional prioritizing criteria.

"Priority Area" Prioritizing Criteria	Specific Examples	Applicable WRAPS/other data sources	Other considerations
"Tipping Point: Barely Impaired" Water bodies that are impaired but have a relatively smaller reduction or improvement goal	**North Fork of the Watonwan River** and **Butterfield Creek** need relatively small reductions to meet TSS standards and a long-term TSS improving trend has been observed in the major watershed. **Butterfield Lake** needs a relatively small phosphorus reduction to meet standards and has a small watershed. **Unnamed Creek reach 505** (Headwaters to Mountain Lake) is impaired for M-IBI but supporting for F-IBI with only two identified stressors: habitat and nitrogen. **Watonwan River reach 563** is impaired for F-IBI but supporting M-IBI with only two identified 2 stressors: habitat and TSS.	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 criterion can be especially important if the primary goal of the funding entity is to achieve restoration of impaired water bodies.
"Protection of Supporting Waters" or "Reverse Degrading Trends" Water bodies that are currently meeting the water quality standard (beneficial use or for any parameter) or any water body (assessed or not) should have an improving or stable trend in water quality	**Fish Lake** and **St. James Lake** are the two lakes supporting aquatic recreation and both have improving trends. These lakes are also the 2 most sensitive lakes according to the lake P sensitivity analysis. Only five stream reaches were found to support one or more beneficial uses: **Unnamed ditch reach 545** (tributary to N Fork) supports aquatic life (modified use standard) and aquatic rec. **CD1 reach 553, Tributary to Watonwan reach 555**, **St. James creek reach 576**, and **Unnamed Creek 584** were found to support aquatic life (modified use standard).	The "green" water bodies in the status maps and assessment tables 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 useful prioritizing criteria for protection include: hydrologic alteration, trends, HSPF-modeled yields, phosphorus sensitivity, local pollutant sources, etc. The MPCA Lakes Phosphorus Sensitivity Analysis can be used to prioritize lakes that are estimated to be the most sensitive to additional phosphorus inputs.
"Dirtiest Watersheds or Waters" Watersheds with high pollutant/stressor yields or water bodies that have higher amounts of pollutant/stressor using either: 1) estimated reductions/TMDL based on observed concentrations, or 2) model data (yields or concentrations), 3) total number of identified parameters not supporting water quality goals.	**St. James Creek** (inlet to Kansas Lake) needs the highest estimated TSS reduction and **Kansas Lake** needs the highest estimated P reduction of lakes based on TMDL data. **Butterfield Creek** has the most identified parameters not meeting standards/stressing aquatic life. According to HSPF modeling, the **Lower Watonwan, Spring Creek, and Perch Creek subwatersheds** have the highest modeled yields of TN and TP, and portions of the **North Fork, Butterfield Creek, the Lower Watonwan, and the Lower South Fork Subwatersheds** have the highest modeled sediment concentration.	1) The goals maps (Section 2.2 - Goals Subsections) illustrate areas that need pollutant reductions- the darker the gray 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). 2) Data are available online and additional interpretations are available in the SID and the DNR hydro/geomorph reports. 3) HSPF-modeled concentrations are in the status subsections in Section 2.2 and yield maps are presented in Appendix 4.2.	1) Subwatershed goals maps can be used to estimate the dirtiest areas but are only presented when there is TMDL data and only apply to TSS, TP, and bacteria. 2) Observed data should be corroborated by that parameter being assessed as a pollutant or stressor 3) Model data are an estimate, may not represent real world conditions, and may be limited by model mechanics or assumptions. Coupling model data with additional prioritizing criteria (versus being a single driver in selecting a priority area) is recommended.
"Highly Hydrologically Altered" Subwatersheds or waterbodies identified as highly hydrologically altered	**Headwaters portions of Perch Creek, Spring Branch Creek, Tributaries to Lake Hanska, the Upper Watonwan River** are among the areas in the watershed that were estimated to have the highest level of altered hydrology. The **original Mountain Lake** (Figure 21 in the DNR Hydrology report) is a drained basin area that could be restored.	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. 1855 land survey or other past landscape imagery/analysis can identify drained lakes/wetlands.	Altered hydrology is the second most commonly identified stressor in the Watonwan watershed and a driver of most other stressors like sediment, habitat, and nitrogen.

"Priority Area" Prioritizing Criteria	Specific Examples	Applicable WRAPS/other data sources	Other considerations
"Connectivity/Fish Passage Barriers" stream reaches where connectivity was identified as a stressor or other known fish passage barriers	**South Fork of the Watonwan River** (near Long Lake), **Butterfield Creek, Perch Creek,** and **JD1** were the four reaches identified as stressed by a lack of connectivity due to fish passage barriers.	Streams stressed by connectivity barriers were identified in the Stressor ID report and summarized in the WRAPS. A more comprehensive inventory of fish passage barriers is presented in the DNR Hydrology & Geomorphology report.	Work with county and township officials to opportunistically eliminate other small barriers when culverts are replaced.
"Measurable waters" Water bodies with ample monitoring data to establish baseline conditions prior to work being done and future monitoring data can be used to track changes in water quality	**Hanska, Fish, and St. James** lakes have sufficient prior data that trends should emerge when sufficient changes are made. Ample data to report trends (see Trends Overview section) include, 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:	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 to show changes in. Depending on the kind of work to be done, biological data may change. Solid, long-term data is taken at WPLMN sites, but the watersheds of these sites are very large and substantial change is likely necessary before changes in water resources will be detected.
"Impaired Waters" Water bodies that have a 303d listed impairment	**34 stream reaches and 6 lakes** are impaired for one or more beneficial uses.	The status overview map in section 2.1 shows the impairments by beneficial use, and the status maps throughout section 2.2 illustrate the parameters causing the beneficial use impairment (by water body). The Assessment Table in Appendix 4.1 tabulates all the beneficial use impairments and parameters causing the impairment together.	Use the strategies table (referring to the effectiveness column) to identify which practices could be the most effective on the parameter causing the impairment, applying local knowledge of local sources and opportunities. Use additional prioritizing criteria to strengthen the case for selecting a specific impaired water.
"Drinking water and Ground water" Areas contributing water or risks to drinking and ground water resources	**La Salle area,** the **North Fork Watonwan,** and the **St James Wellhead protection area** have been identified by local and state partners to be high priority for protecting ground water due to the soils, geology, and other attributes.	Nitrogen concentration/load observed and modeled data and soils data (course textured and tile drained) can estimate higher yielding areas. MDH also provides information for targeting for drinking water source restoration and protection. A narrative is included in the WRAPS Appendix or contact MDH for more info.	Outlet of Watonwan River Watershed contributes to the Blue Earth River, which recharges the surficial sands aquifer used for Mankato's drinking water source, which often has excessive N contributions.
"Wildlife habitat" Areas that provide critical habitat including endangered species and ecologically sensitive areas	**Perch Creek** provides Blanding's Turtle (endangered species) habitat. **Lake Hanska** is a designated wildlife lake. **Bat Lake** is in the 'outstanding' biological significance class with higher quality aquatic plant assemblages, and **Linden Lake** and an **unnamed wetland** located East of Lewisville ranked as moderate with diverse bird life. **Kansas, Hanska, Bingham, Fedji Lakes** have opportunities to improve waterfowl production.	Wetland Management Areas, National Wetland Inventory/Restorable Wetlands, and River Corridors are all data sets useful for identifying and prioritizing habitat. DNR Fisheries Lakes of Biological Significance (2015 GIS layer) identifies high quality lakes based on unique in-lake habitat features.	
"Popular recreational water bodies" Water bodies that are commonly used for recreation	**Lake Hanska**	Civic engagement and the day-to-day work of local partners have identified several priority areas based on local values and special uses. 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.	

