Yellow Medicine River

and Surrounding Direct Minnesota River Tributaries

Watershed Restoration and Protection Strategies

Minnesota Pollution Control Agency

CLEAN WATER LAND & LEGACY AMENDMENT

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Cover Photo: Courtesy of Yellow Medicine River Watershed District, photo in May 2010 or 2011 at the sampling site for the South Branch Yellow Medicine River, south of Minneota

Table of Contents

Preface ... *4*
Executive Summary ... *5*
Legislative Requirements ... *8*
1 Background Information ... **9**
1.1 Watershed Approach and WRAPS ... *9*
1.2 Watershed Description ... *9*
1.3 Watershed Characteristics that Impact Water Quality ... *11*
1.4 Assessing Water Quality ... *13*
Water Quality Standards ... 14
Water Quality Assessment ... 14
Monitoring Plan ... 14
Computer Modeling ... 15
2 Water Quality Conditions ... **16**
2.1 Conditions Overview ... *16*
Status Overview ... 16
Trends Overview ... 17
Sources Overview ... 18
Goals & Targets Overview ... 18
2.2 Identified Pollutants and Stressors ... *18*
Altered Hydrology ... 19
Sediment ... 23
Phosphorus ... 26
Nitrogen ... 28
Fecal Bacteria ... 30
Habitat ... 32
Dissolved Oxygen ... 33
3 Restoration & Protection ... **35**
3.1 Scientifically-Supported Strategies to Restore and Protect Waters ... *35*
Agricultural BMPs ... 35
Urban and Residential BMPs ... 35
Stream and Ravine Erosion Control ... 36
Lake Watershed Improvement ... 36
Computer Model Results ... 36
3.2 Social Dimension of Restoration and Protection ... *36*
3.3 Restoration and Protection Strategies ... *38*
Protection Considerations ... 39
Prioritizing and Targeting ... 40
4 Appendix
4.1 Assessments by Stream Reach ... *42*
4.2 Stream Biological Assessments ... *43*
4.3 TMDL Calculated % Reductions ... *44*
4.4 Altered Hydrology GIS Analysis ... *46*
4.5 Minnesota State Nutrient Reduction Strategy ... *47*
4.6 ET Rate Data & Calculation ... *47*
4.7 Lake Restoration and Protection Strategies ... *48*
4.8 Nutrient BMP Summary Info from Minnesota and Iowa State Reduction Strategy Reports ... *50*
4.9 Agricultural BMP Summary Table ... *57*
4.10 Modeled BMPs ... *58*
4.11 Source Assessment Summary ... *59*
4.12 Water Portioning Calculator ... *60*
4.13 Available GIS Targeting Tools/Data Layers ... *61*
4.14 Usefulness of GIS Data Layers/Tools ... *63*
4.15 Locally selected priorities ... *64*
4.16 Discovery Farms Information ... *65*
4.17 Point Source Data Summary ... *66*
4.18 Point Source Pollutant Loads versus Watershed Outlet Loads ... *67*
4.19 NPDES Permit Holders in the Yellow Medicine Watershed ... *68*
4.20 References ... *71*
4.21 Glossary ... *75*

Preface

Lakes and rivers in the Yellow Medicine Watershed, similar to other watersheds in the Minnesota River Basin, have widespread water quality problems. Every resident of the watershed has an impact on water resources. Accordingly, every managed land use (i.e. residential yards, animal operations, and cultivated crops) has opportunities to help improve water quality. With 80% of the watershed in cultivated crops, the greatest opportunity for water quality improvement is from this sector. To achieve clean water, sustainable farming practices must replace the practices currently common in farming: unmitigated tile drainage, heavy tillage and fertilization, monocultures with bare fields fall through spring, and farming marginal and high risk areas. Likewise, cities, residents, animal operations, and other activities must transition to more sustainable practices.

Current trends in land management and climate change continue to degrade some water quality conditions. Agricultural drainage and ditch system improvement projects increase the amount and timing of water leaving the landscape, which accelerate stream bank erosion, flood downstream areas, and deliver excess nutrients. This altered hydrology is further magnified as climate change increases storm intensities. Further compounding problems, conservation grasslands and other conservation practices have been removed from the landscape. Losing these features has decreased the ability of the landscape to buffer climate and human impacts. Unless the landscape is used to buffer hydrologic changes and drainage projects are mitigated, watershed conditions are unlikely to improve.

In order to meet water quality goals, a thoughtful and comprehensive change in land management norms is necessary. However, changing norms will likely require substantial changes in policies, programs, and other support. Conservation programs need to be re-structured to empower farmers to make sustainable changes while ensuring the farms' and communities' long term profitability. Re-structuring most conservation programs (which are through the federal Farm Bill Program), however, would be slow or unlikely to happen. For this reason, local leadership and the strategic use of local and state funds are keys to making Yellow Medicine Watershed farms more sustainable in the short term.

Financial and staff resources would be more efficiently spent on landscape-wide prevention projects (e.g. helping farmers transition to applying soil health principles) in addition to isolated projects that try to cure cumulative, downstream problems (e.g. dams and stream bank stabilizations). Historically, conservation implementation has focused on discrete, engineered projects that treat the symptoms of a significantly altered landscape. In some instances, these projects are necessary to protect costly infrastructure. However, isolated projects alone will not address the root cause of water resource degradation. Instead, landscape-wide changes in field-scale management are most necessary for water quality restoration for all pollutants and stressors.

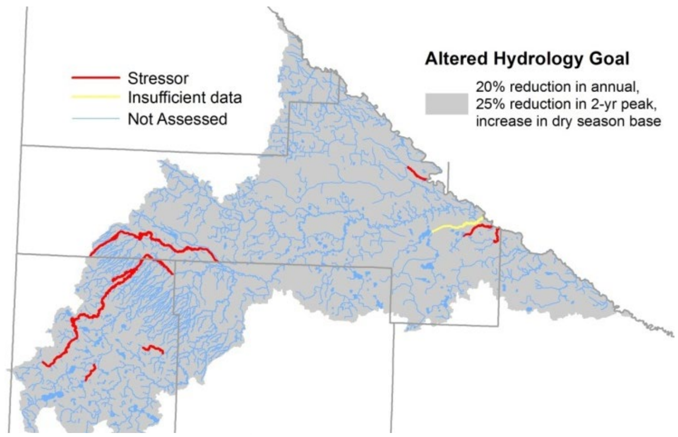
Citizens, local politicians, government staff, community organizations, businesses, and other local leaders have the opportunity to improve the quality of their watershed. By identifying mutually-beneficial goals, local leaders can build a framework to ensure the long-term sustainability of many sectors – farms, businesses, communities and natural resources. The next generation of watershed residents and the watershed's health rely on today's leaders to develop sustainable solutions.

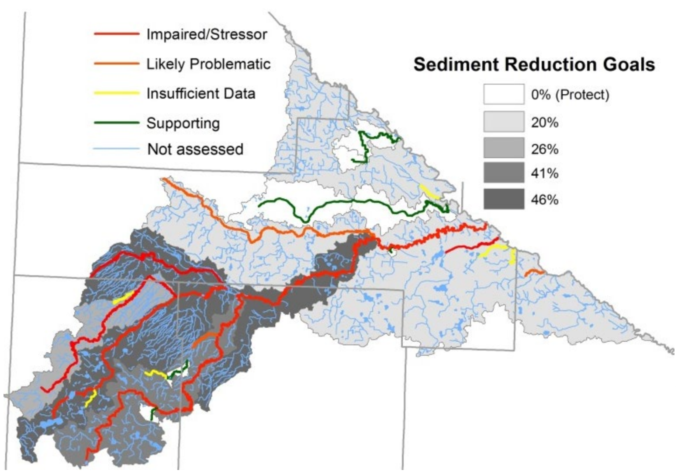
Executive Summary

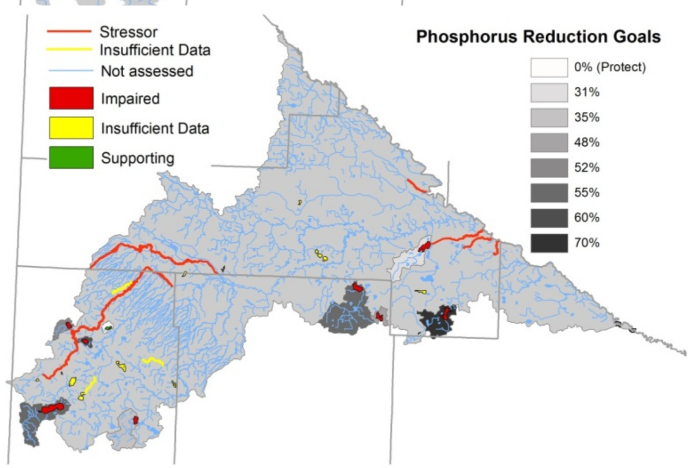
The Yellow Medicine Watershed in southwestern Minnesota drains over 700,000 acres into the Minnesota River. This Watershed Restoration and Protection Strategies (WRAPS) report summarizes the condition of surface water resources (i.e. lakes and streams), the scale and types of changes needed to restore and protect waters, and options and available tools to prioritize and target conservation work on the landscape in the Yellow Medicine Watershed. The work summarized in the WRAPS report will be expanded and revised every 10 years as part of the state of Minnesota's "Watershed Approach".

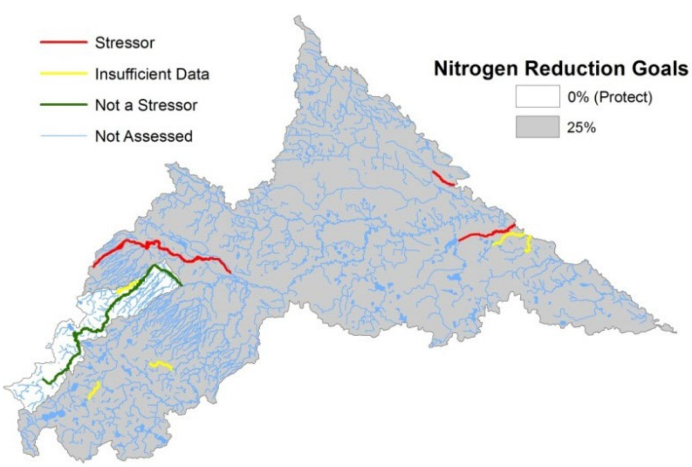
The identified pollutants and stressors in the Yellow Medicine are: altered hydrology, sediment, phosphorus, nitrogen, bacteria, habitat and dissolved oxygen (DO). The figures on this page illustrate the stream reaches and lakes found to be impaired or supporting the water quality standards along with the estimated reductions needed for the identified pollutants/stressors. Note that only a fraction of the total water bodies was tested or assessed. This does not imply that pollutants/stressors are only problematic where identified as impaired. Rather, the high percent of tested waters that were found to have problems indicates that the pollutant/stressor is likely common across the watershed.

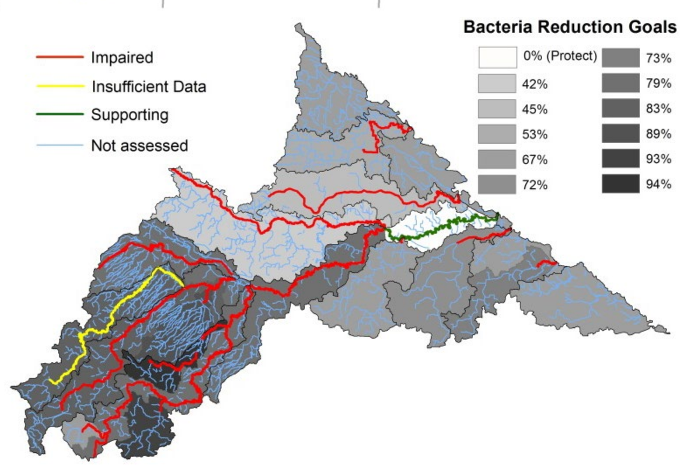
Additional information on the current status, known trends, reduction goals, and 10-year interim reduction targets is presented in Section 2.2 and is summarized in Table 12A.



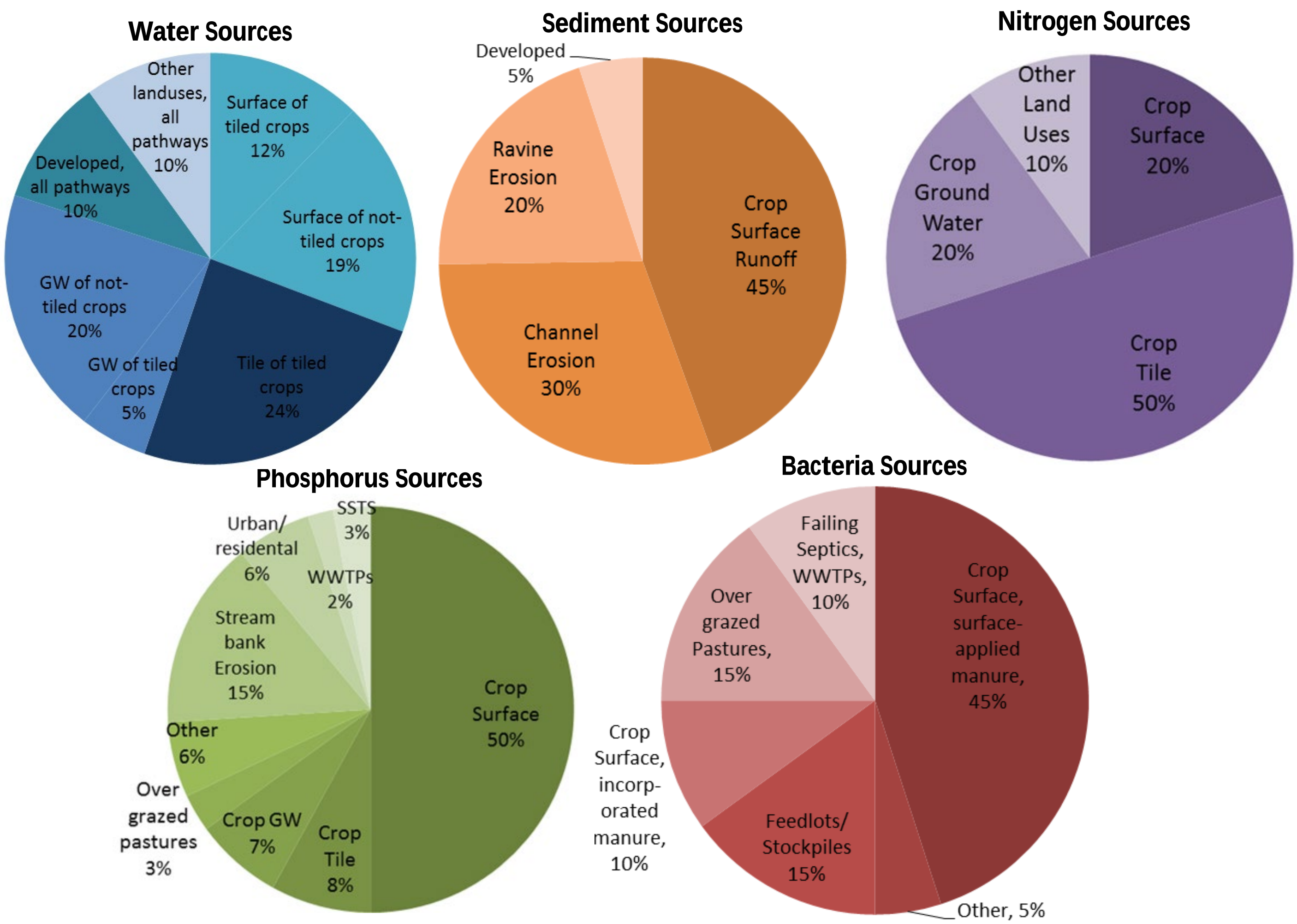








For each of the identified pollutants and stressors, a source assessment process was undertaken. Source assessment work focused on the land use and pathway delivering the pollutant/stressor to water. Multiple lines of scientific evidence on sources were compiled (summarized in Appendix 4.11). The "WRAPS Workshop Team", composed of local and state conservation staff (see inside front cover for participants), reviewed the multiple lines of scientific evidence and developed a source assessment for the Yellow Medicine Watershed based on this evidence, applying their professional judgment and local knowledge of the watershed. The final source assessments are presented in pie charts below. Refer to Section 2.2 for more details on source assessment work.



A conceptual description of how to meet water quality goals is presented in Table 12A, based on model analyses (summarized in Appendix 4.10 and 4.8). Because the timeline to meet water quality goals was estimated by the WRAPS Workshop Team to be roughly 50 years, and the full range of technologies, programs, and markets is not established to support the wide scale changes needed to meet the goal, the specific practices and adoption rates were not calculated to meet the goal. Instead, the practices and adoption rates to meet the 10-year water quality targets are presented for the watershed as a whole in Table 12B. The 10-year targets are most useful for local planning efforts because local plans are done every 10 years.

The development of the practices and adoption rates to meet the 10-year targets (presented in Table 12B) relied primarily on the WRAPS Workshop Team, but involved additional numeric modeling with a spreadsheet tool. The practices and the relative (higher to lower) adoption rates were developed by the WRAPS Workshop Team after review of best management practice (BMP) effectiveness data (summarized in Section 3.1, and Appendices

4.8, 4.9, and 4.10). Then, using the source assessment and BMP reduction efficiencies, the spreadsheet tool was developed and used to estimate the numeric adoption rates needed to meet the 10-year water quality targets for all pollutants and stressors. The WRAPS Workshop Team developed the responsibilities presented in Table 12B. The spreadsheet tool was also used to estimate the relative effectiveness of practices. An excerpt of this table is presented below. Refer to the full table and the associated key for details.