4 Appendix

4.1 Watershed Conditions and Background Information – Related Appendices

Stream Monitoring and Assessment Results

				Beneficial Use and Associated Biology, Stessors, and Pollutant Assessment																		
				Aquatic Life														Aq Rec		Lim Use		
					Bio		Stressors									Pollutants			Pol.		Pol.	
AUID-3	Stream	Reach Description	Stream Class	Assessment*	F-IBI	M-IBI	Habitat	Hydrology	Nitrates	TSS	Connectivity	DO	Eutro (P)	Chloride	Ammonia	TSS	DO	Assessment*	Bacteria	Assessment*	Bacteria	DO
501	Watonwan River	Perch Cr to Blue Earth R	2Bg, 3C	x	x	x	x	?	?	x	+	?	?	+	+	x	+	x	x	-		
502	St James Creek	T106 R31W S18 south line to Bu	7	-														-		x	x	+
505	Unnamed Creek	Headwaters to Mountain	2Bm, 3C	x	+	x	x	?	x	+	+	+	?	+	+					-		
510	Watonwan River	S Fk Watonwan R to Perch Cr	2Bg, 3C	x	x	x	x	?	?	x	+	?	?	?	+	x	+	x	x	-		
511	Watonwan River	Butterfield Cr to S Fk Watonwa	2Bg, 3C	x	x	x	x	?	?	x	+	?	?	+	+	x	?	x	x	-		
515	St James Creek	Butterfield Cr to Watonwan R	7	-														-		x	x	+
516	Butterfield Creek	Headwaters to St James Cr	2Bg, 3C	x	x	x	x	x	x	x	x	?	x	?	?	x	+	x	x	-		
517	Watonwan River	South Fork Willow Cr to Waton	2Bg, 3C	x	x	x	x	x	x	x	+	?	?	+	+	x	+	x	x	-		
523	Perch Creek	Spring Cr to Watonwan R	2Bg, 3C	x	x	+	x	?	?	x	+	+	?	+	+	?	+	x	x	-		
524	Perch Creek	Headwaters (Perch Lk 46-0046-	2Bg, 3C	x	x	x	x	x	x	x	x	+	?	+	+	x				-		
526	Unnamed Creek	T105 R30W S24 south line to Pe	2Bm, 3C	x	x	x	x	x	x	?	?	x	?	?	+					-		
528	St James Creek	Headwaters to Kansas Lk	2Bg, 3C	x												x				-		
540	Spring Brook	Unnamed Ditch to S Fk Watonw	2Bg, 3C	x	x	x	x	?	?	?	?	?	?	+	+					-		
542	Judicial Ditch 5	CD 2 to Lk Hanska	2Bg, 3C	?													?			-		
545	Unnamed Ditch	Unnamed Ditch to N Fk Waton	2Bm, 3C	+	?	+										+	?	+	+	-		
547	Watonwan River	South Fork Irish Lk to Willow C	2Bg, 3C	x	x	+	x	x	?	x	?	?	?	+	+	x				-		
549	Unnamed Creek	Unnamed cr to N Fk Watonwar	2Bg, 3C	x	x	x	x	x	x	?	+	+	?	+	+					-		
552	Unnamed Creek	CD 4 to Butterfield Cr	2Bm, 3C	x	x	x	x	?	?	?	?	?	?	+						-		
553	County Ditch 1	Unnamed cr to S Fk Watonwan	2Bm, 3C	+	+	+														-		
555	Unnamed Creek	Unnamed cr to Watonwan R	2Bm, 3C	+	+	+														-		
557	Unnamed Creek	Unnamed cr to Perch Cr	2Bg, 3C	x	x		x	x	?	+	?	+	?	+	+					-		
559	County Ditch 78	164th St to Watonwan R	2Bg, 3C	x	x	x	x	?	x	+	+	?	?	+	+					-		
561	Unnamed Creek	Unnamed cr to JD 1	2Bg, 3C	x	x	x	x	x	x	?	?	?	?	+	+					-		
562	Watonwan River	N Fk Watonwan R to T107 R32V	2Bg, 3C	x												x		x	x	-		
563	Watonwan River	T107 R31W S18 west line to Bu	2Bg, 3C	x	x	+	x	?	?	x	+	+	?	+	+	x	?	x	x	-		
564	Watonwan River	North Fork Headwaters to T10	2Bg, 3C	x	x	x	x	x	x	?	?	?	?	+	+	x	+	x	x	-		
565	Watonwan River	North Fork T107 R32W S5 west	2Bm, 3C	x	x	+	x	x	+	?	+	?	?	+	+					-		
566	Watonwan River	Headwaters to T107 R33W S33	2Bg, 3C	x	x	x	x	x	x	x	+	?	?	+	+	x		x	x	-		
567	Watonwan River	T107 R33W S34 west line to N F	2Bm, 3C	x	x	+	x	x	+	x	+	+	?	+	+	x	+	x	x	-		
568	Watonwan River	South Fork -94.8475 43.8813 to	2Bg, 3C	x	x	x	x	x	x	x	x	?	?	+	+	?	+	x	x	-		
569	Watonwan River	South Fork -94.9121 43.8594 to	2Bm, 3C	x	x		x	x	?	?	x	?	?	+	+					-		
571	Willow Creek	JD 4 to S Fk Watonwan R	2Bg, 3C	x	x	x	x	x	x	x	?	?	?	+	+					-		
574	Spring Branch Creek	T106 R30W S22 west line to Pe	2Bm, 3C	x	x	+	x	x	+	?	?	?	?	+	+	?	+	x	x	-		
576	St James Creek	T106 R32W S25 west line to T1(	2Bm, 3C	+	+	+										?	+	x	x	-		
577	Mink Creek	Unnamed cr to Perch Cr	2Bg, 3C	x	x	x	x	x	x	?	?	?	?	+	+					-		
579	Judicial Ditch 1	Headwaters to -94.9058 43.909	2Bg, 3C	x	x	x	x	x	x	?	x	?	?	+	+					-		
580	Judicial Ditch 1	-94.9058 43.9095 to T105 R33W	2Bm, 3C	x	x		x	x	?	?	?	?	?	+	+					-		
581	Judicial Ditch 1	T105 R33W S8 west line to Irish	2Bg, 3C	x	x	+	x	x	?	?	x	?	?	+	+	+	+	x	x	-		
583	Unnamed Creek	T106 R35W S1 west line to Unn	2Bg, 3C	x	x	x	x	x	x	?	+	+	?		+					-		
584	Unnamed Creek	Unnamed cr to T105 T29W S6 e	2Bm, 3C	+	+	+														-		

Beneficial Use Assessment*

- X = impaired
- ? = inconclusive (need more data)
- \+ = supporing
- \- = not applicable

Parameter/Stressor Assessment

- x = failing standard/ stressing
- ? = inconclusive (need more data)
- \+ = supporting standard/not stressing
- <blank> = not monitored/assessed

*benefical use assessment considers the status of multiple parameters and professional judgement

Lake Monitoring and Assessment Results

Lake ID	Lake Name	Aquatic Rec. (Phosphorous)	Aquatic Life (Fish IBI)	Trend
08-0026-00	Hanska	?	x	x
17-0003-00	Mountain	?	x	-
17-0007-00	Bingham	x	x	-
17-0012-00	Three	?		?
17-0020-00	Eagle	x	?	?
32-0018-03	Fish (Main)	+	x	+
46-0084-00	Round	?		?
83-0021-00	Fedji	?	?	?
83-0035-00	Mary	?		?
83-0036-00	Kansas	x	?	?
83-0040-00	Long	?	x	-
83-0043-00	St. James	+	+	+
83-0051-00	Sulem	?		?
83-0056-00	Butterfield	x	?	?
83-0060-00	Wood	?	?	?

+	= supporting/not a stressor/improving trend
?	= inconclusive (need more data)
x	= impaired/stressor/declining trend
-	= no trend detected

WPLMN Data Summary

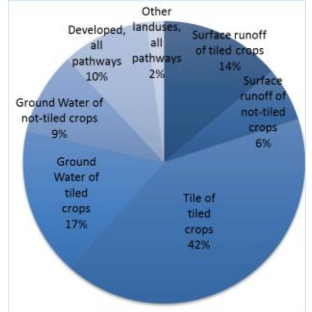
SITE	YEAR	PARAMETER	Mass (kg)	Vol (acre ft)	FWMC (mg/L)
Watonwan River nr Garden City, CSAH13	2007	TP	108051	302987	0.289
Watonwan River nr Garden City, CSAH13	2008	TP	56284	260786	0.175
Watonwan River nr Garden City, CSAH13	2009	TP	30868	110565	0.226
Watonwan River nr Garden City, CSAH13	2010	TP	232505	736570	0.256
Watonwan River nr Garden City, CSAH13	2011	TP	180828	614114	0.239
Watonwan River nr Garden City, CSAH13	2012	TP	69503	183157	0.308
Watonwan River nr Garden City, CSAH13	2013	TP	58130	151974	0.31
Watonwan River nr Garden City, CSAH13	2014	TP	66493	191238	0.282
Watonwan River nr Garden City, CSAH13	2015	TP	38132	165099	0.187
Sum of the 5 year load (2011-2015)			413,086		
Averaged annual FWMC					0.25
Multi year FWMC (2007-2015)			840,794	2,716,490	0.25
Watonwan River nr Garden City, CSAH13	2007	TN	3435184		9.19
Watonwan River nr Garden City, CSAH13	2008	TN	4563279		13.77
Watonwan River nr Garden City, CSAH13	2009	TN	925953		6.82
Watonwan River nr Garden City, CSAH13	2010	TN	8147845		8.97
Watonwan River nr Garden City, CSAH13	2011	TN	7686210		10.14
Watonwan River nr Garden City, CSAH13	2012	TN	2624280		11.58
Watonwan River nr Garden City, CSAH13	2013	TN	2132781		11.39
Watonwan River nr Garden City, CSAH13	2014	TN	2769147		11.76
Watonwan River nr Garden City, CSAH13	2015	TN	2998269		14.51
Sum of the 5 year load (2011-2015)			18210687		
Averaged annual FWMC					10.9
Multi year FWMC (2007-2015)			53,493,635	2,716,490	15.97
Watonwan River nr Garden City, CSAH13	2007	TSS	34787544	302987	93
Watonwan River nr Garden City, CSAH13	2008	TSS	24104778	260786	75
Watonwan River nr Garden City, CSAH13	2009	TSS	5904046	110565	43
Watonwan River nr Garden City, CSAH13	2010	TSS	69543105	736570	77
Watonwan River nr Garden City, CSAH13	2011	TSS	49935082	614114	66
Watonwan River nr Garden City, CSAH13	2012	TSS	27281190	183157	121
Watonwan River nr Garden City, CSAH13	2013	TSS	22312490	151974	119
Watonwan River nr Garden City, CSAH13	2014	TSS	23056930	191238	98
Watonwan River nr Garden City, CSAH13	2015	TSS	16131636	165099	79
Sum of the 5 year load (2011-2015)			138717328		
Averaged annual FWMC					85.7
Multi year FWMC (2007-2015)			273,056,801	2,716,490	81.5