Land use/Source Type	**Watershed Restoration and Protection Strategies** estimated to meet 10-year target at specified adoption rates	**Adoption Rate**		**Pollutants/ Stressor** addressed by strategy & relative effect of strategy on water quality goal per treated acre					
		% watershed to newly adopt (treated area)	Acres to newly adopt (treated acres)	Flow	TSS	Phosphorus	Nitrogen	Bacteria	Habitat**
Cultivated Crops	Nutrient management (for P & N)	10%	70,700			o	X		
	Cover crops	5%	35,400	x	X	o	X	X	-
	Conservation tillage/residue management	5%	35,400	x	x	o	x	o	-
	Buffers, border filter strips*	5%	35,400	-	o	o	-	o	x
	WASCOBS, terraces, flow-through basins (for surface	5%	35,400	-	x	o	-	-	-
	Grassed waterway*	2%	14,100	-	x	-	-		-
	Treatment wetland (for tile drainage system)*	2%	14,100	-		-	X		-
	Crop rotation (including small grain)	2%	14,100	o	o	-	o		-
	Alternative tile intakes*	1%	7,100		x	o			
	Wood chip bioreactor*	1%	7,100			-	x		
	Saturated buffers*	1%	7,100	-		-	x		-
	Controlled drainage, drainage design*	1%	7,100	-		-	x		-
	Restored wetlands	0.5%	3,500	X	X	x	X	X	x
	Contour strip cropping (50% crop in grass)	0.5%	3,500	x	X	x	X	x	-
	Improved manure application, better setbacks & trainin	0.5%	3,500	o		o	x	X	-
	Conservation cover	0.1%	700	X	X	X	X	X	x
	Extended retention (culvert design)*	0.1%	700	-	x	-	-		-
	Side inlet control to ditch (w serious erosion)*	0.1%	700		x	o			
	Two stage ditch*	0.1%	700	-	o	-	o	-	-

Information for local conservation planners, staff, and leadership to prioritize regions and practices is summarized in Section 3.3. The conditions, reduction and protection goals, modeled subwatershed pollutant yields, and other analyses presented in the report are key tools for prioritizing. Additional prioritizing and targeting work via the One Watershed, One Plan (1W1P) planning process should develop local priorities that consider surface water quality in addition to other priorities. Tools available and the tool usefulness for targeting work are summarized in Appendices 4.13 and 4.14.

Legislative Requirements

There are specific legislative definitions and requirements associated with legislation on WRAPS (ROS 2013). This table is provided to help reviewers ensure those requirements are adequately addressed.

114D.26 Section	Description	Location in WRAPS report
(1)	impaired and supporting waters	Section 2.2, Status subsections
(2)	biotic stressors	
(3)	watershed modeling summary	Section 2.2, Sources subsections; Appendix 4.10
(3)	priority areas	Section 3.3, Prioritizing and Targeting subsection
(4)	NPDES-permitted point sources	Appendix 4.17
(5)	non-point sources	Section 2.2, Sources subsections; Appendix 4.10
(6)	current pollutants and load reductions	Table 12A, pollutants/stressors, goals
(7)	monitoring plan	Section 1.4, Monitoring Plan
(8)	strategies to meet pollutant reductions	Tables 12A General Strategies and 12B Strategies
(i)	water quality parameter of concern	Tables 12A and 12B, Pollutants/Stressors
(ii)	current conditions	Table 12A, Current Known Status
(iii)	water quality goals and targets	Table 12A, Goal and 10-year Target
(iv)	strategies by parameter	Tables 12A and 12B, Strategies
(iv)	strategy adoption rates	Tables 12A, Rough Estimate..; Table 12B Adoption Rate
(v)	timeline to achieve water quality targets	Table 12A, Years to Goal
(vi)	responsibility	Table 12B, Responsibility
(vii)	timeline and 10-year milestones	Table 12A, Years to Goal and 10-year Target

Legislation also requires that the WRAPS and TMDL reports have a public comment period. An opportunity for public comment on the draft WRAPS report was provided via public notice in the State Register from May 16, 2016 to June 15, 2016.

1 Background Information

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 (Figure 1). In each cycle of the Watershed Approach, rivers, lakes and wetlands across the watershed are monitored, pollution sources are identified, needed pollutant reductions are calculated, water body restoration and protection strategies are developed, and progress is tracked and reported as conservation practices are continually implemented. The Watershed Approach provides information to local partners, landowners, and other stakeholders to prioritize and target conservation practice implementation – to strategically address water quality in the watershed.

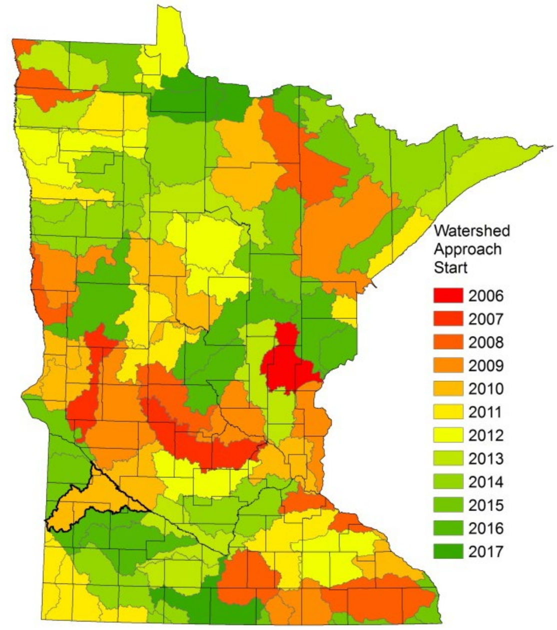


Figure 1: In the "Watershed Approach", approximately eight major watersheds are evaluated every year. After 10 years, a watershed is re-visited to see how water quality has changed and to improve and expand work done in previous years. Work in the Yellow Medicine Watershed (in bold) started in 2010.

The ***purpose*** of this WRAPS report is to summarize work done in this first application of the Watershed Approach in the Yellow Medicine Watershed, which started in 2010. The ***scope*** of the report is the restoration and protection of water bodies to meet aquatic life and aquatic recreation beneficial uses, as currently assessed by the MPCA. The primary ***audience*** for the WRAPS report is local planners, watershed policy and program decision-makers, and conservation practice implementers; watershed residents, governmental agencies, and other stakeholders are also the intended audience. The WRAPS report is intended to concisely summarize 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 Yellow Medicine Watershed (Figure 2) is part of the Hawk-Yellow Medicine Major (HUC-8, [USGS 2014]) Watershed, draining 707,000 acres in southwest Minnesota. The Yellow Medicine Watershed includes the Yellow Medicine River and several direct tributaries to the Minnesota River. In total, this area contains more than 1,700 miles of streams and ditches and 16,000 acres of lakes. The most upstream portion of the watershed originates in the Prairie Couteau, a steep area left untouched by the glaciers that scraped and flattened much of Minnesota. Rivers flow downstream through the Prairie Couteau's rolling hills and lakes, down the prairie escarpment, and meander through the flat, prairie lands before abruptly descending through the carved knick zone (Gran et al. 2011b) just before reaching the Minnesota River.

Roughly 15,000 people live in the watershed, 9,000 of which live in 12 rural towns including Cottonwood, Clarkfield, Minnesota, and Ivanhoe. The watershed also contains the Upper Sioux Community and portions of five counties: Yellow Medicine, Lincoln, Lyon, Redwood and Lac qui Parle. In addition to the county and tribal jurisdictions in the watershed, the Yellow Medicine River Watershed District (YMRWD) has jurisdiction within the statutory watershed boundary.

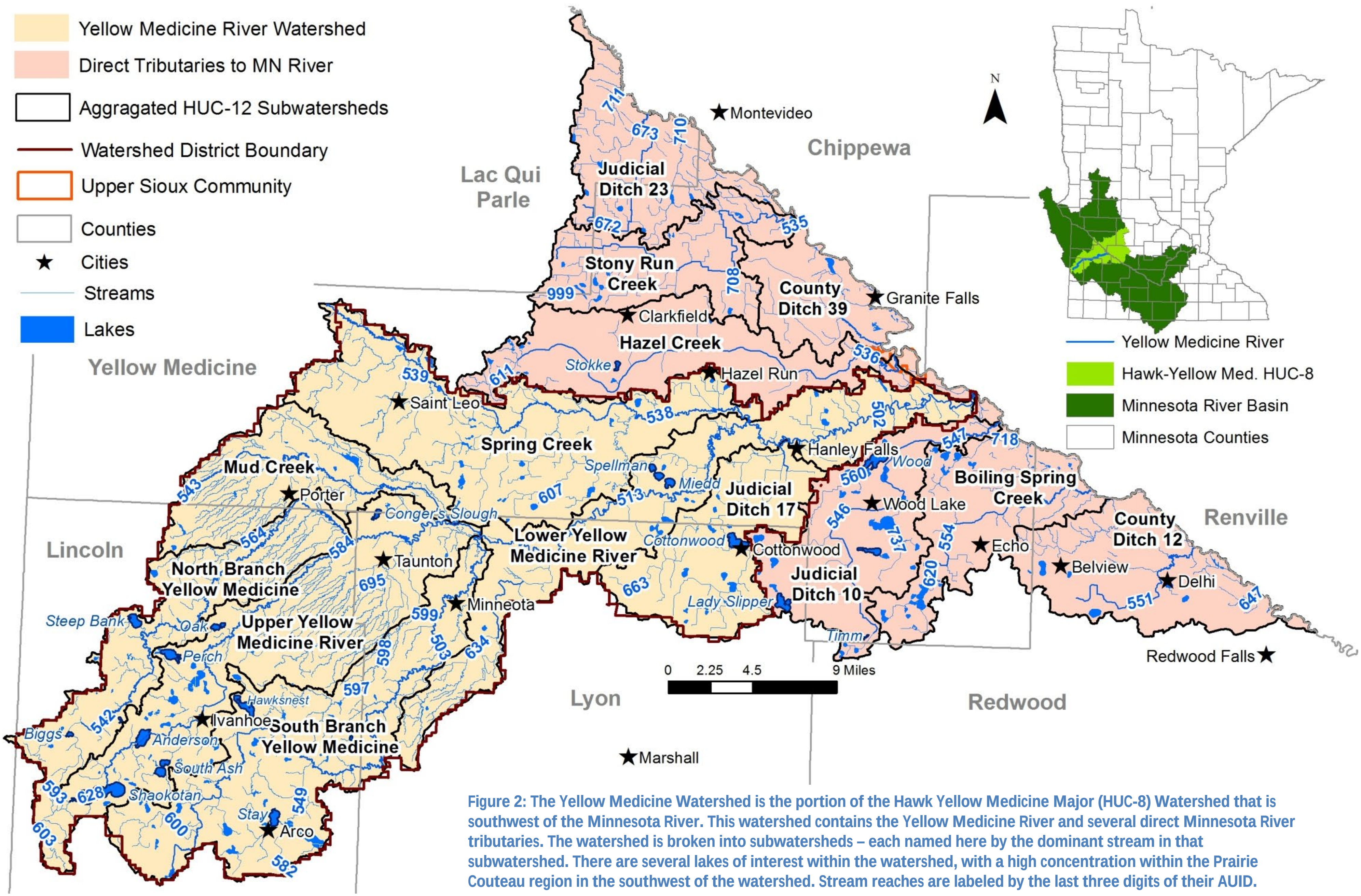


Figure 2: The Yellow Medicine Watershed is the portion of the Hawk Yellow Medicine Major (HUC-8) Watershed that is southwest of the Minnesota River. This watershed contains the Yellow Medicine River and several direct Minnesota River tributaries. The watershed is broken into subwatersheds – each named here by the dominant stream in that subwatershed. There are several lakes of interest within the watershed, with a high concentration within the Prairie Couteau region in the southwest of the watershed. Stream reaches are labeled by the last three digits of their AUID.

1.3 Watershed Characteristics that Impact Water Quality

Section 1.3 is intended to provide a conceptual understanding of both the natural conditions and human uses that influence water quality. Specific pollutant source identification work is presented in Section 2.

Land use and vegetation typically correlate to water quality: areas with high concentrations of cultivated crops, industry, people, or animals tend to have poor water quality when impacts are not optimally managed. Similarly, areas with high concentrations of natural perennial vegetation (forest, grasses, wetlands, etc.) typically correlate to better water quality.

Today, the Yellow Medicine Watershed landscape is dominated by cultivated crops with small portions of grassed and developed areas (Figure 3). The watershed contains roughly: 150,000 feedlot animal units (AUs), 2,000 wildlife AUs, and 15,000 humans. There are a dozen small wastewater treatment facilities.

Prior to European settlement, however, the landscape was covered by prairie and wetlands (Figure 4).

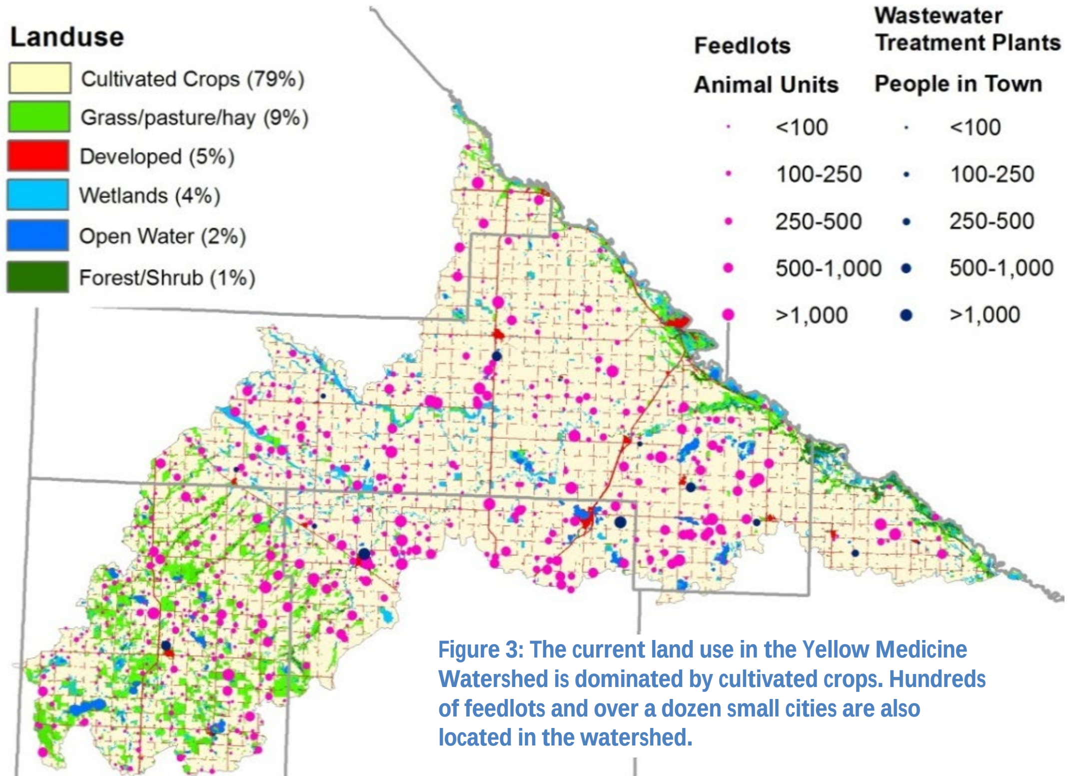


Figure 3: The current land use in the Yellow Medicine Watershed is dominated by cultivated crops. Hundreds of feedlots and over a dozen small cities are also located in the watershed.

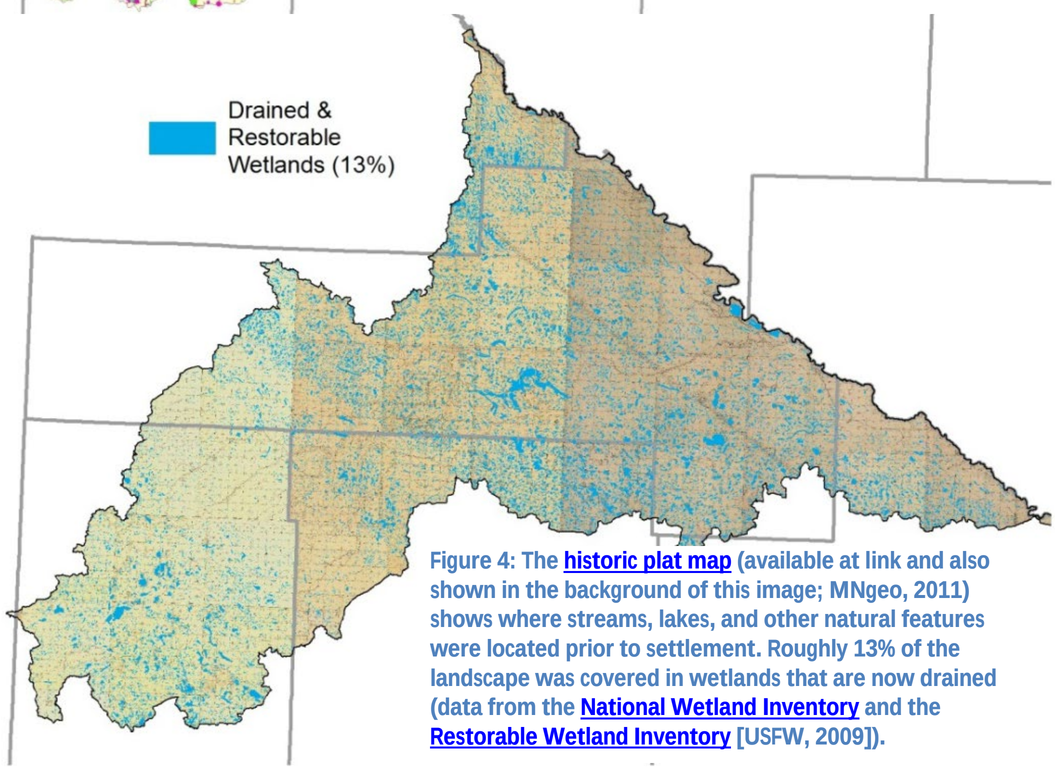


Figure 4: The historic plat map (available at link and also shown in the background of this image; MNgeo, 2011) shows where streams, lakes, and other natural features were located prior to settlement. Roughly 13% of the landscape was covered in wetlands that are now drained (data from the National Wetland Inventory and the Restorable Wetland Inventory [USFW, 2009]).