4.2 Source Assessment –Related Appendices

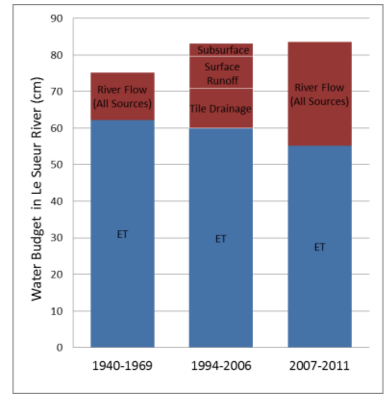
Multiple Lines of Evidence

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

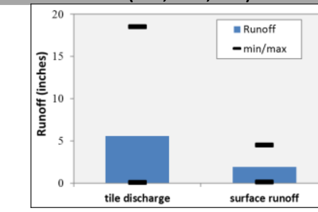
Q

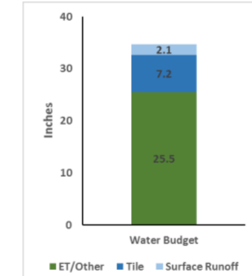


water portioning calculator (boettcher), assumes 60% of watershed tiled

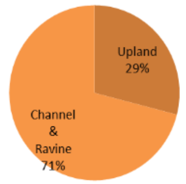


Middle bar of water budget: SWAT modeling of water budget by Folle

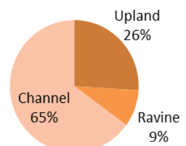




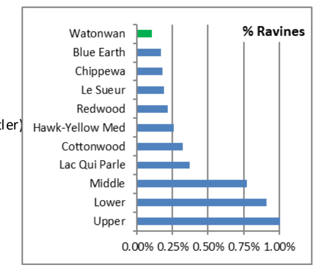
TSS

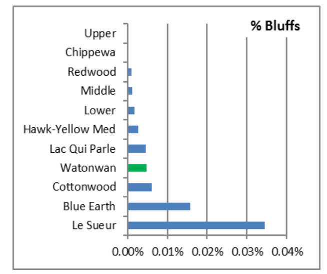


finger-printing, MN River US from mid mn (schottler)



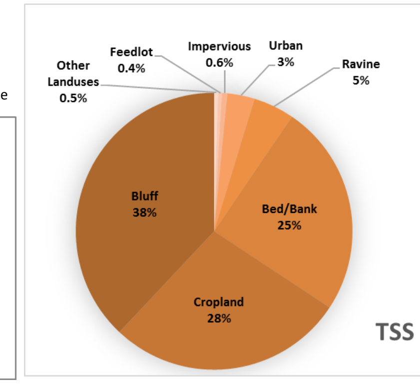
Gran Sediment Budget for Le Sueur River

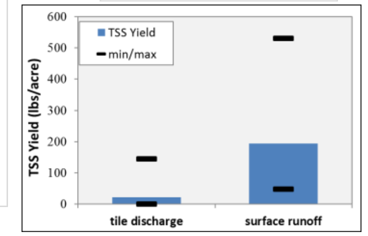


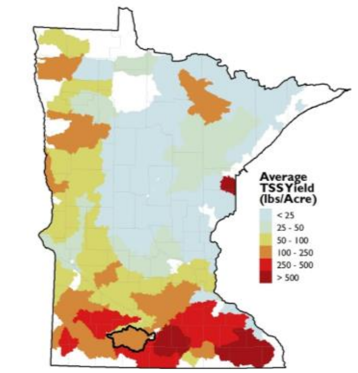


Mulla estimate of bluff and ravine areas per major watershed

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







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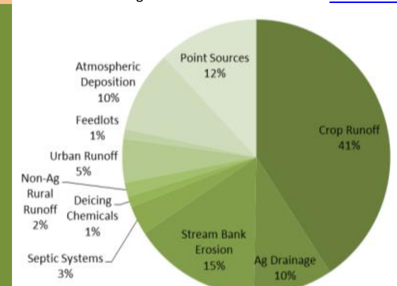
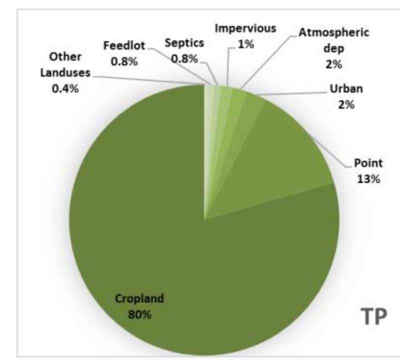
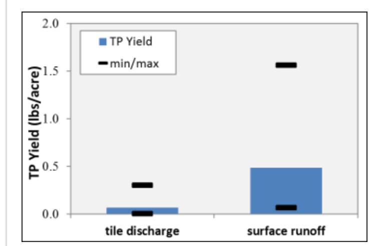
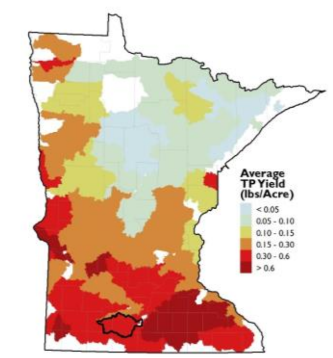


[Detailed Assessments of Phosphorus Sources to Minnesota Watersheds]

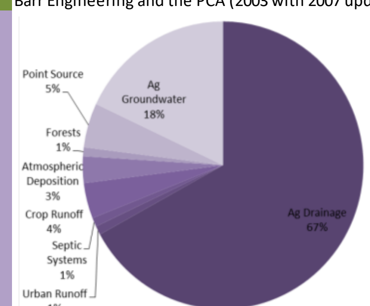
Barr Engineering and the PCA (2003 with 2007 update)