According to an analysis of the restorable and inventoried wetlands, roughly 17% of the watershed was once covered with wetlands, but extensive drainage has left only 4% of the watershed in wetlands today. Historic plat maps (currently in image format) illustrate the streams, wetlands, and other natural features that existed prior to European settlement.

Table 1: Most of the watershed has relatively flat slopes. However, nearly 20% of the watershed has slopes over 5%. The higher the slope, the more likely erosion is to occur.

Slope (%)	Watershed Area
0	1.3%
0-1	18.5%
1-3	43.8%
3-5	18.5%
5-8	9.4%
8+	8.5%

High slopes

are areas with abrupt elevation changes and can make soils more prone to erosion, especially when vegetation or hydrology is disturbed. In the Yellow Medicine Watershed, much of the watershed has higher slopes (Table 1). An aerial view (Figure 5) along with a profile view (Figure 6) of the watershed illustrates how elevation changes across the watershed. From the highest headwaters to the lowest point at the Minnesota River confluence, the watershed drops roughly 900 feet. The elevation changes abruptly in the Prairie Couteau region (about a 650-foot drop from distance 0 to 20 miles), becoming gentle and fairly continuous through much of the watershed (about a 150-foot drop from distance 20 to 50 miles), and again changes abruptly through the knickzone region (about 100 foot drop from distance 52 to 55 miles).

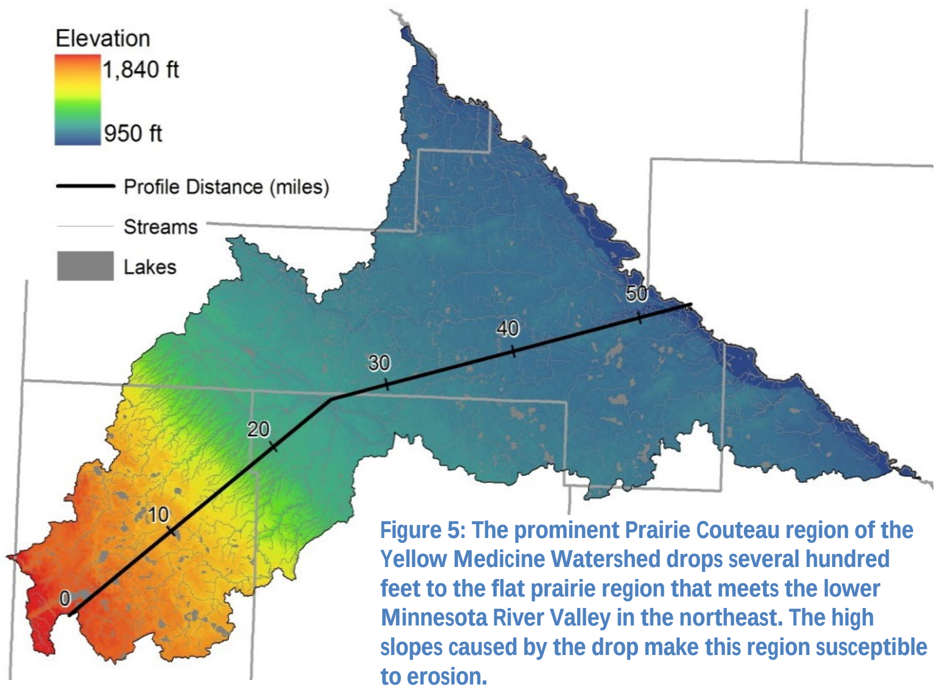


Figure 5: The prominent Prairie Couteau region of the Yellow Medicine Watershed drops several hundred feet to the flat prairie region that meets the lower Minnesota River Valley in the northeast. The high slopes caused by the drop make this region susceptible to erosion.

Soil types and properties

affect water quality in many ways. The fine-loamy soils that dominate the watershed can be prone to erosion, particularly on higher sloped regions or in areas with disturbed vegetation. The watershed soils tend to be naturally poorly drained in the flat region of the watershed. Because of this poorly drained natural condition, much of the watershed's natural hydrology has been altered by adding artificial drainage to make settlement and farming possible. When unmitigated, artificial drainage (such as tile drainage and urban storm water) can increase the total amount of water leaving the landscape,

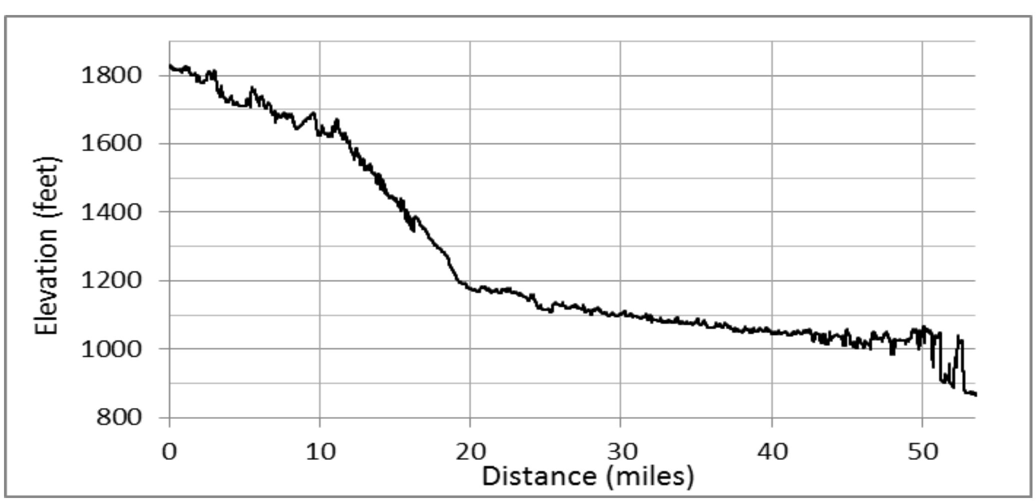


Figure 6: The watershed elevation drops from about 1840 to about 950 feet at the confluence of the Minnesota River. The slope of the watershed is drastically higher in the Prairie Couteau region (distance 0-20) and in the knickzone region (distance 52-55).

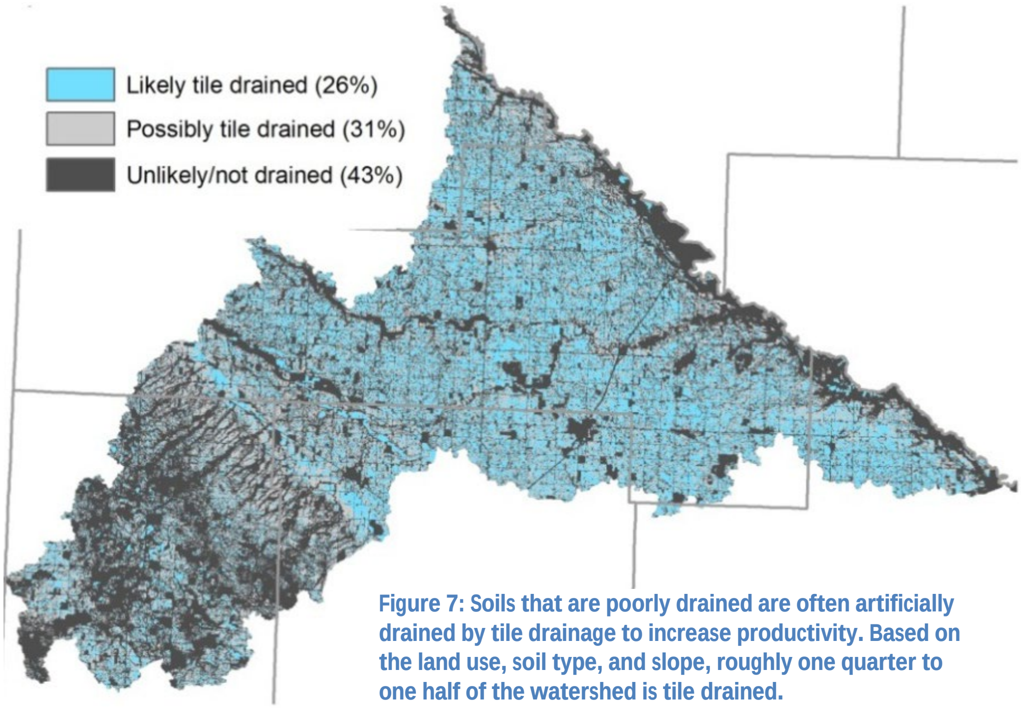


Figure 7: Soils that are poorly drained are often artificially drained by tile drainage to increase productivity. Based on the land use, soil type, and slope, roughly one quarter to one half of the watershed is tile drained.

accelerate the transport of other pollutants to streams and lakes, and impact groundwater recharge. Based on a geographic information system (GIS) analysis, roughly 25% to 50% of the watershed is estimated to be tiled (Figure 7), with higher concentrations in the flat portion of the watershed. While a tile install record is not readily available for comparison, local conservation staff estimates that roughly 50% of the watershed is tiled.

Water table depth
influences water quality. The shallow [water table](#) (DNR 2015b) (Figure 8), interrelated to the poorly draining soils, puts groundwater at higher risk of contamination. Pollutants added to the environment are able to reach the shallow groundwater before being consumed or breaking down. Once pollutants are in the shallow groundwater, the pollutants can travel to and become problematic in deep aquifers (which are the primary supply of drinking water in the watershed), streams, and wetlands.

More information
on the Yellow Medicine Watershed can be found at the *Rapid Watershed Assessment* (NRCS 2010), the *Watershed Health Assessment Framework* (DNR 2013) and the *Nutrient Planning Portal* (MSU 2014).

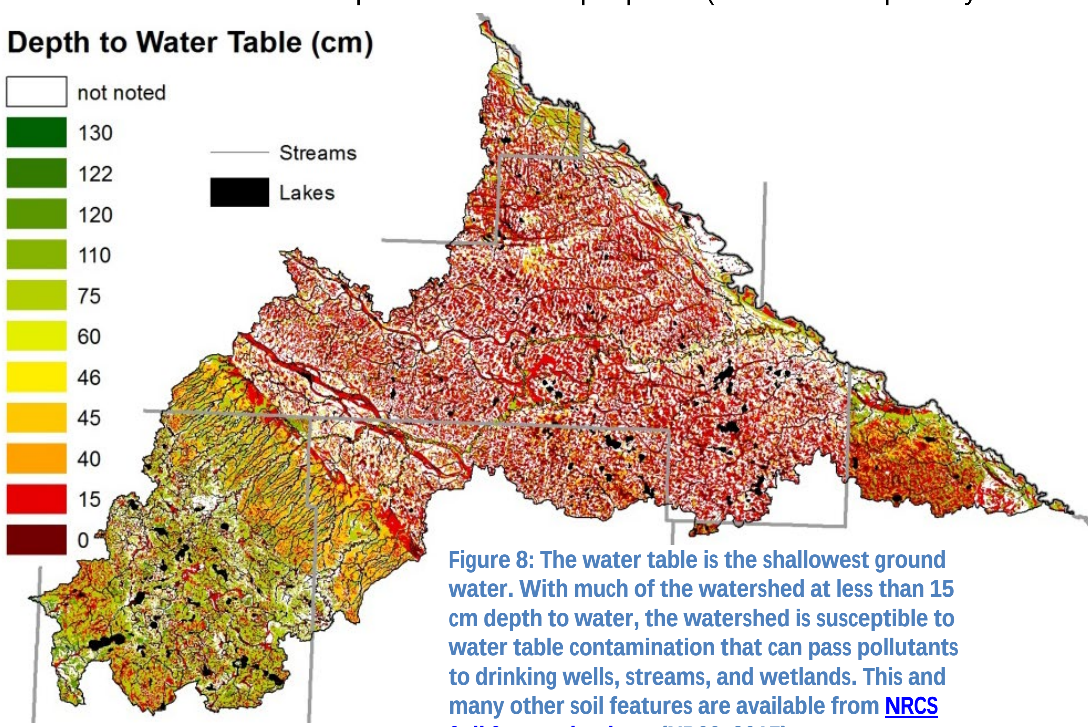


Figure 8: The water table is the shallowest ground water. With much of the watershed at less than 15 cm depth to water, the watershed is susceptible to water table contamination that can pass pollutants to drinking wells, streams, and wetlands. This and many other soil features are available from **NRCS Soil Survey database** (NRCS, 2015).

1.4 Assessing Water Quality

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

Water Quality Standards

Water quality is not expected to be as healthy as it would under undisturbed, "natural background" conditions. However, water bodies are expected to support designated 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 information and data about the safe level of pollutants for different beneficial uses.

Water Quality Assessment

To determine if water quality is supporting its designated use, data on a water body are compared to relevant standards. When pollutants/parameters in a water body exceed the water quality standard, the water body is considered impaired (MPCA 2011a). When pollutants/parameters in a water body meet the standard (when the monitored water quality is cleaner than 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 do not clearly indicate the waterbody condition, an assessment is delayed until further data are collected; this is referred to as an inconclusive or insufficient finding.

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 Yellow Medicine Watershed as part of *Minnesota's Water Quality Monitoring Strategy* (MPCA 2011b). Combined, these programs collect data at dozens of locations around the watershed (Figure 9). Data needs are considered by each program and additional monitoring is implemented when deemed necessary and feasible. These monitoring programs are summarized below:

Intensive Watershed Monitoring (IWM; MPCA 2012a) data provide a periodic but intensive "snapshot" of water quality throughout the watershed. This program collects water quality and biological data at roughly 75 stream and 25 lake monitoring stations across the watershed in 1 to 2 years, every 10 years. Monitoring sites are generally selected to provide comprehensive coverage of the watershed. This work is scheduled to start its second iteration in the Yellow Medicine Watershed in 2020.

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 Yellow Medicine Watershed, there is annual (continuously monitored) site near the outlet of the Yellow Medicine River and two seasonal (spring through fall) subwatershed sites.

Citizen Stream and Lake Monitoring Program (MPCA 2015d) data provide a continuous record of water body transparency throughout much of the watershed. This program relies on a network of volunteers who make monthly lake and river measurements. Roughly 10 volunteer-monitored locations exist in the Yellow Medicine Watershed.

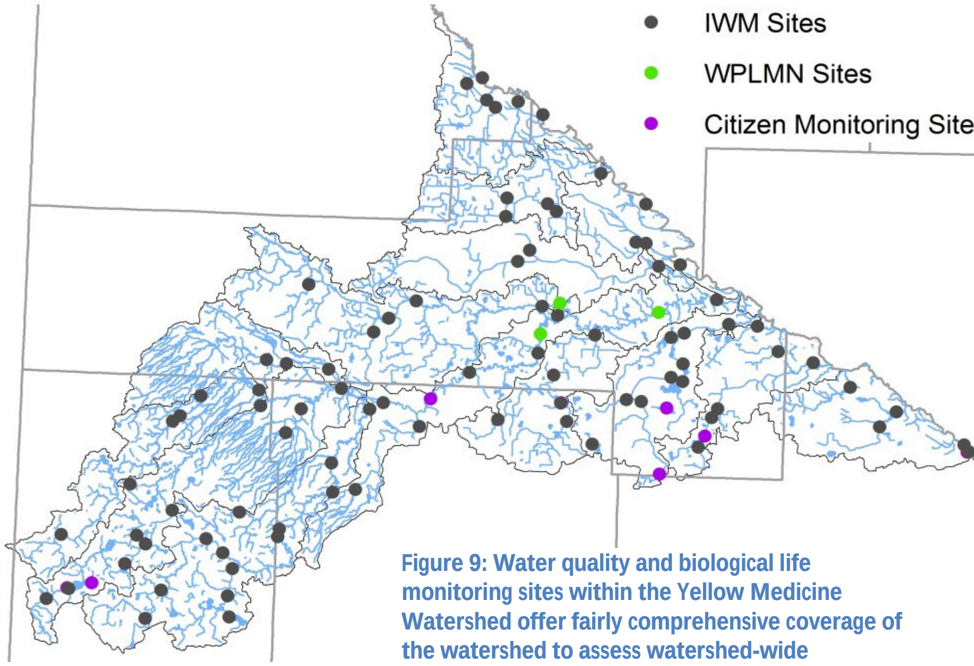


Figure 9: Water quality and biological life monitoring sites within the Yellow Medicine Watershed offer fairly comprehensive coverage of the watershed to assess watershed-wide

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. The HSPF model 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 Yellow Medicine Watershed are available*:*

- *HSPF Model Development and Hydrologic Calibration Report* (Tetra Tech 2011a)
- *HSPF Water Quality Calibration and Validation Report* (Tetra Tech 2011b)
- Model Resegmentation and Extension for Minnesota River Watershed Model Applications (RESPEC 2014a)
- Hydrology and Water Quality Calibration and Validation of Minnesota River Watershed Model Applications (RESPEC 2014b)

These model data provide a reasonable estimate of pollutant concentrations across watersheds. The output can be used to target conservation practices to reduce local or downstream pollutants. However, these data are not used for impairment assessments since monitoring data are required for those assessments. Modeled pollutant and stressor yields are presented in Section 2.2 and modeled landscape and practice changes (referred to as scenarios) are discussed in Section 3.1, summarized in Appendix 4.10. Modeled flow data (along with observed data/samples) was used to calculate the estimated pollution reductions in the TMDL, summarized in Appendix. 4.3.