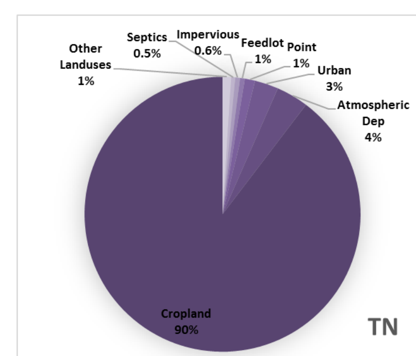


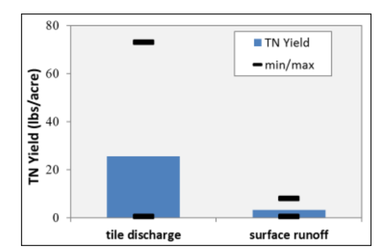


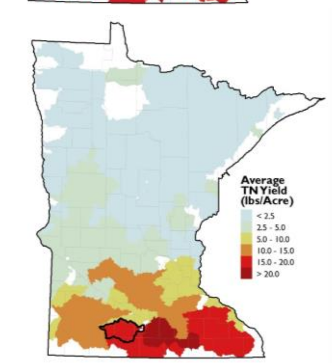
TN



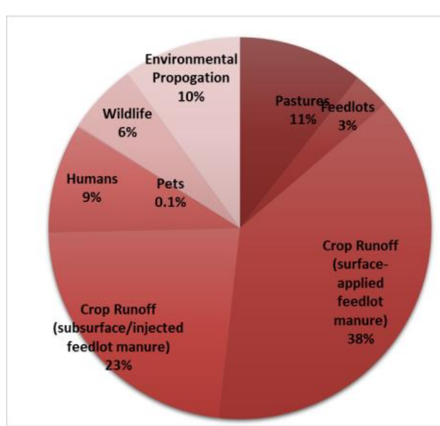
PCA Assessment for MN Basin, avg yr







Bacteria

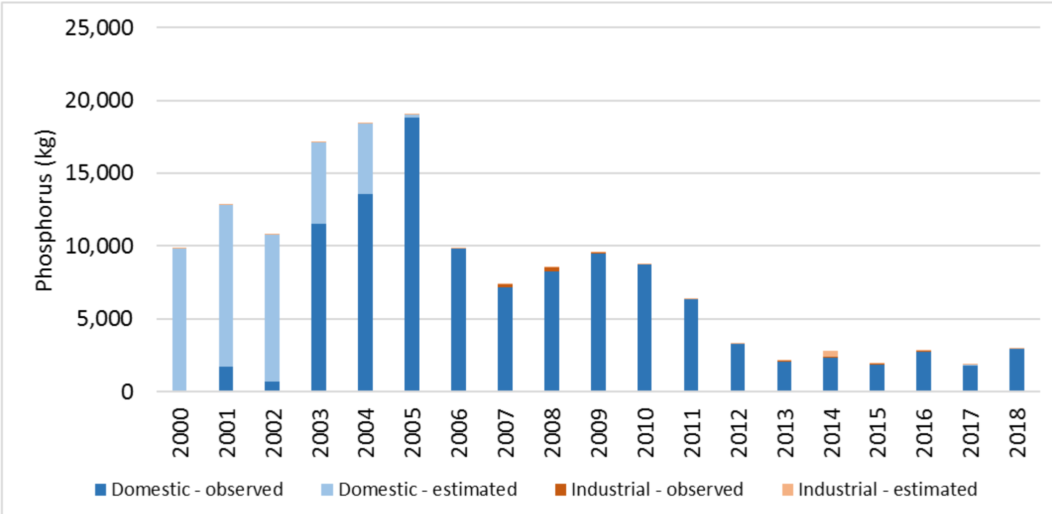


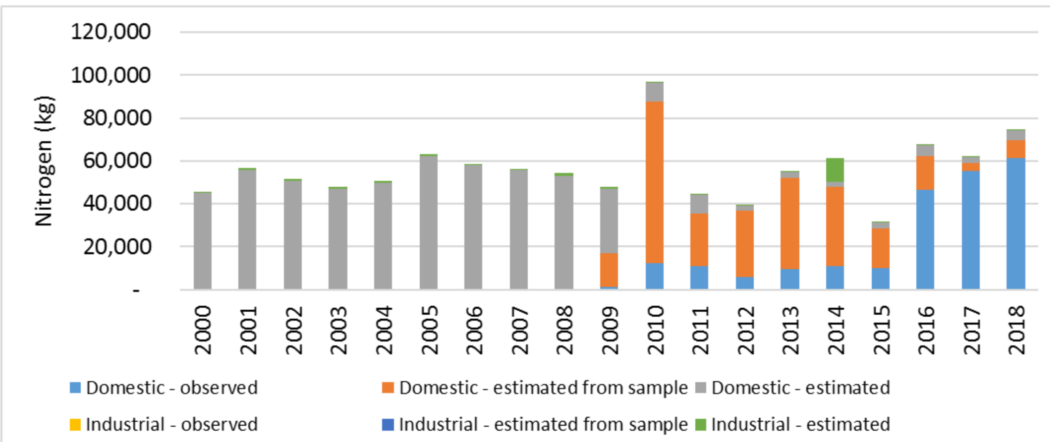
Bacteria Calculator, Boettcher

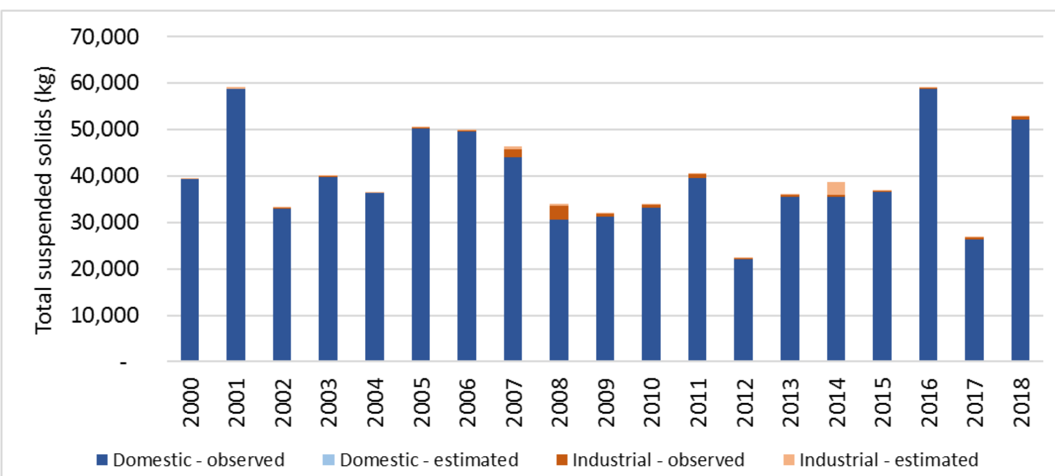
Strong relationship to fecal bacterial contamination in water	**Weak** relationship to fecal bacterial contamination in water
• High storm flow (the single most important factor in multiple studies) • % rural or agricultural areas greater than % forested areas in the landscape (entire watershed area) • % 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

Point Source Data Summary







Point Source Contribution to Total Watershed Load Calculation

2011-2015 Load	WPLMN	Point Sources	% Point Source
TP (kg)	413086	16422.30199	3.98%
TN (kg)	18210687	230717.9791	1.27%
TSS (kg)	138717328	174227.5083	0.13%

Regulated Facilities that do not Discharge to Surface Waters

Non Discharging	County
Milk Specialties Co	Cottonwood
RCP Transit LLC	Brown

Pre-Settlement Landscape Map Data Sources

This map graphic 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 maps and notes (from 1848 to 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 to 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 to determine natural community potential, productivity indexes and patterns of natural disturbance.

Phosphorus from Agricultural versus Native Land Use

The amount of 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 to 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 typical cultivated crop P application rates on Minnesota River basin farms are 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 10-20 times more P is applied to a typical farm field 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 organic material, 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 was provided by the MPCA feedlot staff.

- Surface applied manure generally tends to come from smaller feedlots or "smaller" dairies or poultry facilities.
- Facilities with <300 AU generally have limited manure storage so manure application occurs on a more frequent basis and facilities are not required to have a manure management plan or test their soils for P.
- Facilities with <100 AU have fewer restrictions under the feedlot rules.
- Poultry litter does not follow the general rule of being spread close to the facility as it is generally brokered out to area crop farmers who are willing to pay for the manure. Because of the higher nutrient value and ease at which it can be hauled in a semi, poultry manure is more "mobile" then other manures. Implications of this include:
    - most of the manure is surface applied
    - generally, manure from these facilities is sold to nonlivestock farmers
    - barns are cleaned out when barns are emptied of mature birds which tends to lead to a significant amount of temporary manure stockpiles in fields 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. The MPCA and/or delegated counties have the authority to request these records but due to a 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.

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-September 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. Minnesota Irrigation Scheduling Checkbook, Waseca station temp	NDSU (2012)	42 cm
4. Minnesota 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 noncrop ET rates. 3) Errors 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.

Bacteria Sources Calculator

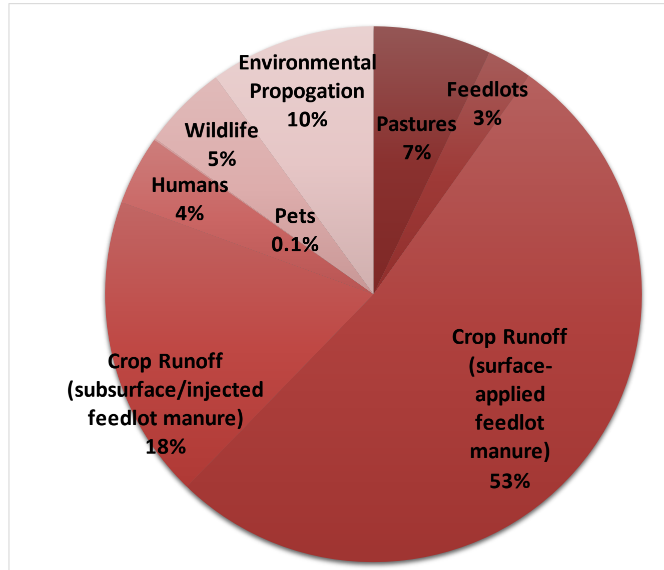
DIRECTIONS : [orange cell] = enter value for watershed (known or assumption).

Waterhsed	**wat.**
Total area (ac)	562000
Total Pasture (ac)	3500
Pasture <1000ft of water body (ac)	2000
Total AUs	236000
% feedlot AUs whose manure stockpiles w/o runoff controls	5%
number of pasture acres per 1 grazed AU	2
% Feedlot manure applied Surface	16%
% Feedlot manure applied Subsurface	84%
Pasture >1000 ft (ac)	1500
pasture <1000ft AUS	1000
pasture >1000ft AUs	750
Feedlot AUs	234250
Feedlot inadequate runoff AUs	11713
Feedlot surface applied AUs	37480
Feedlot subsurface applied AUs	196770
Human population	18000
number of failing septics per 1,000 acres	2
number of people per failing septic	2
# humans comparable to 1 AU	7
# acres per 1 wildlife AU of total watershed	250
humans per pet (one pet for every x humans)	3
# pets comparable to 1 AU	30
% of total load due to environmental propogation	10%
people using failing septics	2248
% of human wastewater inadequatetly treated (on failing septics)	12%
of human wastewater is adequately treated	88%
Human - inadequate treatment AUs	321
Human - adequate treatment AUs	2250
Pet AUs	200
Wildlife AUs	2248
Wet conditons (time with active runoff)	5%
Dry conditions (no active runoff)	95%

Total Livestock 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		2.5	0.4		2.9	56.2	19.7		0.1	3.4		0.1	0.3	
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		4.8	0.0		0.0	0.0	0.0		0.0	2.1		1.1	3.1	
Total Delivered Units		7.3	0.4	7.6	2.9	56.2	19.7	4.5	0.1	5.5	11	1.1	3.4	75.9
Total Delivered Percentage		6.8%	0.3%	7.1%	2.7%	52.4%	18.3%	4.2%	0.1%	5.1%	10.0%	1.0%	3.1%	70.7%



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%	68.7%
not tiled ag	21%	18.3%
all ag	100%	87%

Estimate tiled ag % on local knowledge, tiled acres GIS estimate, or can estimated % c

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 an	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 fi	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%	72%
not tiled land	0%	31%	36%	18%	16%
all ag land	100%	100%	100%	100%	88%

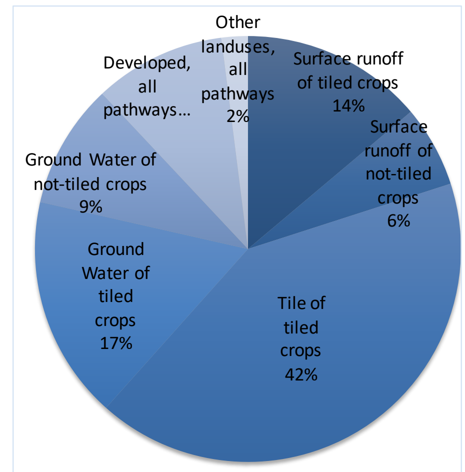
Flow contributions by flow path toward total watershed contributions

	tiled ag	not tiled ag	all ag land
% from tile	42%	0%	42%
% from surface	14%	6%	20%
% from GW	17%	9%	26%
% from all ag paths	72%	16%	88%

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 Farn	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 tiled 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	



Stressor Identification Source Assessment for Bio-impaired Reaches

	Eutrophication					Nitrate			TSS						Habitat						Connect-ivity		Altered Hydrology				Chloride		Ammonia	
AUID	Wetland Influence	Excess Phosphorous	Algae/Plant Shift	Unidentified	Additional Monitoring?	Tile Drainage/Land Use	Point Sources	Additional Monitoring?	Flow Alteration/Connectivity	Streambank Erosion	Altered	Urbanization	Local Land Use or Pasture	Additional Monitoring?	Flow Alteration/Connectivity	Pasturing/ Lack of Riparian	Altered	Bedded Sediment	Erosion	Lack of Cover/Other Habitats	Dams/Impoundments	Road Crossings/Culverts	Water Withdrawal	Altered	Tile Drainage/Landuse	Additional Monitoring?	Wastewater or Industrial	Additional Monitoring?	Wastewater or Industrial	Additional Monitoring?
501		x	?		x	x		x		x								x	x	?					x	x				
505		x			x	x					x					x	x	x		x				x	x	x				
510		x	?		x	x	x	x		x	x					x		x	x	x					x	x	x	x	x	
511		x			x	x		x		x	x							x	x	x					x	x				
516		x	x		?	x	x		x	x	x				x	x	x	x	x	x		?		x	x	x	x	x	x	x
517		x			x	x			x	x			x		x	x		x	x	x					x					
523		x			x	x		x		x								?	x	x		?			x	x				
524		x	?		x	x			x	x						x		x	x	x		?			x					
526		x	?		x	x	x		x	?	x			x	x	x	x	x	?	x		?		x	x		x	x	x	
540		?			x	x			x	?	x						x	x	?			?		x	x	x				
547		x			x	x		x	x	x				x	x			x	x		?	?			x					
549		x			x	x			x		x		x	x	x	x	x		x	x				x	x					
552			x		x	x		x			x	?		x		x	x	?		x		?		x	x	x				
557		x			x	x		x	x	x	x				x		x	x	x			?		x	x					
559		x	?		x	x				x	x					x	x		x	x				x	x	x				
561				x	x	x			x	x	?		x	x	x	x	?	x	x	x		?		x	x	?				
563		x			x	x	x	x		x								x	x						x	x	x		x	
564		?	?		x	x			x	x	x			x	x	x	x	x	x			?		x	x	x				
565		x			x	x			x	x	x			x	x		x		x			?	x	x	x					
566	?	?	x		x	x	x		x	x					x	x		x	x					x	x		x		x	
567				x	x	x			x	x	x				x	x	x	x	x	x				x	x					
568		?			x	x			x	x			x	x	x	x		x	x		x	?			x					
569		x			x	x		x	x	x	x			x	x	x	x	x	x	x		?		x	x					
571		x	x		x	x			x	x			x	x	x	x		x	x	x		?			x					
574		x	x		x	x		x	x	x	x			x	x	x	x	x	x	x	x	?		x	x					
577		x			x	x			x	x	x			x	x	x	x	x	x			?		x	x					
579				x	x	x	x		x	x	x			x	x	x	x	x	x	x	x	?		x	x		x		x	
580		x	x		x	x	x	x	x		x			x	x		x	x		x		?		x	x	?	x		x	
581		x			x	x		x	x	x	x			x	x	x	x	?	x	x		x		x	x					
583		x	?		x	x			x	x	x			x	x	x	x	x	x	x				x	x					

4.3 Water Quality Goals– Related Appendices

TMDL Summary

	Bacteria			TSS			
					Whole Data Set		Jun-Aug only Data
AUID	Months with Data (in which std applies)	Maximum Monthly Geomean (TMDL report calc method)	Flow Wt'd Monthly Geomean (WRAPS report calc method)	Months with Data (in which std applies)	Excel Calculated 90th Percentile (TMDL report calc method)	Load Sum Compared to Standard Load Sum	Load Sum Compared to Standard Load Sum (WRAPS report calc method)
07020010_501				Jan-Dec	54%	39%	42%
07020010_502	Jun-Aug	58%	40%				
07020010_510	Jun-Aug	75%	71%	May-Sep	32%	33%	40%
07020010_511				Mar-Oct	59%	10%	11%
07020010_515	Jun-Aug	18%	10%				
07020010_516	Jun-Aug	82%	78%	May-Sep	16%	-28%	-17%
07020010_517				Mar-Oct	51%	37%	47%
07020010_523	Jun-Aug	89%	72%				
07020010_563				May-Sep	17%	60%	13%
07020010_564	Jun-Aug	85%	83%	May-Sep	0%	-31%	-21%
07020010_567				May-Sep	20%	40%	45%
07020010_568	Jun-Aug	85%	84%				
07020010_574	Jun-Aug	83%	81%				
07020010_576	Jun-Aug	81%	84%				
07020010_581	Jun-Aug	86%	74%				
Average		74%	68%		31%	-5%	-4%

Lake Name	Data Months, Years	Modeled Inflow Load Reduction (TMDL report calc method)	Reduction from Mean Observed Lake Concentration - Months & Years Avg'd (WRAPS report calc method)
Bingham	6-9 2007	60%	42%
Butterfield	6-9 2014	7%	4%
Eagle	6-9 2007, 2008	59%	42%
Kansas	6-9 2014	58%	47%
Average		46%	34%

Minnesota State Nutrient Reduction Strategy

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

The P 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 100units-33units=67 units. The reduction from 2014 to the final goal is (67units to-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 that the Mississippi River Basin reduction goal.