2 Water Quality Conditions

Section 2 summarizes the conditions of the watershed. The “condition” refers to the water bodies’ ability to support fishable and swimmable water quality standards. Summarized information includes 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. Refer to Appendix 4.1 for a table of all impairments, stressors, and pollutants by stream reach. More information on individual streams and lakes, including water quality data and trends can be reviewed on the Environmental Data Application (MPCA 2015e).

This report covers only impairments to aquatic recreation and aquatic life. Several lakes and stream reaches are impaired for aquatic consumption (due to mercury and PCBs). The *State-wide Mercury TMDL* (MPCA 2015f) has been published and *Fish Consumption Advice* (MDH 2013) is available from the Department of Health.

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 each pollutant and stressor will be examined individually. The four subsections below: status, trends, sources, and goals will be presented for each of the identified pollutants and stressors in Section 2.2.

Status Overview

Generally, impairments to aquatic recreation (swimming) and aquatic life (fish and macroinvertebrates) are widespread in the Yellow Medicine Watershed (Figure 10, red). In other words, most of the streams and lakes do not safely or adequately support swimming or fishing. Only a few stream reaches and lakes are meeting standards (Figure 10, green). Several reaches and lakes need more data to make a scientifically-conclusive finding (Figure 10, yellow).

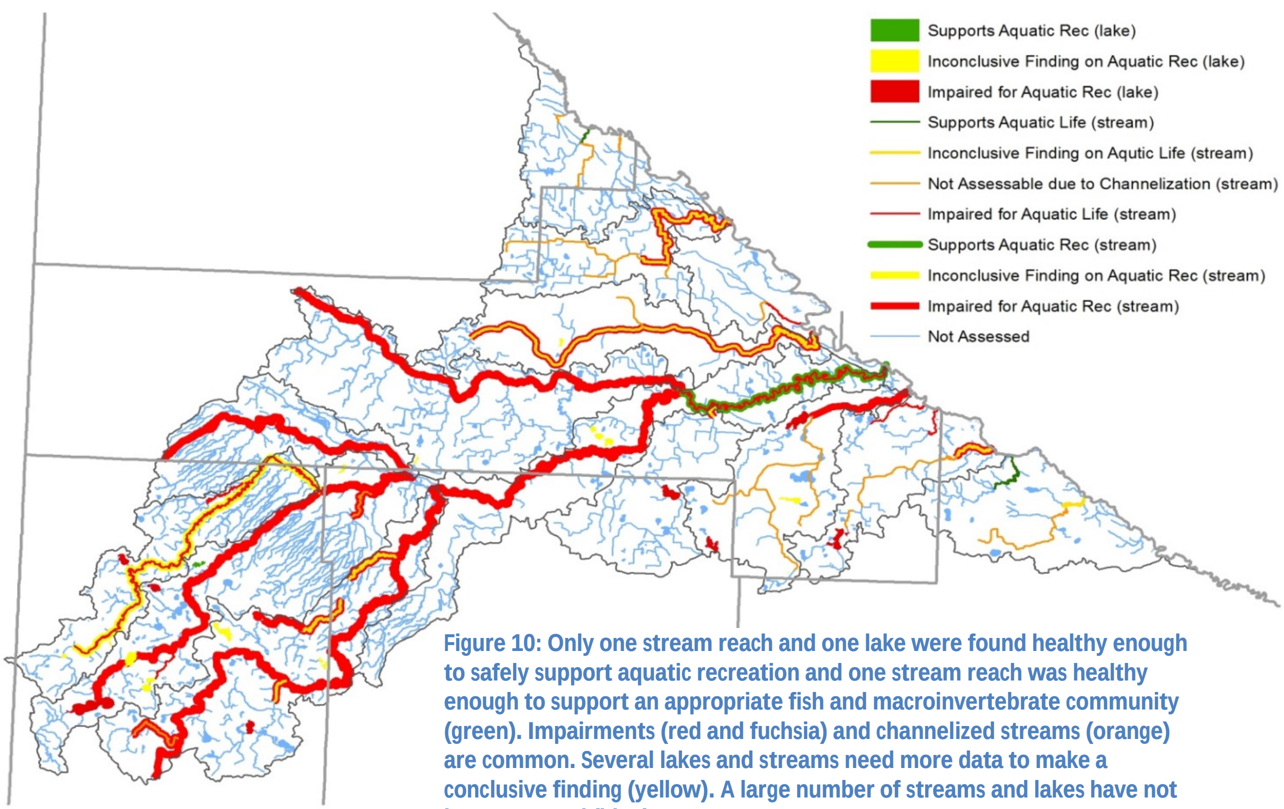


Figure 10: Only one stream reach and one lake were found healthy enough to safely support aquatic recreation and one stream reach was healthy enough to support an appropriate fish and macroinvertebrate community (green). Impairments (red and fuchsia) and channelized streams (orange) are common. Several lakes and streams need more data to make a conclusive finding (yellow). A large number of streams and lakes have not been assessed (blue).

Water bodies are monitored for specific parameters to make an assessment. For aquatic recreation assessment, streams are monitored for bacteria and lakes are monitored for clarity and algae-fueling phosphorus. For aquatic life assessment, streams are monitored for both aquatic life populations and pollutants that can harm these populations. When monitored parameters (bacteria, phosphorus, fish populations, etc.) do not meet the water quality standard, the water body is impaired. The specific pollutants and/or stressors that are causing the impairments are identified in Section 2.2.

Of the 42 lakes greater than 100 acres in the watershed, 23 were monitored for aquatic recreation assessment and the results were:

- 8 impaired
- 1 supporting
- 14 inconclusive

Of the 114 stream reaches in the watershed, 18 were monitored for aquatic recreation assessment and the results were:

- 16 impaired
- 1 supporting
- 1 inconclusive

Of the 114 stream reaches in the watershed, 40 were monitored for aquatic life assessment and the results were:

- 14 impaired
- 2 supporting
- 8 inconclusive
- 16 deferred

The deferred stream assessments were due to channelization and will not be assessed until the standards for modified streams are finalized through the tiered aquatic life use framework (TALU; MPCA 2015g). At the time monitoring occurred in this watershed, lakes were not assessed for aquatic life.

Nine of the fourteen stream reaches with an aquatic life impairment were impaired due to low and/or imbalanced fish or macroinvertebrate populations, which are referred to as "bio-impaired". The causes, or "stressors", of these bio-impairments were identified as detailed in the *Yellow Medicine River Watershed Biotic Stressor Identification* report (MPCA 2013a). The identified stressors were: altered hydrology, high phosphorus, lack of habitat, low DO, high turbidity, and high nitrates. Each of these stressors along with the identified pollutants will be discussed in Section 2.2. See Appendix 4.2 for more detail on bio-impaired streams.

Trends Overview

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

Statistical trends in water quality parameters cannot be observed without a substantial data set. Furthermore, trends in environmental data can be difficult to identify due to the "noisy" nature of environmental data – in other words, weather variation can cause large variations in environmental data and make trends difficult to identify.

The *Minnesota River Basin Statistical Trend Analysis* (MSU 2009b) analyzed statistical water quality trends. At this time, few trends in water quality data have been observed in the Yellow Medicine Watershed. As more data is collected through the WPLMN and Citizen Monitoring programs, additional trends in water quality in the Yellow Medicine Watershed should emerge. Trends in individual pollutants and stressors are presented when known.

Sources Overview

Pollutants and stressors are mostly from non-point (MPCA 2013d) sources in the Yellow Medicine Watershed (see Appendices 4.17 and 4.18 for a summary of point source contributions and total watershed loads). There are, however, a dozen wastewater treatment plants (WWTPs), several construction projects, and many larger feedlots that require National Pollutant Discharge Elimination System (NPDES) Permits (Permit) (EPA 2014a). These Permit holders are identified in Appendix 4.19.

To determine the non-point pollutant and stressor contributions, multiple lines of evidence were compiled (see summary in Appendix 4.11). The compiled information included state and basin-level reports, model studies, TMDLs, and field and watershed data. Because this information did not always apply directly to the Yellow Medicine River Watershed (for instance, basin-level data applies to the larger Minnesota River Basin as a whole), the WRAPS feedback team was asked to review and use this information, applying their professional judgement and local knowledge, to develop source assessments specifically for the Yellow Medicine 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.

Goals & Targets Overview

Water quality goals aim to enable water bodies within the watershed to meet the water quality standards and also enable downstream waters to meet water quality goals (e.g. Lake Pepin and Gulf Hypoxia goals). The goals may be reassessed in future iterations of the Watershed Approach due to changes in water body conditions reflected by new data or due to changes in standards or state-wide goals. Interim water quality "10-year targets" are set and allow opportunities to adaptively manage implementation efforts. With each iteration of the Watershed Approach, progress will be measured, goals will be reassessed, and 10-year targets will be set.

Goals are illustrated in Section 2.2 for each pollutant and stressor, where darker colors of grey correspond to higher pollutant/stressor reductions and lighter colors correspond to lower reductions, with white illustrating areas in need of protection. The maps illustrate both the watershed-wide goal and individual lake or stream reach subwatershed goals. The watershed-wide goals are calculated using standards and/or other goals as specified. Lake and subwatershed goals are from the TMDL (see Appendix 4.3 for table of reductions). Goals for subwatersheds without ample data to calculate an individual goal reflect the watershed-wide goal.

2.2 Identified Pollutants and Stressors

Section 2.2 investigates each of the pollutants and stressors identified as the cause of the impairments. The presented information includes: the extent of the pollutant/stressor, the sources or causes of the pollutant/stressor, what areas may be contributing higher amounts of pollutant/stressor, known trends in the pollutant/stressor, and the amount of pollutant/stressor reduction that is necessary to meet water quality and downstream goals.

Often times, pollutants and stressors, along with their causes or sources, 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. For instance, degraded habitat is a commonly identified stressor; the cause of degraded habitat is commonly excess sediment; the cause of the excess sediment is commonly stream bank erosion; the cause of the stream bank erosion is commonly altered hydrology, etc.

The information in this section is a compilation of many scientific analyses and reports. Information on the pollutants and stressors is summarized from the *Monitoring and Assessment Report* (MPCA 2013e) and the

[Stressor ID Report](MPCA 2013a); the reader should reference those reports for additional details. Information on the necessary pollutant reductions is summarized from *Total Maximum Daily Load* (TMDL) studies (MPCA 2013b) and from additional studies and analyses as noted. Completed TMDLs include the draft Yellow Medicine Watershed TMDL (MPCA 2016) produced as part of the new Watershed Approach and public noticed with this WRAPS, and older TMDLs: *Lake Shaokotan Phosphorus TMDL* (MPCA 2014a) and *South Branch Yellow Medicine Fecal Coliform TMDL* (MPCA 2005).

Altered Hydrology

Altered hydrology can directly harm aquatic life by affecting the amount of water in the stream; too little and too much stream flow impact aquatic life. Furthermore, altered hydrology accelerates the movement and amount of other pollutants and stressors (nutrients, sediment, etc.) in water bodies.

Hydrology (USGS 2014b) is the study of the amount of and way that water moves through the landscape. Altered hydrology refers to changes in hydrologic parameters including: stream flow, precipitation, drainage, impervious surfaces, wetlands, stream paths, vegetation, soil conditions, etc. Hydrology is interconnected in a landscape; when changes are made to one hydrologic factor, there are responses in other hydrologic factors. For instance, tile drainage quickly removes ground water from the soil profile, increasing the total volume and timing of water inputs to rivers. Changes in stream flow are symptoms of this and other changes in hydrologic parameters.

Table 2: Stream reaches assessed for altered hydrology

Stream	Reach AUID	Assessment
Yellow Medicine River, NB	542	x
Mud Creek	543	x
Judicial Ditch 10	547	?
Unnamed creek	564	x
Unnamed creek	595	x
Unnamed creek	694	x
County Ditch 39	713	x
County Ditch 2	717	x
Unnamed creek	718	x

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

Status

Altered hydrology was the most commonly identified stressor to aquatic life in the Yellow Medicine Watershed, found to affect eight of nine investigated stream reaches (Table 2). Both high and low stream flow conditions were identified as problematic in the watershed. Altered hydrology is only investigated when a bio-impairment is identified, but the sources of altered hydrology (discussed later in this section) are common across the watershed. Therefore, altered hydrology is likely negatively impacting water quality watershed-wide, despite being identified as a stressor in only select locations.

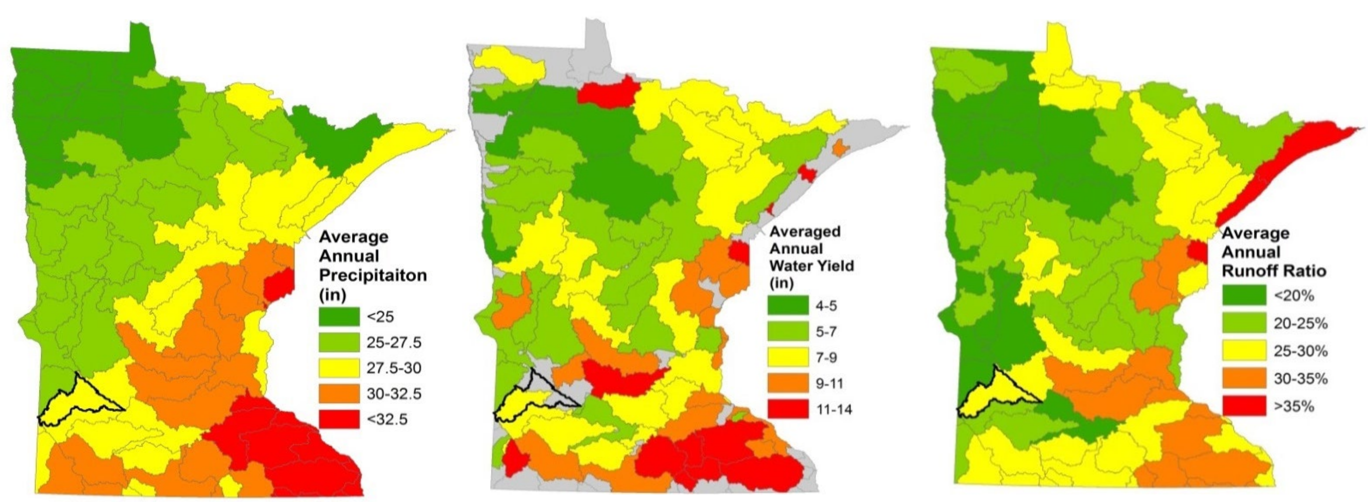


Figure 11: Precipitation, water yield - the amount of river flow per land area, and the runoff ratio - the percent of rain that runs off the landscape through river flow, are hydrologic parameters. Precipitation is a result of climatic and weather features. The water yield, however, is influenced by precipitation but also by a myriad of hydrologic factors including the slope, soil types, long-term storage, etc. These data are for 2008-2012 from the WPLMN and State of MN climatology (DNR 2015c).

From a state-wide perspective, the Yellow Medicine Watershed has a moderate amount of precipitation, runoff, and runoff ratio, which is the percentage of precipitation that ends up as stream flow (Figure 11). These hydrologic parameters are useful data for tracking hydrologic status and changes.

Trends

The Yellow Medicine River's flow has roughly doubled and the runoff ratio has increased substantially over the last 80 years. Over this same period, there have been minimal changes in annual precipitation (Figure 12). More detail on hydrology conditions and trends is presented in the *Yellow Medicine River Hydrologic Analysis* (DNR 2015a).