4.4 Strategies and Priorities – Related Appendices

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 P from being delivered to a lake and are the basis for any restoration work.

- **Manage nutrients** – carefully planning for and applying P fertilizers decreases the total amount of P runoff from cities and fields.
    - Examples: crop nutrient management, city rules on P fertilizer use, etc.
- **Reduce erosion** – preventing erosion keeps sediment (and attached P) in place.
- Examples: construction controls, vegetation (see below).
- **Increase vegetation** – more vegetative cover on the ground uses more water and P 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 P) 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.

Lakeshore-specific Strategies – These strategies are a subset of watershed strategies that can be directly implemented by lakeshore residents.

- **Eco-friendly landscaping** – poor landscape design and impervious surfaces increase runoff and loading of nutrients into lakes.
    - Examples: aeration, rain barrels or cisterns, rain gardens, permeable pavers, sprinkler and drainage systems, septic systems maintenance, 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 re-generation of native trees, proper turf grass and 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 P (from within the lake). These strategies are only effective if external P 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 lakeshore 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-lakeshore 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 lakeshore habitat is important to absorb P in the lake as part of a long-term approach to P 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.

Strategies Table Menu/Key

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 pesticide 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

Precision/variable rate 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)
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

Model Summary Table

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 Watonwan River watershed for average weather conditions. The first/top scenario achieves a 12% N reduction from all crop lands (enough to meet the 10-year target by making changes to crop land uses alone). The second/bottom scenario achieves a 77% N reduction from all crop lands (enough to meet the full goal by making changes to crop land uses alone). 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.	17% N Reduction from Crops	31% of land receives target N fertilizer rate			4 lb/ac	**$-3/lb**
			9% of land receives Fall N inhibitor			3 lb/ac	$2/lb
			9% of land uses rye cover crop			2 lb/ac	$32/lb
			6% of land switches from fall to split fertilizer application			6 lb/ac	$3/lb
			5% of land switches from fall to spring fertilizer application			6 lb/ac	**$-1/lb**
			2% of land short season crops adopt a rye cover crop			6 lb/ac	$9/lb
			1% of land is treated by tile line bioreactors			2 lb/ac	$20/lb
			0.7% of land converts to perennial crop			15 lb/ac	$3/lb
			0.3% of land adopts riparian buffers 50 feet wide			12 lb/ac	$14/lb
			0.2% of land adopts controlled drainage			5 lb/ac	$2/lb
			0.2% of land adopts saturated buffers			6 lb/ac	$2/lb
			0.2% of land is drained to treatment wetlands			8 lb/ac	$1/lb
		77% N Reduction from Crops	74% of land converts to perennial crop			11 lb/ac	$16/lb
			19% of land adopts saturated buffers			6 lb/ac	$2/lb
			19% of land is treated by tile line bioreactors			2 lb/ac	$20/lb
			18%of land adopts controlled drainage			5 lb/ac	$2/lb
			16% of land (corn & bean crops) uses rye cover crop			2 lb/ac	$32/lb
			14% of land is drained to treatment wetlands			8 lb/ac	$1/lb
			5% of land receives target N fertilizer rate			3 lb/ac	$-3/lb
			4% of land receives Fall N inhibitor			3 lb/ac	$2/lb
			4% of land (short season crops) adopt a rye cover crop			6 lb/ac	$9/lb
			1% of land adopts riparian buffers 50 feet wide			12 lb/ac	$16/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 Watonwan River watershed for average weather conditions. The first/top scenario achieves a 12% P reduction from crop lands (enough to meet the 10-year target by making changes to crop land uses alone). The second/bottom scenario achieves a 50% P reduction from all crop lands. 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.	12% P Reduction from Crops	19% of land adopts reduced P application rate		0.05 lb/ac		$-248/lb
			13% of land (>2% slopes) uses reduced tillage		0.09 lb/ac		$-171/lb
			9% of land (corn & bean crops) uses rye cover crop		0.05 lb/ac		$988/lb
			6% of land switches to preplant/starter fertilizer application		0.02 lb/ac		$1150/lb
			4% of land adopts alternative tile intakes		0.12 lb/ac		$5/lb
			3% of land injects/incorporates manure		0.13 lb/ac		$37/lb
			2% of land (short season crops) adopt a rye cover crop		0.12 lb/ac		$463/lb
			0.6% of land converts to 50 ft stream buffers		1.74 lb/ac		$45/lb
			0.6% of land converts to perennial crop		0.25 lb/ac		$126/lb
			0.2% of land adopts controlled drainage		0.17 lb/ac		$60/lb
		50% P Reduction from Crops	96% of land adopts reduced P application rate		0.04 lb/ac		$-349/lb
			91% of land (corn & bean crops) uses rye cover crop		0.05 lb/ac		$988/lb
			32% of land (>2% slopes) uses reduced tillage		0.11 lb/ac		$-147/lb
			19% of land adopts controlled drainage		0.17 lb/ac		$60/lb
			17% of land adopts alternative tile intakes		0.12 lb/ac		$5/lb
			12% of land switches to preplant/starter fertilizer application		0.03 lb/ac		$1053/lb
			5% of land injects/incorporates manure		0.13 lb/ac		$37/lb
			4% of land (short season crops) adopt a rye cover crop		0.12 lb/ac		$463/lb
			3% of land converts to 50 ft buffers		1.7 lb/ac		$54/lb
			0.6% of land converts to perennial crop		0.25 lb/ac		$126/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 scenarios ran in the Watonwan River watershed. 3 Scenarios cost optimized to to meet (roughly) the 10-year targets for N (15%), P (10%), and Sediment (4%) and 3 Scenarios cost optimized to meet (roughly) the full goal for N (70%), P (40%), and Sediment (20%). All scenarios ran for load reduction at the watershed outlet. Most scenarios looked at all possible areas in watershed, but some scenarios looked only at 2/3 of the watershed due to some bugs/constraints running HSPF for the scenario. Each scenario had multiple BMPs to choose from, and those selected by the program created the lowest cost option to meet the specified water quality reduction. The default values changed in SAM included reducing the cost of nutrient management from $8/ac to $2/ac and reducing the treated area per open tile intake from 44 acres to 2.2 acres. Otherwise, current SAM default values were used. In some cases, the scenario does not represent feasible options, as SAM allows multiple BMPs to be applied on the same land.	N-10 yr	74%	of area adopts Nutrient Management	3%	7%	15%	$2.1M $4/ac/yr
			9%	of area adopts 16' buffers				
			5%	of area restores wetlands				
		P-10 yr	74%	of area adopts Nutrient Management	5%	10%	18%	$2.8M $5/ac/yr
			14%	of area adopts 50' buffer				
			10%	of area adopts 16' buffer				
			6%	of area adopts Reduced Tillage (30%+ residue cover)				
			3%	of area adopts Alternative Tile Intakes				
		S - 10 yr	4%	of area adopts Filter Strips, 50 ft wide (Cropland field edge)	3%	3%	4%	$0.2M $1/ac/yr
			3%	of area adopts 50' buffer				
			19%	of area adopts Reduced Tillage (30%+ residue cover)				
		N - full goal	83%	of area adopts Conservation Cover Perrenials	20%	45%	64%	$80M $143/ac/yr
			81%	of area adopts Nutrient Management				
			81%	of area adopts Corn & Soybeans with Cover Crop				
			17%	of area adopts Restore Tiled Wetlands (Cropland)				
			14%	of area adopts Reduced Tillage (30%+ residue cover)				
			14%	of area adopts Riparian Buffers, 50 ft wide (replacing row crops)				
			14%	of area adopts Filter Strips, 50 ft wide (Cropland field edge)				
		P - full goal	40%	of area adopts Conservation Cover Perrenials	14%	39%	38%	$28M $50/ac/yr
			28%	of area adopts Nutrient Management				
			13%	of area adopts Reduced Tillage (30%+ residue cover)				
			7%	of area adopts Corn & Soybeans with Cover Crop				
		S - full goal	51%	of area adopts Corn & Soybeans with Cover Crop	12%	14%	17%	$15M $27/ac/yr
			8%	of area adopts Filter Strips, 50 ft wide (Cropland field edge)				
			7%	of area adopts Reduced Tillage (30%+ residue cover)				
			5%	of area adopts 16' buffer				

Model(s) & Reference	Summary & Notes	Scenario		Modeled BMPs/Landscape									Reduction in Parameter: Sediment	Phosphorus	Nitrogen	Cost
		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%
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.	**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 Redu		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)		

Modeled Nutrient Reductions from Minnesota and Iowa State Reduction Strategy Reports

Minnesota: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/nutrient-reduction/nutrient-reduction-strategy.html

Iowa: 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 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)	-100$^{\gamma}$
		Land Retirement (CRP) Compared to Spring- Applied Fertilizer	85 (9)	-100$^{\gamma}$
	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. 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 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.

		Nitrate-N	Phosphorus	Cost of N Reduction from baseline ($/lb)	Initial Investment (million $)	Total EAC* Cost (million $/year)	Statewide Average EAC Costs ($/acre)
Name	Practice/Scenario**	% 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.

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/

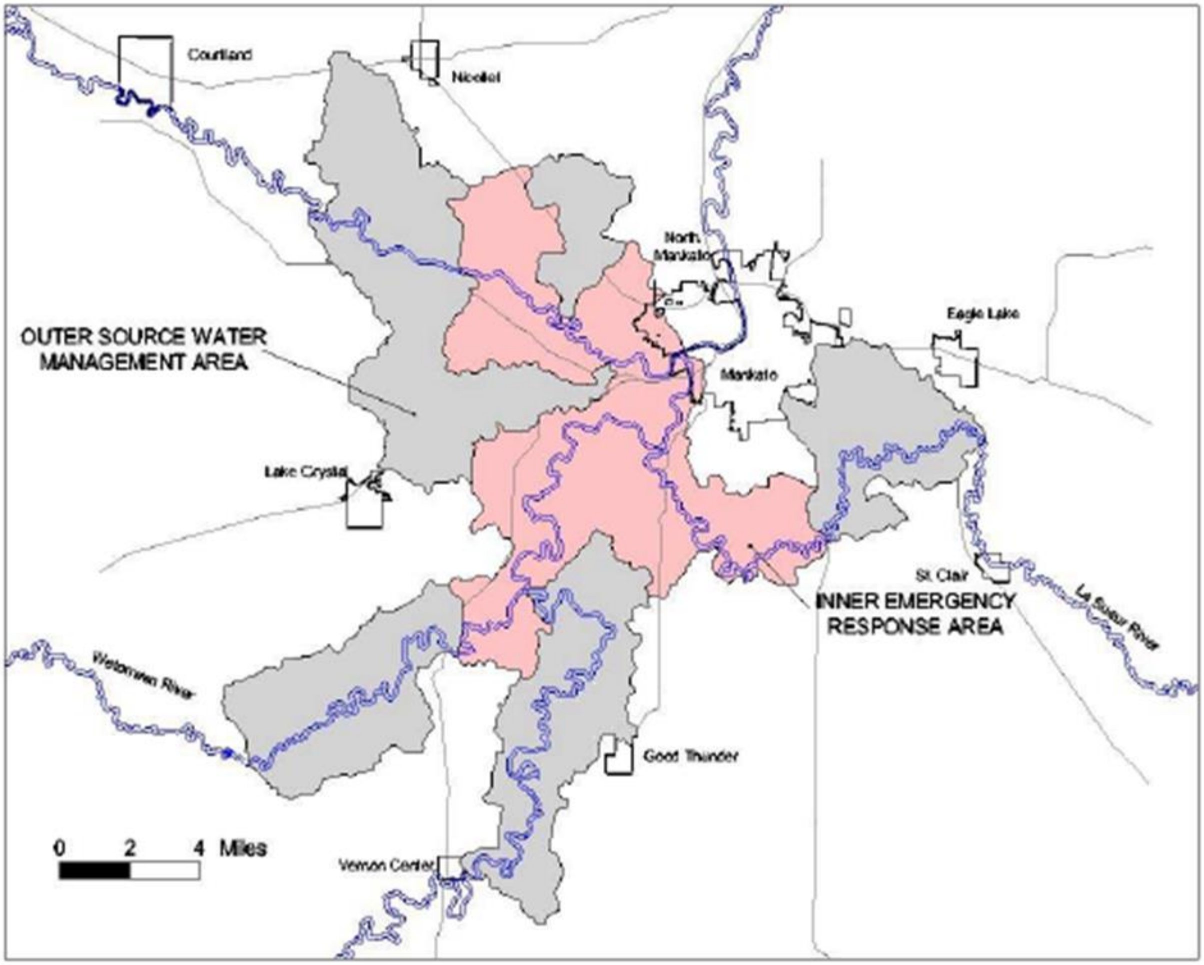
Restorable Wetland Prioritization Tool	The base layer is a restorable wetlands inventory that predicts restorable wetland locations across the landscape. There are also three decision layers including a stress, viability, and benefits layer. The stress and viability decision layers can be weighted differently 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/

Phosphorus Sensitivity Scores for Lakes in the Watonwan River Watershed

https://gisdata.mn.gov/dataset/env-lakes-phosphorus-sensitivity

Lake	Lake P Sensitivity Score	Protection Class
Fish	20	Highest
St. James	14	Highest
Long	10	Higher
Swan	5	Higher
Fedji	3	Higher
Mountain	0.2	High
Wood	0.2	High
Perch	0.1	High
Hanska	0.1	High
Sulem	0.0	High
Butterfield	0.2	N/A (Impaired)
Bingham	0.1	N/A (Impaired)
Kansas	0.1	N/A (Impaired)
Eagle	0.0	N/A (Impaired)

Source Water Assessment Area for the City of Mankato Ranney Well

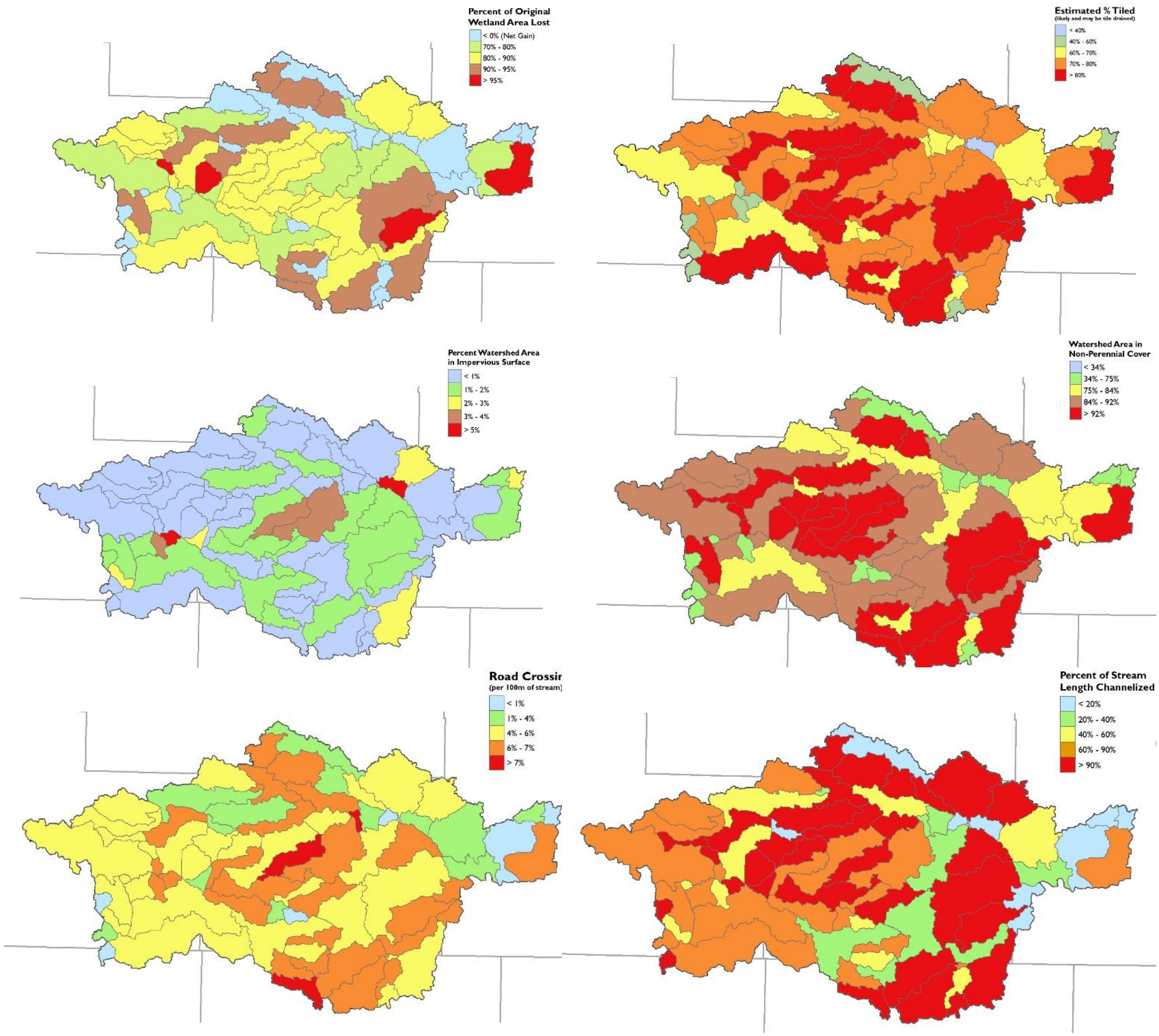


The Source Water Assessment Area map outlines the closest watershed areas to the city of Mankato's Ranney wells. These wells pump water from a shallow aquifer that is heavily influenced by the Minnesota and Blue Earth Rivers. As shown in the map, the Watonwan River is a contributing watershed of the Blue Earth River, and therefore water quality of the Watonwan River impacts water quality in the Ranney wells at Mankato. The Source Water Assessment for Mankato's surface water supply is on schedule to be amended in early 2020.