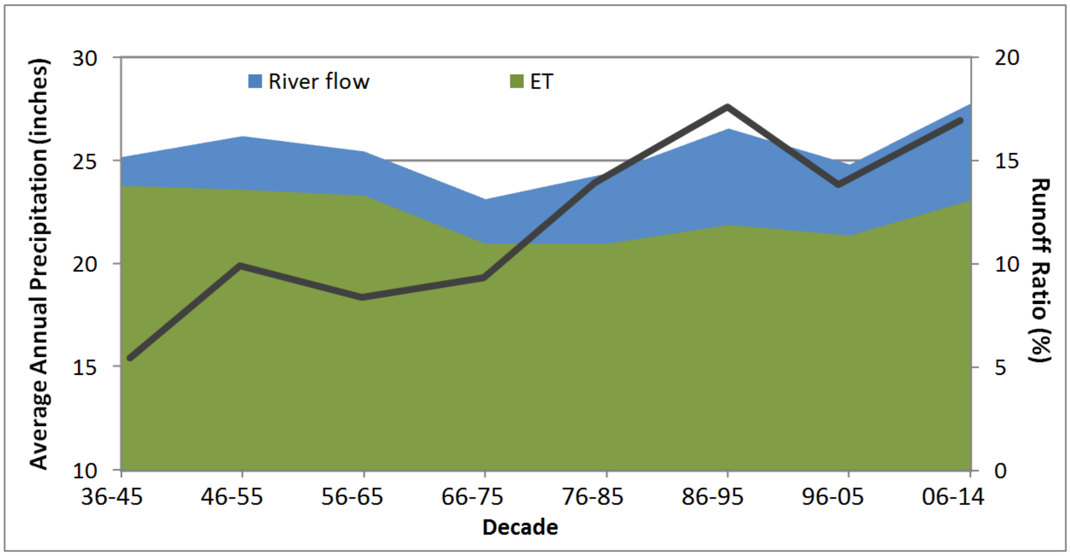


Figure 12: A water budget analysis for the Yellow Medicine River Watershed illustrates that flow (blue band) and the runoff ratio (grey line, which is the amount of precipitation that ends up as river flow) have increased substantially over the last 80 years. Annual precipitation (total height of graph) has increased modestly while evapotranspiration (ET) has decreased modestly. These changes reflect hydrologic changes in the watershed. This analysis assumes net contributions to ground water are zero over the long time step. Data Sources: USGS (2015) and DNR (2015c).

Many of the hydrologic alterations in the Yellow Medicine Watershed occurred in the late-19th through the 20th century, such as the draining and ditching of the landscape and the replacement of prairies by diverse crops and later by monocultures of corn and soybeans. However, hydrologic alterations continue today including: increases in tiled acres, tile density, precipitation intensity, impervious surface, grassland conversion, and loss of Conservation Reserve Program acres (FSA 2013).

Sources

The increase in stream flow between mid to late 20th century is primarily due to human changes as reported in *Twentieth Century Agricultural Drainage Creates More Erosive Rivers* (Schottler et al. 2013). Additional causes of increased stream flow include wetland loss, precipitation changes, and decreased/shifted evapotranspiration (ET) due to cropping changes.

Changes in the amount and timing of ET affect hydrology. Figure 13 illustrates the monthly average ET of crops, grass, and wetlands and the monthly average precipitation. The monthly average precipitation corresponds more closely to the ET of perennial crops such as hay and alfalfa. Contrastingly, corn and soybeans use much less water than precipitation supplies in the spring and much more than is supplied later in the summer. Therefore, a landscape that dominated by corn and soybeans is less synced with historic precipitation patterns and more prone to exacerbate high flows in the spring and low flows in the later summer.

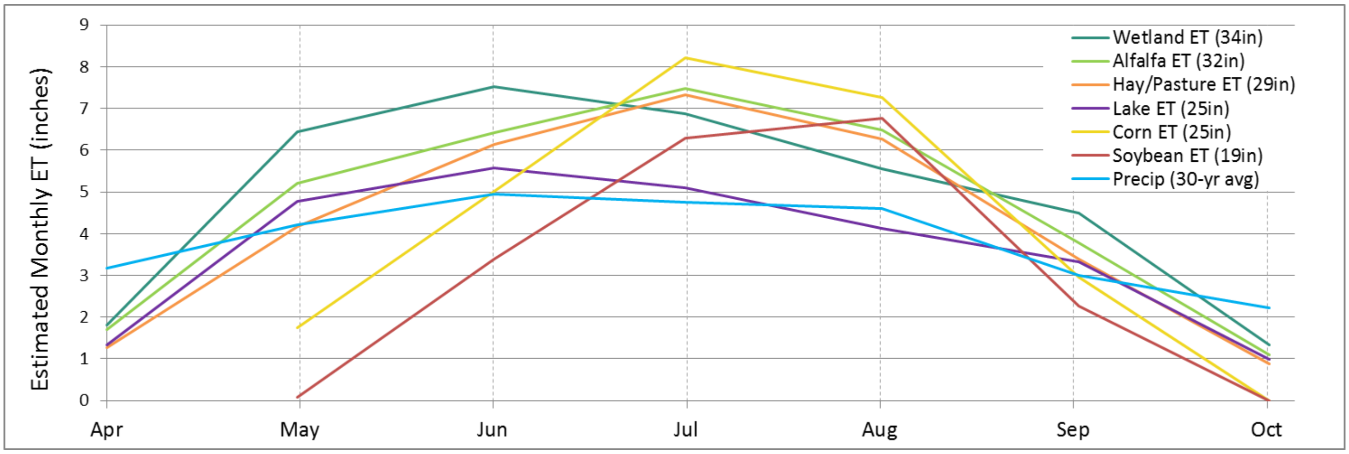


Figure 13: Since European settlement, prairies and wetlands were replaced first by diverse crops and later by corn and soybeans. The total annual ET rates (indicated in the figure legend) of these replacement crops are smaller and the timing of ET through the year has shifted. These changes affect the hydrology of the watershed. See Appendix 4.5 for data sources and calculations.

Numeric estimates of the land uses' water delivery to water bodies were created by the WRAPS Workshop Team participants after review of multiple lines of evidence (Appendix 4.11), applying their local knowledge and professional judgement. From that, a water portioning calculator (Appendix 4.12) was developed to estimate the contributions from different pathways from the largest land use, agriculture. Figure 14 shows the results of these analyses.

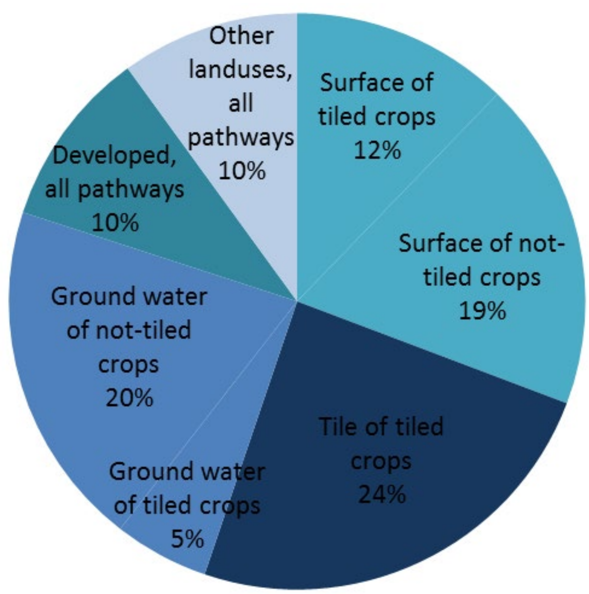


Figure 14: Water that enters water bodies originates as precipitation on the landscape. This figure provides an estimate of the land uses and via which pathway water travels before reaching a water body. The different pathways include: surface runoff, ground water (which here includes any water that moves subsurface that is not intercepted by subsurface drainage), and tile drainage. This analysis assumes 35% of the watershed (45% of crops) is tiled drained.

Areas of the watershed with higher levels of hydrologic alteration were estimated using GIS. By combining several hydrologic factors, an overall estimate of the relative amount of hydrologic alteration per subwatershed was estimated. Hydrologic factors considered in the analysis presented in Figure 14 include: 1) the estimated percentage of land area that is tile drained, 2) the percentage of stream length that has been channelized/artificially straightened, 3) the percentage of watershed area where wetlands were drained, 4) the percentage of land in non-perennial vegetation, 5) the percentage of land covered in impervious surfaces, and 6) the percentage of stream length affected by road crossings. Refer to Appendix 4.4 for analysis details.

Goal & 10-year Target

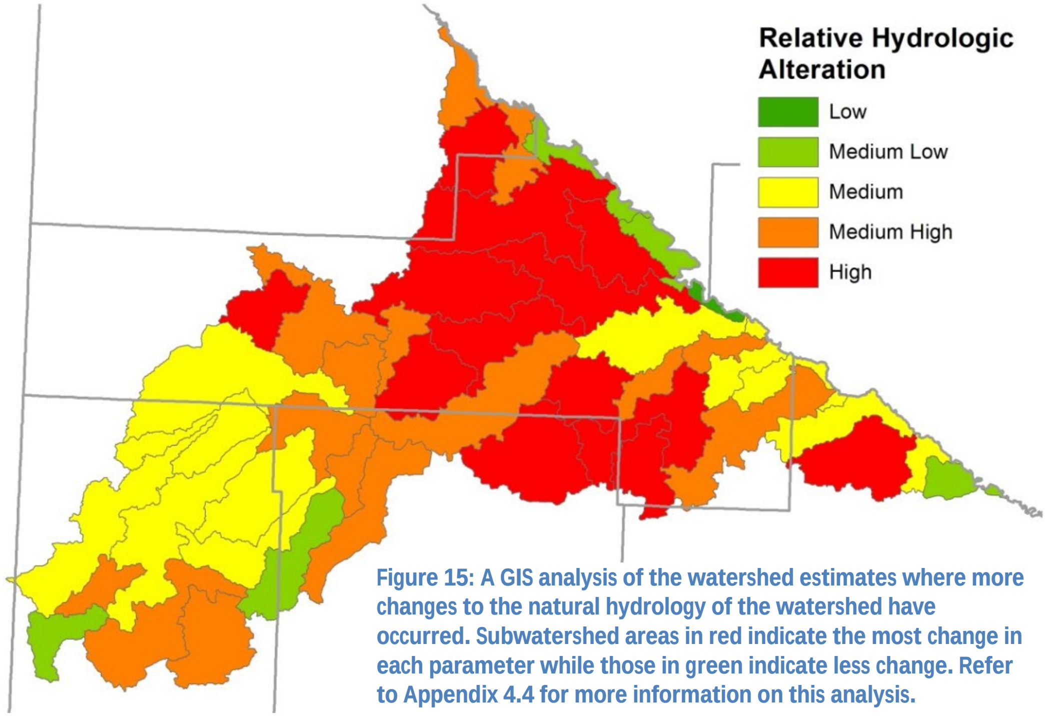


Figure 15: A GIS analysis of the watershed estimates where more changes to the natural hydrology of the watershed have occurred. Subwatershed areas in red indicate the most change in each parameter while those in green indicate less change. Refer to Appendix 4.4 for more information on this analysis.

For watershed conditions to improve, many of the hydrologic alterations that have been made and most of the alterations that continue to be made must be mitigated. Furthermore, the *[Sediment Reduction Strategy for the Minnesota River Basin]* (MPCA 2015h) identifies the need for flow reduction across the Minnesota River Basin.

Based on historic flow trends, the basin-level sediment reduction strategy, and the identified stressors, the selected hydrology goal is: a 20% reduction in annual flow volume (or yield), with a 25% decrease in 2-year peak flow and duration, and an increase in dry season base flow. The goal and known impairments are illustrated in Figure 16. Compared to the 2003-2012 baseline period, this goal represents a drop in the average annual water yield from 4.5 inches to 3.6 inches. A 10-year target was selected by the WRAPS Workshop Team of a 5% reduction in annual/peak flow and a 3% increase in dry season baseflow.

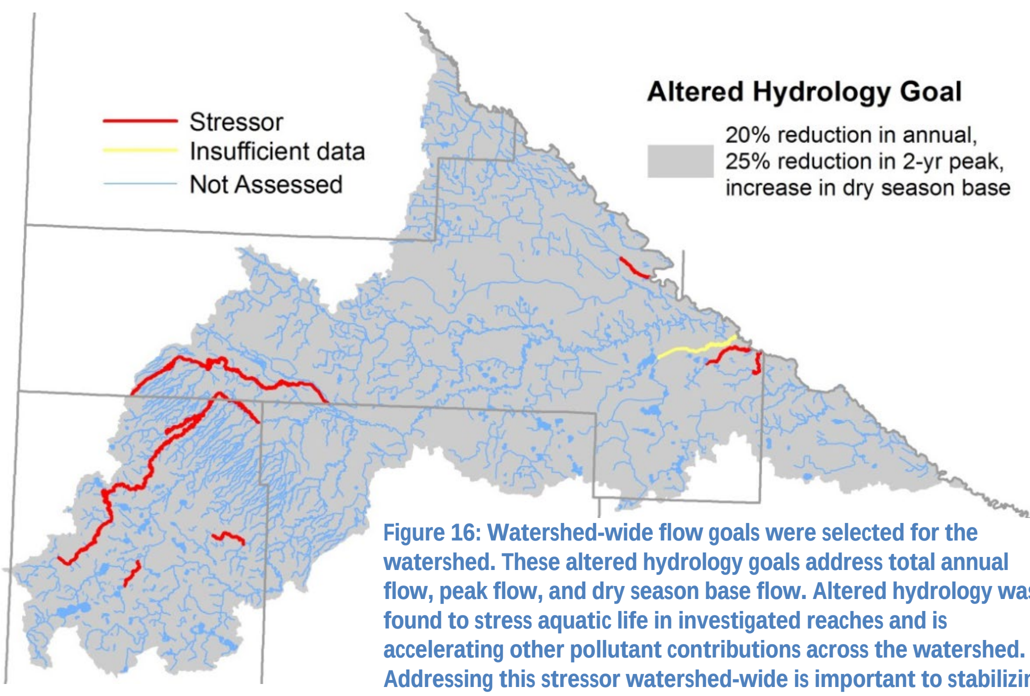


Figure 16: Watershed-wide flow goals were selected for the watershed. These altered hydrology goals address total annual flow, peak flow, and dry season base flow. Altered hydrology was found to stress aquatic life in investigated reaches and is accelerating other pollutant contributions across the watershed. Addressing this stressor watershed-wide is important to stabilizing and improving watershed conditions.

Decreases in the total annual flow volume should focus on decreasing peak flows, shifting flow timing to the dry season, and maintaining the biologically and geomorphologically-important dynamic properties of the natural hydrograph. Strategies to accomplish these tasks must increase ET to reduce the total flow volume 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.

Sediment

Sediment impacts aquatic life by: reducing visibility which reduces feeding, clogging gills which impairs respiration, and smothering substrate which limits reproduction. Sediment also impacts downstream waters used for navigation (larger rivers) and recreation (lakes).

Status

Sediment was identified as a pollutant or stressor across much of the Yellow Medicine Watershed. Seven stream reaches were directly impaired by sediment (i.e. the concentration of sediment exceeded the standard) and three of the nine bio-impaired stream reaches were stressed by sediment (i.e. the fish and macroinvertebrate populations indicate problems attributed to excess sediment). Sediment could not be ruled out as a stressor for any of the bio-impaired stream reaches. Six stream reaches meet standards for sediment. Three additional stream reaches are likely impaired by sediment (but more data is needed to be certain), and several more stream reaches need more data (Table 3).

Data from the outlet of the Yellow Medicine River consistently show that the river concentration often spikes above the 65mg/L standard, with a flow-weighted mean total suspended solids (TSS) concentration of 77 mg/L from 2008-2012. From a statewide perspective (Figure 17), the sediment concentration and yield per acre are moderately high in the Yellow Medicine River Watershed.

Table 3: Stream reaches assessed for sediment

Stream	Reach AUID (last 3 digits)	Assessment
Yellow Medicine River	502	X
Yellow Medicine River, SB	503	X
Yellow Medicine River	513	X
Stony Run Creek	535	√
Hazel Creek	536	√
Spring Creek	538	I
Yellow Medicine River, NB	542	X
Mud Creek	543	X
Judicial Ditch 10	547	X
Judicial Ditch 29	550	√
Boiling Spring Creek	555	I
Unnamed creek	564	?
Yellow Medicine River	584	X
Unnamed creek	595	√
Unnamed creek	597	√
Unnamed creek	599	I
Judicial Ditch 17	622	√
Unnamed creek	694	?
County Ditch 39	713	?
County Ditch 2	717	?
Unnamed creek	718	?

√ = supporting/not a stressor
? = inconclusive (need more data)
I = likely impaired (need more data)
x = impaired/stressor

Trends

Water clarity (which is directly related to the amount of sediment in waters) at the outlet of the Yellow Medicine River shows a statistically-significant declining trend – or an increase in sediment over time. No other data sets are ample enough for trend analysis at this time. However, observers report stream bank erosion has increased over the last few decades.

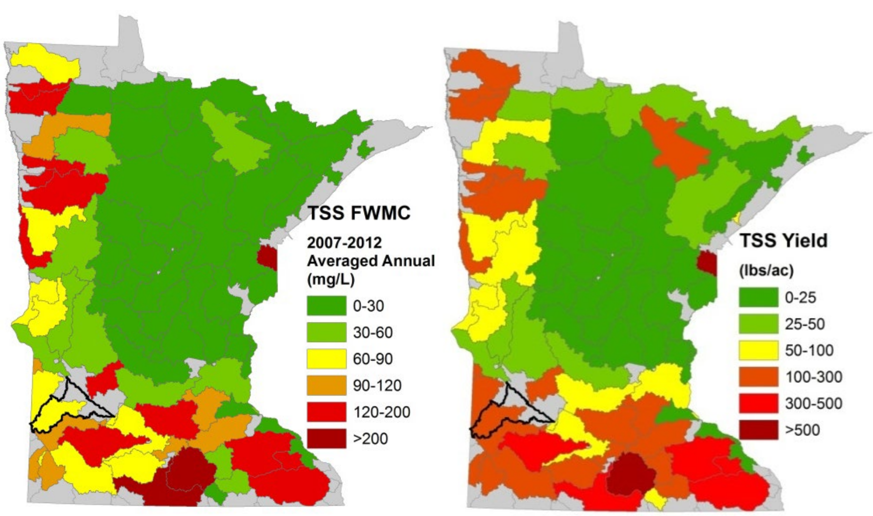


Figure 17: The Yellow Medicine River has a moderately high flow-weighted mean concentration and yield of total suspended solids (TSS). The annual TSS yield of the Yellow Medicine River is 109 lbs/acre. Data are from the WPLMN.