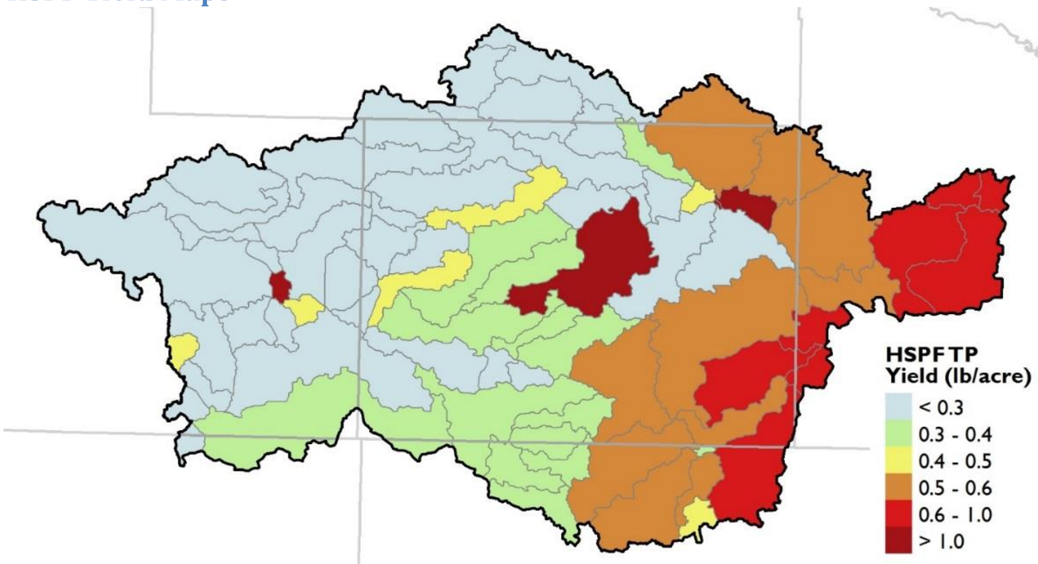
The city's current Source Water Assessment is available on the MDH Source Water Assessment webpage at https://www.health.state.mn.us/communities/environment/water/swp/swa.html.

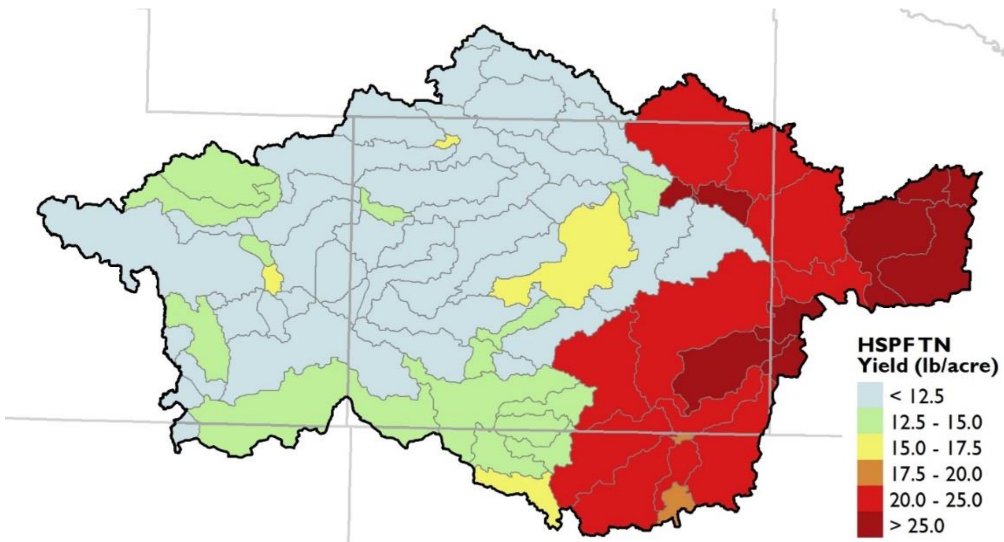
Altered Hydrology GIS Analysis

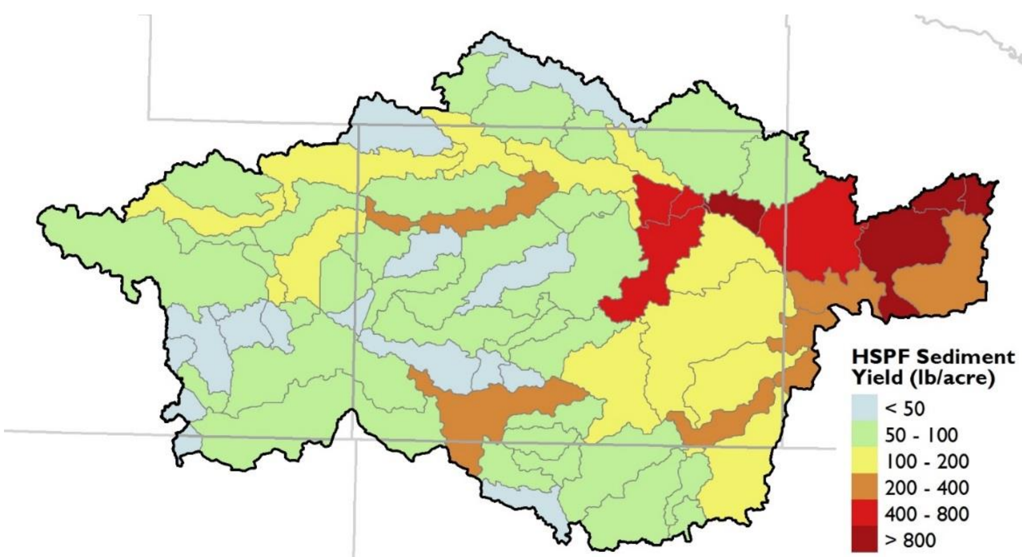
The altered hydrology analysis illustrated in Section 2.2 was created from the following six GIS layers and weights: estimated percent tiled (5), percent of land in nonperennial land uses (5), percent impervious surface (50), estimated percent wetland loss (10), road crossing per 100 m of stream (20), percent of stream length that is channelized (7).



HSPF Yield Maps







Strategies Table Calculator Notes and Assumptions

Strategies Table Calculator Notes and Assumptions
Landuse (known): 87% cultivated ag, 1% grass/pasture, 6% all developed, 5% open water & 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)
5% of the watershed (6% of tiled field acres) drain to open intakes and none of these have effective control of nutrient/sediment runoff
77% of watershed has nutrient/sediment loss from crop groundwater or croprunoff => equivalent of 10% of watershed (11.5% of crops) prevents nutrient loss to surface runoff and groundwater. For example, 35% of crops treat/prevent 1/3rd of its runoff: 1/3*35%=11.5%
0.5% of watershed (50% of pastures) are pastures that are contributing nutrients, sediment, and bacteria
10% of watershed gets manure - 8% of watershed gets subsurface manure, 2% of watershed gets surface manure
When ag-wide control measure goes in, assume manured and non-manured have same adoption rate as do tiled and untiled (by % of landuse)
source assessments presented in WRAPS report used in calculations with the following refinements of the identified sources:
3% of total watershed sediment load travels through open tile intakes (10% of crop surface source travels through this pathway)
1% of stream bank erosion is from bank trampling in addition to other pasture sediment contributions
3% of phosphorus travels through open tile intakes
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 the inherint error estimating BMP reduction effeciences, 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 contraily the basic conservation tillage is adopted exclusively), the reduction from this strategy will likely be higher (contrary case: lower) than the estimated reduction.
Except a few cases where noted, the estimated reduction per strategy adoption is:
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 watershed
% 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)

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