Sources

The primary sources of sediment discussed in *Identifying Sediment Sources in the Minnesota River Basin* (MPCA 2009a) can be summarized into three source categories: upland, channel, and ravine. 1) Upland contributions typically occur after rain events occur on bare soil and include field gully erosion, sheet/rill erosion, and residential/impervious surface contributions. 2) Channel contributions include in-channel bed and bank erosion as well as bluff erosion. This source category is dominated by bank and bluff erosion, which increases exponentially as river flow increases. While some degree of channel migration and associated bank/bluff erosion is natural, altered hydrology has substantially increased stream flow, causing excessive bank/bluff erosion. 3) Ravine contributions occur in locations where a flow path drops elevation drastically. The natural erosion rates of many ravines are exponentially increased as the amount of water traveling down the ravine is substantially increased due to a drainage outlet discharging at the top a ravine. Permitted point source contributions are minimal, totaling less than 0.1% of the watershed outlet's sediment load for the years of 2008 to 2012.

The number of ravines and bluffs (Figure 18) is a partial indication of the likeliness of bluff and ravine erosion potential. In *a Minnesota River Basin Near Stream Sediment Sources* (Mulla 2010) estimates that in the Hawk-Yellow Medicine Major Watershed, there are 3,463 acres of ravines and 37 acres of stream bluffs. This number of ravines and bluffs relative to the watershed size are moderate within the Minnesota River Basin. Streambank erosion causes are summarized by the DNR (2010).

A numeric estimate of sediment sources was created by the WRAPS Workshop Team after review of multiple lines of evidence (Appendix 4.11), applying their local knowledge and professional judgement. The single largest sediment source was estimated to be crop surface runoff, with ravine and channel erosion combined contributing about half of sediment.

The HSPF modeling estimates the subwatershed TSS yields (Figure 19). These estimates can help inform prioritization efforts by modeling which regions of the watershed contribute larger yields.

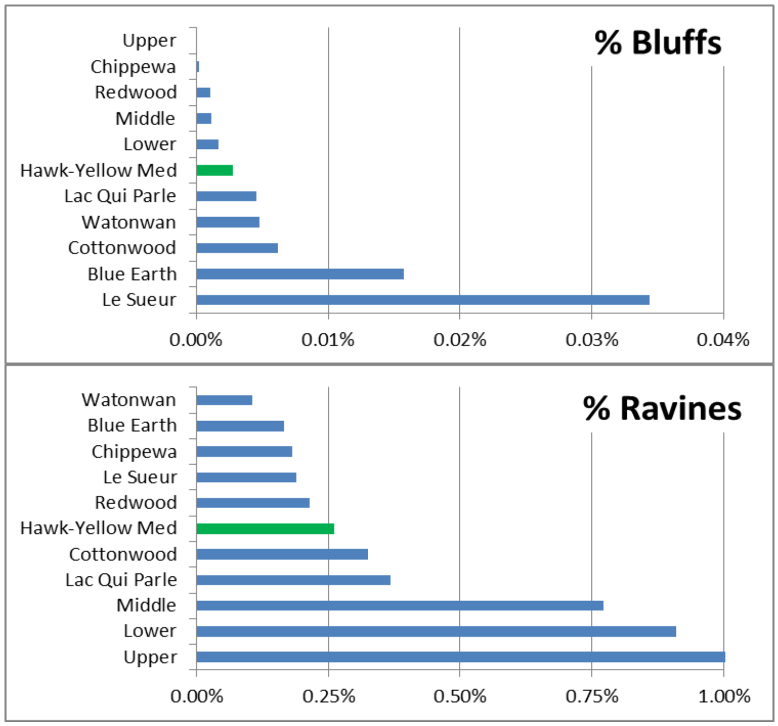


Figure 18: The Hawk-Yellow Medicine Major Watershed area has a moderate number of ravines and bluffs (green bar) compared to other major watersheds in the Minnesota River Basin. The number of bluffs and ravines is represented here as a percent of the watershed land area.

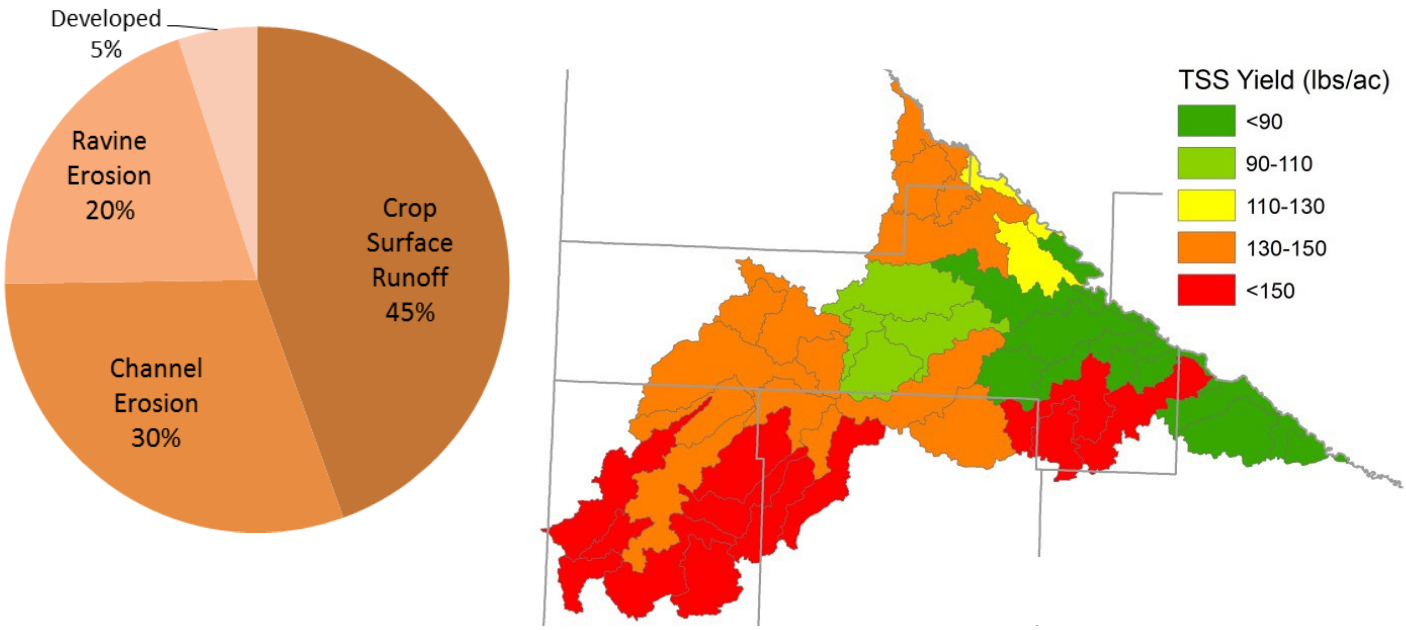


Figure 19: (Left) Surface erosion from crops is a substantial source of sediment in the Yellow Medicine River Watershed. Ravine and channel erosion, increased by altered hydrology, are also substantial sediment sources. (Right) The HSPF model estimates the subwatershed sediment yields. Model revision date: 6/22/15

Goal & 10-year Target

To calculate a watershed-wide TSS reduction goal, the 2008 to 2012 baseline period TSS flow-weighted mean concentration (FWMC) was compared against the water quality standard. The 50% TSS reduction goal and the 25% TSS interim reduction presented in the *Sediment Reduction Strategy for the Minnesota River Basin* (MPCA 2015h) were also considered in conjunction with the relative yield of Minnesota River Basin major watersheds. The selected watershed-wide goal is 20% reduction in sediment concentration and load. This goal is also the adopted goal for any region that does not have data to calculate an individual goal. This goal represents a drop in the TSS FWMC from 77 to 65 mg/L at the Yellow Medicine River outlet. Stream reaches that were analyzed in the TMDL have varied goals based on the data available for that reach. The watershed goals and impairments are illustrated in Figure 20. These goals are revisable and will be revisited in the next iteration of the Watershed Approach. A 10-year target was selected by the WRAPS Workshop Team of an 8% reduction in TSS FWMC. Strategies and methods to prioritize regions to address sediment are summarized in Section 3.

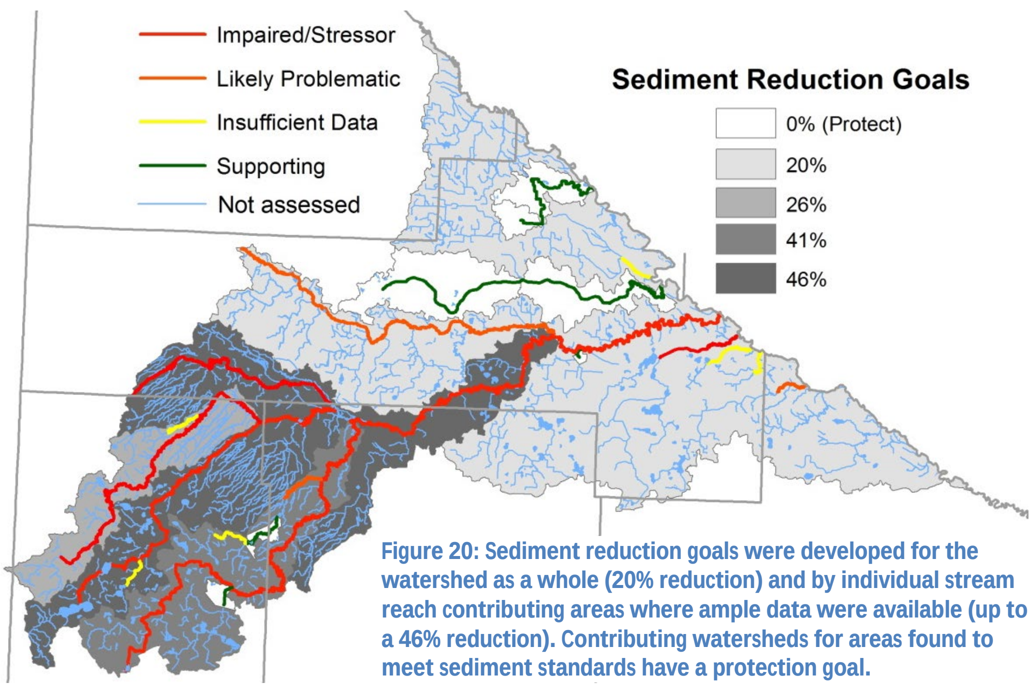


Figure 20: Sediment reduction goals were developed for the watershed as a whole (20% reduction) and by individual stream reach contributing areas where ample data were available (up to a 46% reduction). Contributing watersheds for areas found to meet sediment standards have a protection goal.

Phosphorus

Phosphorus impacts aquatic life by changing food chain dynamics, impacting fish growth and development, decreasing DO, and increasing algae. Phosphorus impacts aquatic recreation in lakes by fueling algae growth, making waters undesirable or even dangerous to swim in due to the potential presence of toxic blue-green algae.

Status

Six of the nine bio-impaired stream reaches are stressed by phosphorus (i.e. the fish and macroinvertebrate populations indicate problems attributed to excess phosphorus). Phosphorus could not be ruled out as a stressor for any of the bio-impaired stream reaches. Of the 24 analyzed lakes, 8 were impaired by phosphorus, one was supporting standards for phosphorus, and 14 needed more data to make a scientifically-conclusive finding (Table 4). Once new stream eutrophication standards are applied, many streams will likely be assessed as impaired by phosphorus (i.e. concentrations will be above the standard).

Data from the outlet of the Yellow Medicine River consistently show that the river concentration often exceeds the new stream eutrophication standard of 0.15 mg/L, with a flow-weighted mean total phosphorus (TP) concentration of 0.23 mg/L from 2008 to 2011. From a statewide perspective (Figure 21), the phosphorus concentration and yield per acre are moderately high in the Yellow Medicine River.

Table 4: Stream reaches and lakes assessed for phosphorus

Stream	Reach AUID (last 3 digits)	Assessment
County Ditch 2	717	x
County Ditch 39	713	x
Judicial Ditch 10	547	x
Mud Creek	543	x
Unnamed creek	564	?
Unnamed creek	595	?
Unnamed creek	694	?
Unnamed creek	718	x
Yellow Medicine River, NB	542	x

Lake	Assessment
Anderson	?
Biggs	?
Conger's Slough	?
Cottonwood	x
Curtis	x
Gislason	?
Hawksnest	?
Lady Slipper	x
Miedd	?
North Ash	?
Oak	√
Perch	x
Shaokotan	x
South Ash	?
Spellman	?
Stay	x
Steep Bank	x
Stokke	?
Timm	?
Tyson	?
Unnamed	?
Widmark Marsh	?
Wood	x

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

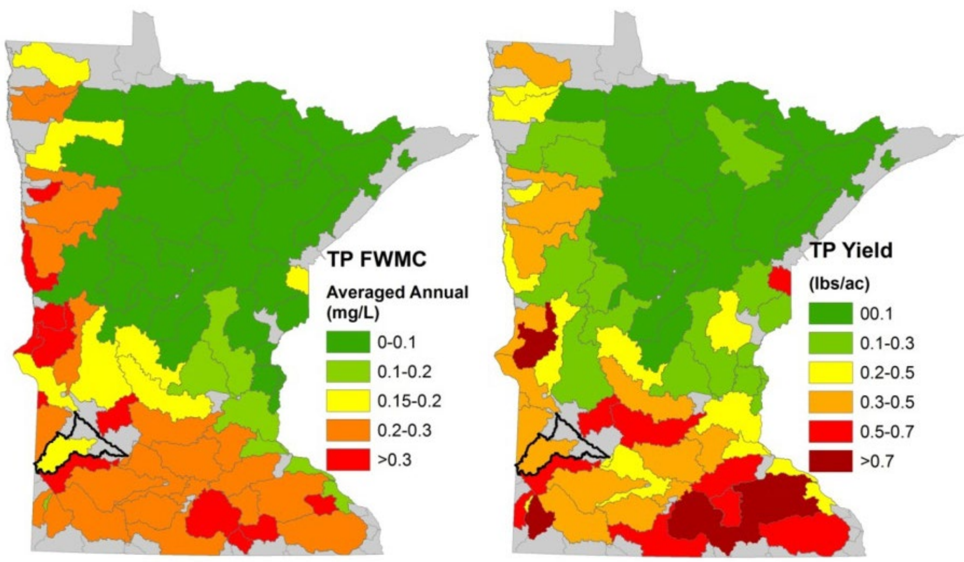


Figure 21: The Yellow Medicine River has a moderately high flow-weighted mean concentration and yield of TP compared to the rest of the state. Data are from the WPLMN.

Sources

In the Yellow Medicine Watershed, most phosphorus that reaches water bodies is from non-point sources. In years 2008 to 2011, 1.6% of phosphorus was from point sources. A numeric estimate of phosphorus sources was created by the WRAPS Workshop Team after review of multiple lines of evidence (Appendix 4.11), applying their local knowledge and professional judgement (Figure 22). The single largest phosphorus source was estimated to be crop surface runoff. Most of the phosphorus leaving agricultural fields is from applied fertilizer and manure.

The subwatershed TP yields were estimated using HSPF (Figure 23). These estimates can help inform prioritization efforts by estimating which regions of the watershed are contributing larger yields.

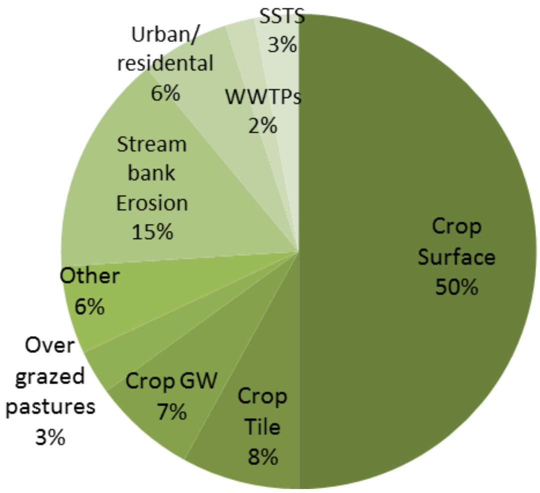


Figure 22: Crop surface runoff is the single largest phosphorus source. Additional non-point sources of phosphorus include crop tile and groundwater, stream bank erosion, and developed areas.

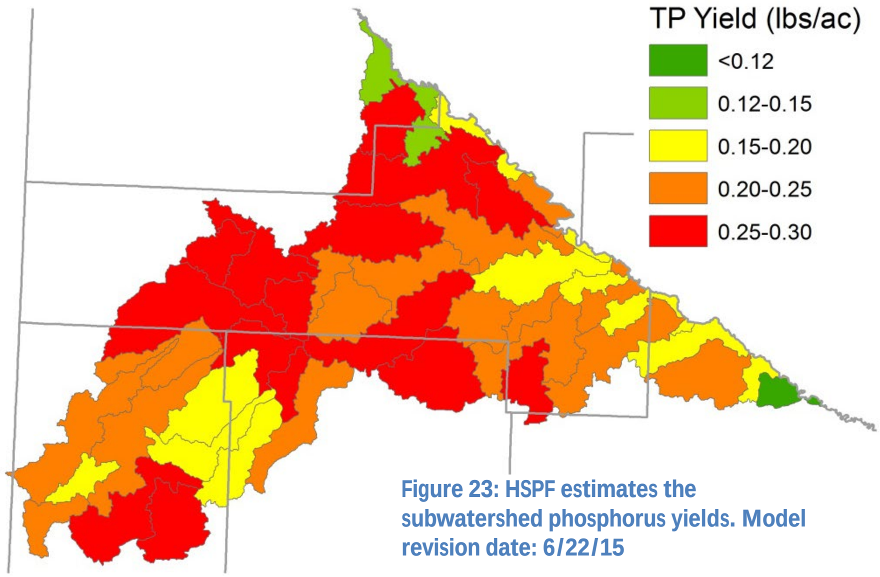


Figure 23: HSPF estimates the subwatershed phosphorus yields. Model revision date: 6/22/15

Goal & 10-year Target

To calculate a watershed-wide phosphorus reduction goal, data from the watershed outlet was compared to the new [River Eutrophication Standard](#) (RES) for southern Minnesota streams of 0.15 mg/L. The [Minnesota Nutrient Reduction Strategy](#) (MPCA 2015) was also considered, which calls for an 18% reduction in Mississippi River basin load from the 2014 load (see Appendix 4.5 for details). Based on the RES standard, the state-wide strategy, and the relative yield of Mississippi River basin major watersheds, a 35% reduction in the baseline 2008 to 2012 FWMC and load is the selected watershed goal.

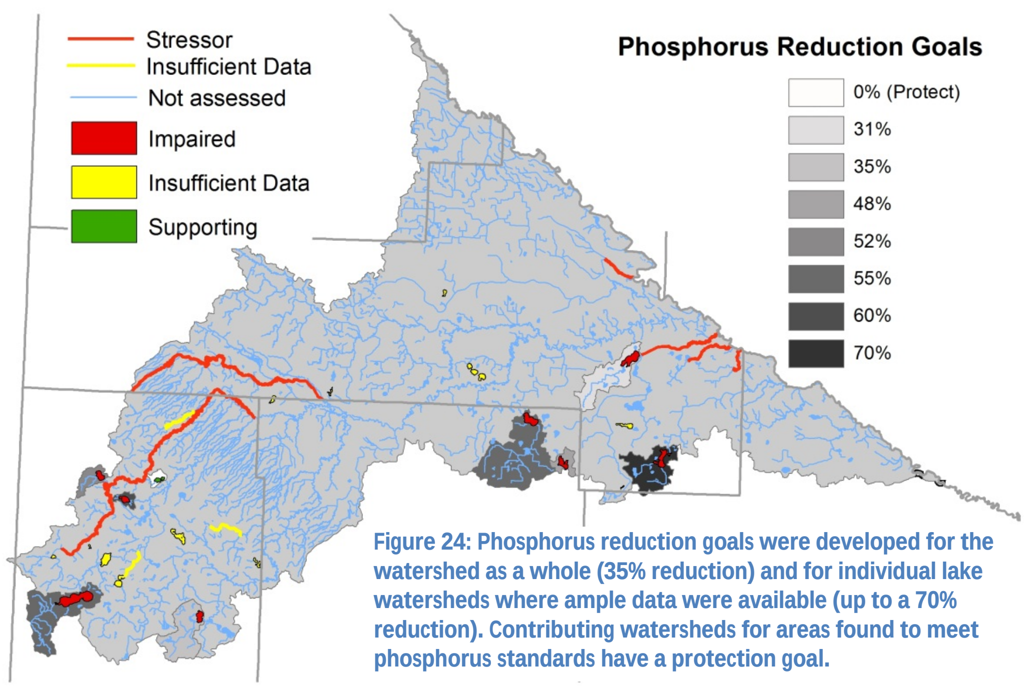


Figure 24: Phosphorus reduction goals were developed for the watershed as a whole (35% reduction) and for individual lake watersheds where ample data were available (up to a 70% reduction). Contributing watersheds for areas found to meet phosphorus standards have a protection goal.

This represents a drop in the FWMC from 0.23 mg/L to 0.15 mg/L. This goal is revisable and will be revisited in the next iteration of the Watershed Approach. Individual subwatershed goals were calculated from TMDL data. Phosphorus goals and impairments are illustrated in Figure 24. A 10-year target was selected by the WRAPS Workshop Team of an average 10% reduction in TP FWMC for watershed streams and an average 12% reduction for watershed lakes. Strategies and methods to prioritize regions to address phosphorus are summarized in Section 3.

Nitrogen

Excessive nitrogen can be directly toxic to fish and macroinvertebrates. Nitrogen can also increase the acidity of waters, limiting sensitive species. Excessive nitrogen contributes to eutrophication and is implicated as the main cause for the Gulf Hypoxic Zone (NOAA 2015). Nitrogen is also a major human health concern, as excessive nitrogen consumption via drinking water causes blue baby syndrome (WHO 2015). Due to this health risk, excessive nitrogen in drinking water can necessitate expensive treatments.

Status

High nitrogen was identified as a stressor in three of nine bio-impaired stream reaches (Table 5). One investigated reach was not impacted by nitrogen, and five of the nine stream reaches needed more information.

Table 5: Stream reaches assessed for nitrogen

Stream	Reach AUID (last 3 digits)	Assessment
County Ditch 2	717	?
County Ditch 39	713	x
Judicial Ditch 10	547	x
Mud Creek	543	x
Unnamed creek	595	?
Unnamed creek	564	?
Unnamed creek	694	?
Unnamed creek	718	?
Yellow Medicine River, NB	542	√

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

Nitrogen is only investigated when a bio-impairment is identified; so excessive nitrogen conditions may be more widespread than appears and are likely problematic in highly tiled areas (refer to source assessment). Once new stream eutrophication standards are applied, many streams will likely be assessed as impaired by nitrogen (i.e. concentrations will be above the standard).

Data from the outlet of the Yellow Medicine River consistently show that the river concentration often exceeds the targets established in the Minnesota Nutrient Reduction Strategy. From a statewide perspective (Figure 25), the nitrogen concentration and yield per acre are moderately high in the Yellow Medicine River.

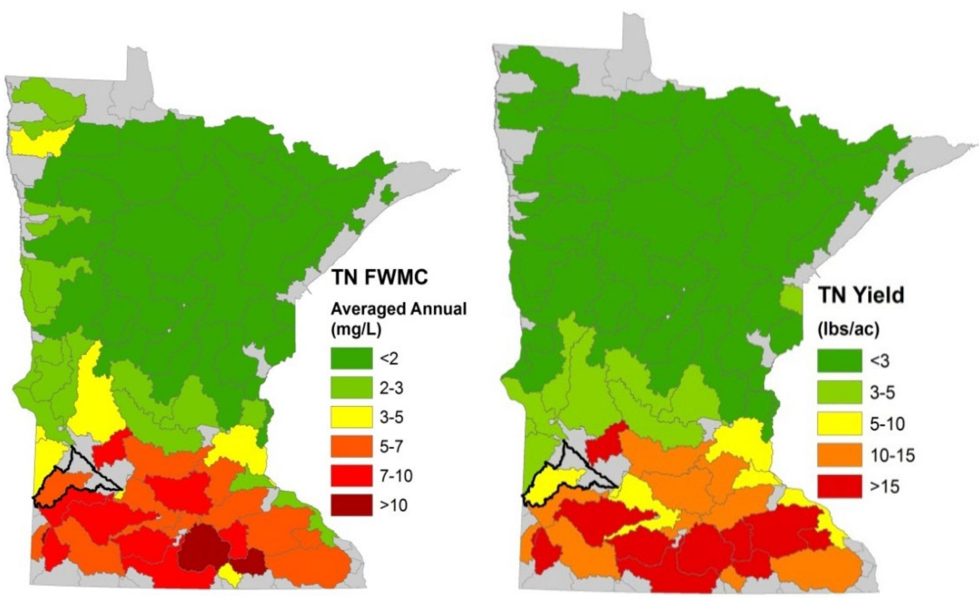


Figure 25: The Yellow Medicine River has a moderately high flow-weighted mean concentration and yield of TN. The Yellow Medicine River's TN yield is 8.3 lbs/ac. Data are from the WPLMN.

Sources

In the Yellow Medicine Watershed, most nitrogen that reaches water bodies is from non-point sources. In years 2008 to 2012, 0.3% of nitrogen was from point sources. A numeric estimate of nitrogen sources (Figure 26) was created by the WRAPS Workshop Team after review of multiple lines of evidence (see Appendix 4.11), applying their local knowledge and professional judgement. The single largest nitrogen source was estimated to be crop tile drainage. Most of the nitrogen leaving agricultural fields is from applied fertilizer and manure.

The HSPF model estimates the subwatershed nitrogen yields (Figure 27). These estimates can help inform prioritization efforts by showing what regions of the watershed are contributing larger loads per region.

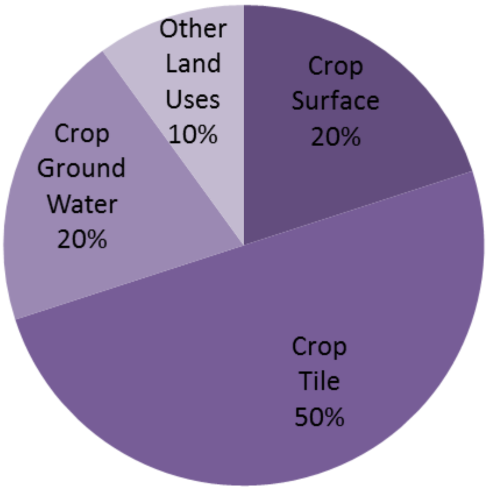


Figure 26: Nitrogen contributions to water bodies are dominated by agricultural sources. Nitrogen dissolves in water and moves easily through tile and subsurface pathways.

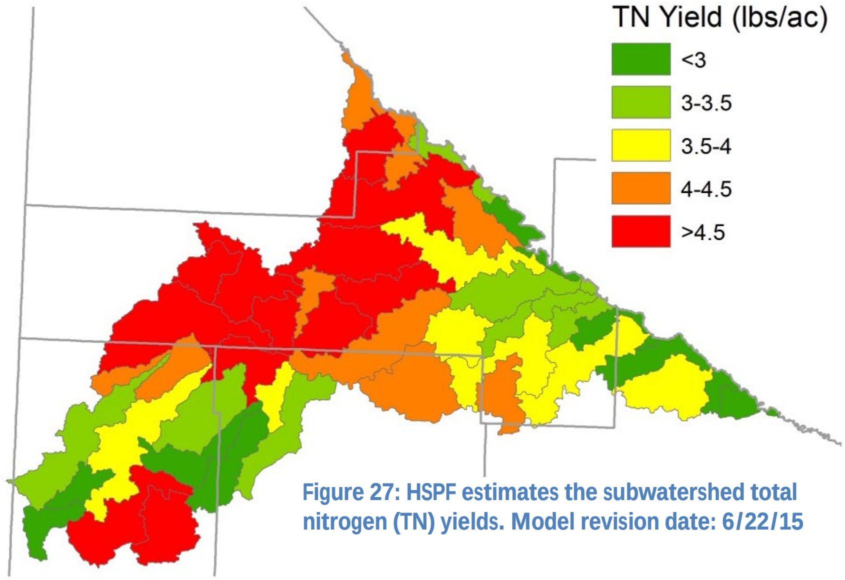


Figure 27: HSPF estimates the subwatershed total nitrogen (TN) yields. Model revision date: 6/22/15

Goal & 10-year Target

To calculate a watershed-wide nitrogen reduction goal, data from the watershed outlet was compared to the [Minnesota Nutrient Reduction Strategy](#) (MPCA 2015j), which calls for a 45% total and a 20% interim (by 2025) total nitrogen (TN) reduction from the Minnesota River Basin. Based on the state-wide strategy and the relative yields of TN of Minnesota River major watersheds, a 25% reduction in the baseline 2008-2012 FWMC and load is the selected watershed goal. This represents a drop in the FWMC from 6.4 mg/L to 4.9 mg/L. This goal is revisable and will be revisited in the next iteration of the

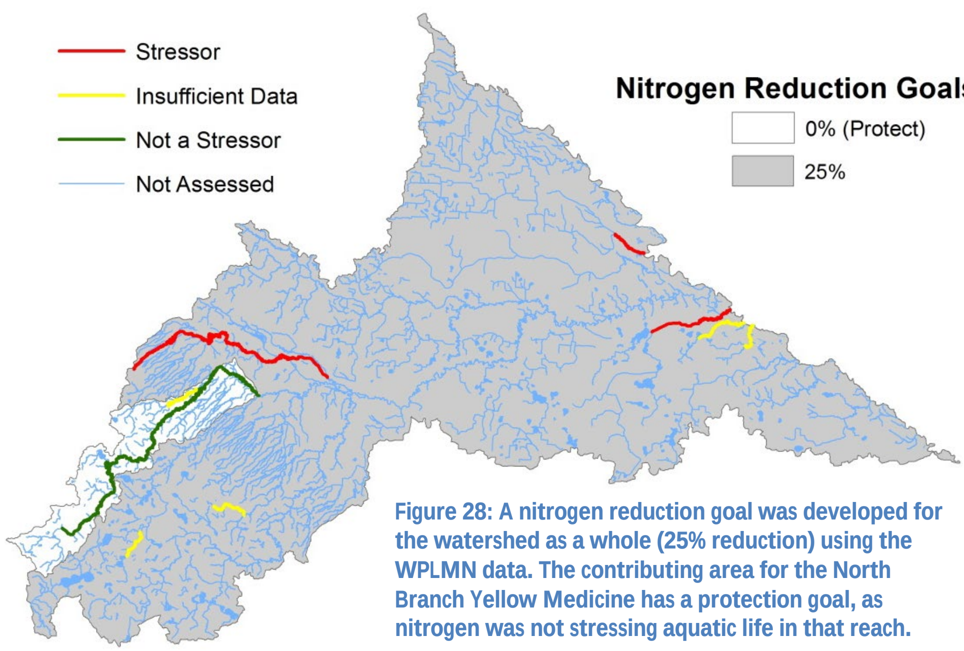


Figure 28: A nitrogen reduction goal was developed for the watershed as a whole (25% reduction) using the WPLMN data. The contributing area for the North Branch Yellow Medicine has a protection goal, as nitrogen was not stressing aquatic life in that reach.

Watershed Approach. The one reach that was not stressed by nitrogen has a protection goal. The goals and impairments are illustrated in Figure 28. A 10-year target was selected by the WRAPS Workshop Team of a 10% reduction in TN FWMC. Strategies and methods to prioritize regions to address nitrogen are summarized in Section 3.

Fecal Bacteria

Fecal bacteria (*E. coli* or fecal coliform) are indicators of animal or human fecal matter in waters. Fecal matter impacts the safety of aquatic recreation because contact with fecal material can lead to potentially severe illnesses. Fecal bacteria are living organisms that can be present in upstream locations due to upstream sources, yet die before reaching downstream waters where they may not be detected.

Status

Fecal bacteria are problematic across much of the watershed. Fecal bacteria have been identified as a pollutant in 16 stream reaches (Table 6). Only one stream reach was found to meet fecal bacteria standards, and one stream reach needs more data.

Table 6: Stream reaches assessed for fecal bacteria

Stream	Reach AUID (last 3 digits)	Assessment
Boiling Spring Creek	555	X
Hazel Creek	536	x
Judicial Ditch 10	547	x
Judicial Ditch 17	622	x
Judicial Ditch 29	550	x
Mud Creek	543	x
Spring Creek	538	x
Stony Run Creek	535	x
Unnamed creek	595	x
Unnamed creek	597	x
Unnamed creek	599	x
Unnamed creek	600	x
Unnamed creek	545	x
Yellow Medicine River	502	√
Yellow Medicine River	513	x
Yellow Medicine River	584	x
Yellow Medicine River, NB	542	?
Yellow Medicine River, SB	503	x

√ = supporting
? = inconclusive (need more data)
x = impaired positive

Sources

Fecal Bacteria source identification 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 weak relationship to fecal bacterial contamination in streams (Table 7).

Table 7: 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 · % urban areas greater than % forested riparian areas in the landscape · High water temperature · Higher % impervious surfaces · Livestock present · Suspended solids	· High nutrients · Loss of riparian wetlands · Shallow depth (bacteria decrease with depth) · Amount of sunlight (increased UV-A deactivates bacteria) · Sediment type (higher organic matter, clay content and moisture; finer-grained) · Soil characteristics (higher temperature, nutrients, organic matter content, humidity, moisture and biota; lower pH) · Stream ditching (present or when increased) · Epilithic periphyton present · Presence of waterfowl or other wildlife · Conductivity

Fecal bacteria source identification is further confounded because some bacteria may be able to survive and reproduce in streams as reported in [*Growth, Survival… of E. coli…*] (*Sadowsky et al*. 2010). This study traced substantial numbers of bacteria to cattle sources, while no samples could be traced to human sources. Because there is currently a lack of ample study on in-stream reproduction and fecal bacteria pose significant risks to human health, the bacterial load attributed to this source is conservatively estimated at zero for this analysis.

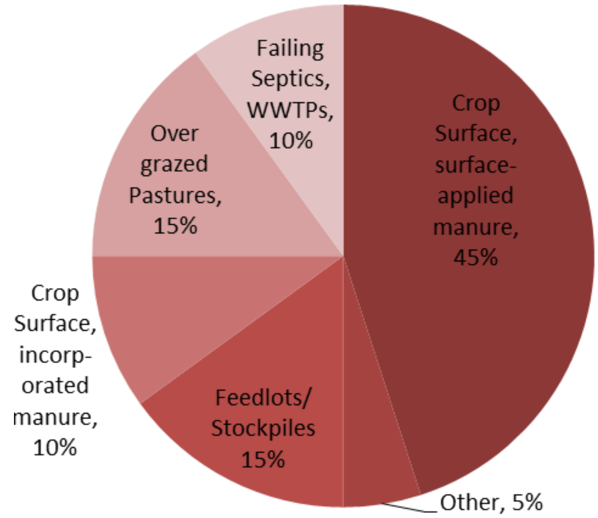


Figure 29: The single largest source of fecal bacteria in the Yellow Medicine Watershed is domesticated animal manure, which is estimated to contribute roughly 85% of bacteria to streams.

A numeric estimate of bacterial sources was created by the WRAPS Workshop Team (Figure 29) after review of multiple lines of evidence (see Appendix 4.11), applying their local knowledge and professional judgement. The single largest fecal bacteria source is crop surface runoff, where manure has not been incorporated.

Most of the manure that is applied to fields originates from feedlot operations. The locations of feedlot headquarters are registered. However, the exact location where manure is spread is not necessarily known. Because transportation costs increase as the distance between the feedlot facility and fields where manure is applied, most manure is applied relatively close to feedlot facilities. For this reason, the number of feedlot AUs per region (Figure 30) is one line of evidence that can be helpful for targeting feedlot-originated manure management on fields. Additional considerations including slope, proximity to surface water, application location and timing, and infield practices are also important considerations.

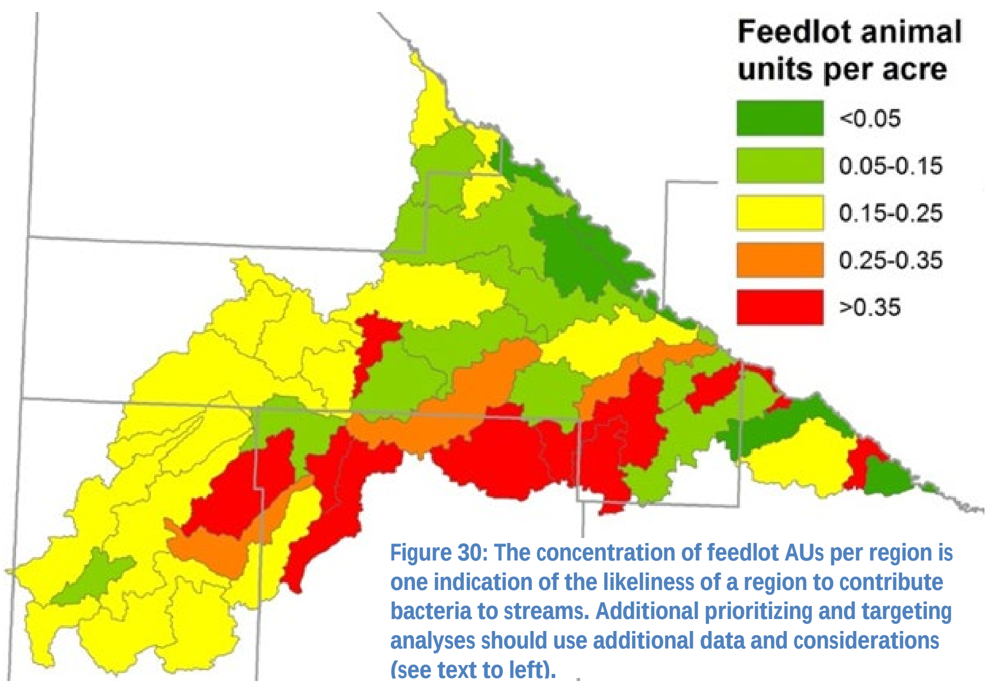


Figure 30: The concentration of feedlot AUs per region is one indication of the likeliness of a region to contribute bacteria to streams. Additional prioritizing and targeting analyses should use additional data and considerations (see text to left).

Goal & 10-year Target

To calculate a watershed-wide bacteria reduction goal, the individual bacteria reduction goals were averaged. These individual reduction goals were calculated by comparing the observed monthly geomean of bacteria concentrations to the water quality standard (126 colony forming units per 100 mL). The watershed goal is to reduce fecal bacteria by 65%. Goals and impairments are illustrated in Figure 31Figure . Strategies and methods to prioritize regions to address bacteria are summarized in Section 3.

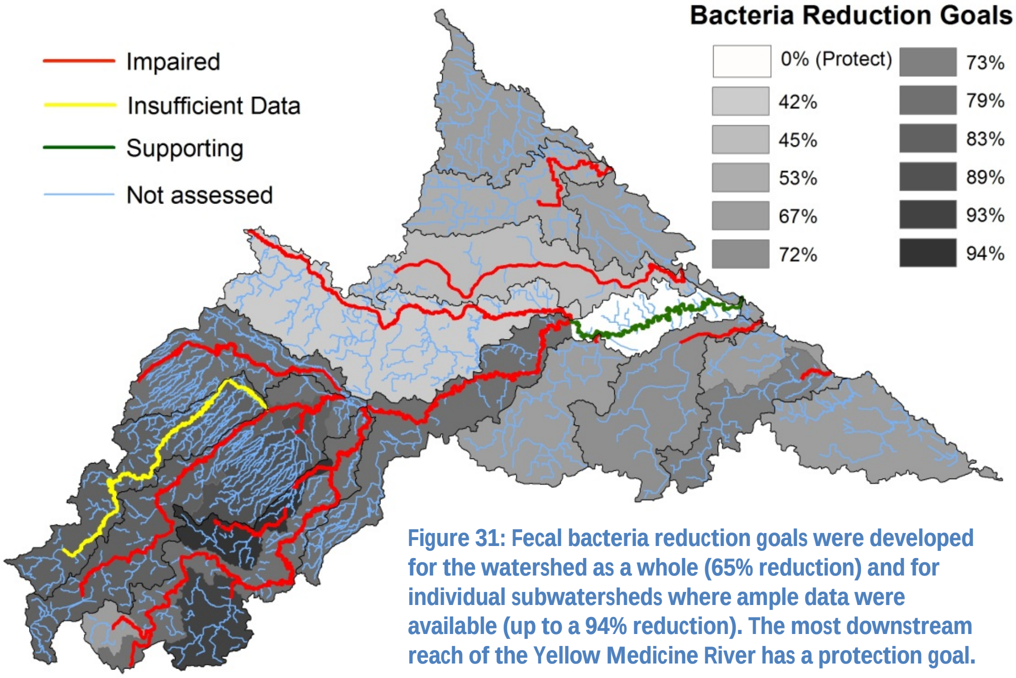


Figure 31: Fecal bacteria reduction goals were developed for the watershed as a whole (65% reduction) and for individual subwatersheds where ample data were available (up to a 94% reduction). The most downstream reach of the Yellow Medicine River has a protection goal.

Habitat

Poor habitat impacts aquatic life by reducing the amount of suitable habitat needed for all aspects of aquatic life: feeding, shelter, reproduction, etc.

Status

Poor habitat was identified as a stressor in five of the nine bio-impaired streams (Table 8). Habitat was sufficient for aquatic life in four of the bio-impaired streams. Although habitat is only investigated when a bio-impairment is identified, MPCA Stream Habitat Assessment (MSHA) (MPCA 2014d) scores are fairly low across much of the watershed, indicating that habitat could be problematic across much of the watershed.

Table 8: Stream reaches assessed for habitat

Stream	Reach AUID (last 3 digits)	Assessment
County Ditch 2	717	√
County Ditch 39	713	√
Judicial Ditch 10	547	x
Mud Creek	543	x
Unnamed creek	564	√
Unnamed creek	595	x
Unnamed creek	694	x
Unnamed creek	718	x
Yellow Medicine River, NB	542	√

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

Sources

The identified physical habitat issues (Table 9) show a complex, interconnected set of factors that are driven by primarily a couple stressors. Excessive sedimentation and/or channel instability was identified in all five streams; additional issues such as limited depth variability and sparse in-stream cover are closely related to channel instability and sediment issues. This stressor is primarily the result of altered hydrology, which causes bank instability and increased channel migration which then chokes streams with the excessively produced sediment, limiting or eliminating necessary habitat. A minimal or degraded riparian zone and/or poor surrounding land use was identified for all five habitat-impaired streams; additional issues including lack of shading are closely related to land use and riparian buffer issues. Riparian areas can be damaged by the effects of altered hydrology that cause excessive bank erosion or can be due to changing the natural vegetation (typically forest or prairie) to a different land use. In summary, most of the habitat problems are driven by altered hydrology and poor riparian land uses.

Table 9: The identified problems with physical habitat identified in the *Yellow Medicine River Stressor ID Report* (MPCA 2013a) show a complex, interconnected set of stressors. The drivers of these issues can primarily be boiled down to altered hydrology and degraded riparian zone.

Stream AUID (last 3 digits)	Identified physical habitat issues
Unnamed Creek (718)	No riparian buffer, severe bank erosion, poor channel stability and development, limited shading, excessive fine sediment on stream bottom, and poor surrounding land use
JD10 (547)	Poor channel stability, excessive fine sediment on stream bottom, moderate to heavy bank erosion, poor surrounding land use
Unnamed Creek (595)	Excessive fine sediment on stream bottom, lack of channel stability and development, and poor surrounding land use
Unnamed Creek (694)	Minimal riparian buffer, poor channel stability and development, excessive fine sediment on stream bottom, little depth variability in the stream, and poor surrounding land use
Mud Creek (543)	Minimal riparian buffer, limited shading, poor channel stability and development, lack of stream depth variability, sparse in-stream cover for fish, and poor surrounding land use

Goal & 10-year Target

Currently, the MSHA scores in the watershed range from 17 to 81 (Figure 32), with an average score of 48. The goal for habitat is for the average MSHA score in the watershed to be greater than 66 ("good"). This goal represents a 40% increase in the average MSHA score. The 10-year target is a 5% increase in the MSHA score. Since scores are mostly due to altered hydrology and degraded riparian zone, these stressors should be addressed to meet the goal and 10-year target. Strategies and methods to prioritize regions to address habitat are summarized in Section 3.

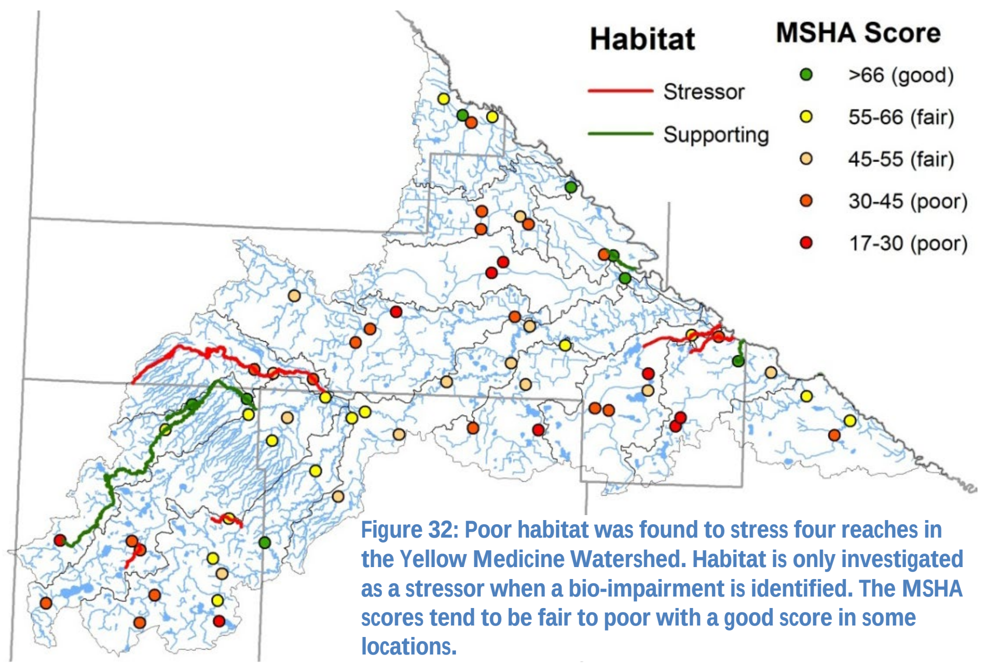


Figure 32: Poor habitat was found to stress four reaches in the Yellow Medicine Watershed. Habitat is only investigated as a stressor when a bio-impairment is identified. The MSHA scores tend to be fair to poor with a good score in some locations.

Dissolved Oxygen

Low DO impacts aquatic life primarily by limiting respiration, which contributes to stress and disease and can cause death.

Status

Low DO was identified as a stressor in five of nine analyzed stream reaches. Two stream reaches meet DO water quality standards, and several stream reaches require more data to make an assessment (Table 10).

Sources

Low DO in water bodies is caused by: 1) excessive oxygen use, which is often caused by the decomposition of excessive algae which is fueled by excess phosphors and/or 2) too little re-oxygenation, which is often caused by minimal turbulence 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.

Goals & 10-year Targets

Because this stressor is primarily a response of other stressors, the goal and 10-year target for DO are to meet the altered hydrology and phosphorus targets, since these are the primary drivers of DO problems in the watershed (Figure 33). 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 and phosphorus are summarized in Section 3.

Table 10: Stream reaches impaired by low DO

Stream	AUID (last 3 digits)	Assessment
Boiling Spring Creek	555	?
County Ditch 12	551	?
County Ditch 2	717	?
County Ditch 39	713	?
Hazel Creek	536	?
Judicial Ditch 10	547	x
Judicial Ditch 17	622	?
Judicial Ditch 29	550	?
Mud Creek	543	x
Stony Run Creek	535	?
Unnamed creek	597	?
Unnamed creek	599	?
Unnamed creek	564	?
Unnamed creek	595	x
Unnamed creek	694	x
Unnamed creek	718	x
Yellow Medicine River	502	√
Yellow Medicine River	513	?
Yellow Medicine River	584	?
Yellow Medicine River, NB	542	√
Yellow Medicine River, SB	503	?

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

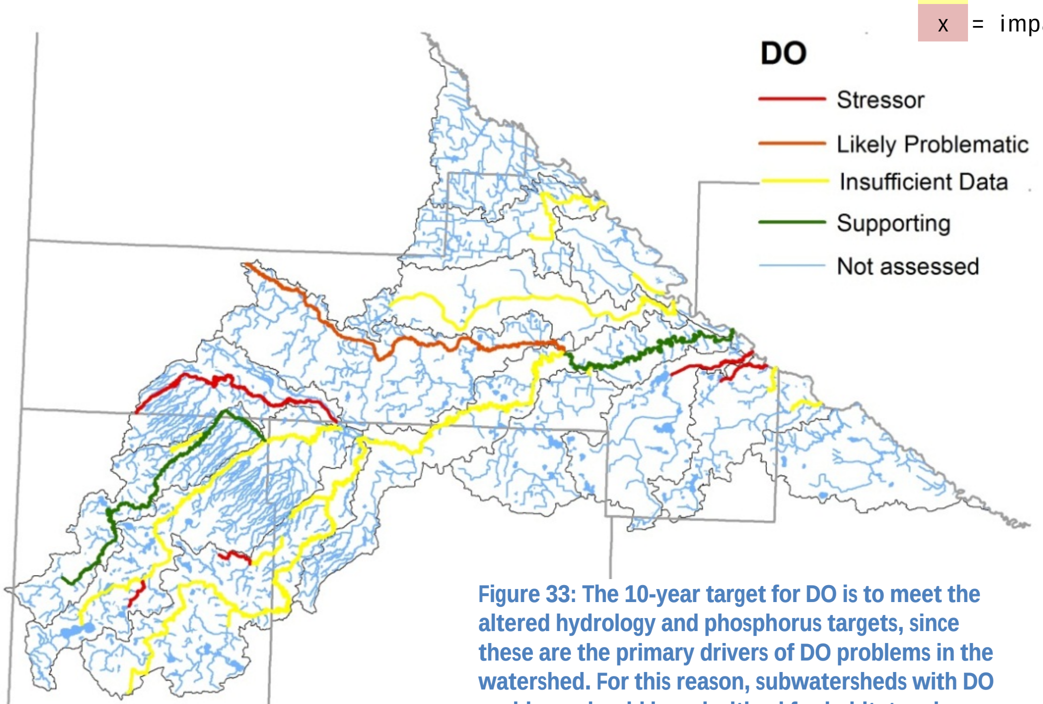


Figure 33: The 10-year target for DO is to meet the altered hydrology and phosphorus targets, since these are the primary drivers of DO problems in the watershed. For this reason, subwatersheds with DO problems should be prioritized for habitat and phosphorus improving projects.

3 Restoration & Protection

Section 3 summarizes scientifically-supported strategies to restore and protect waters and presents the selected strategies for local partners to prioritize and target the strategies for implementation on the landscape.

3.1 Scientifically-Supported Strategies to Restore and Protect Waters

Section 3.1 summarizes studies and data on land management and BMP effects on water quality. This information is more technical in nature, but these summaries may be helpful to landowners, decision makers, and citizens to understand the impact of various strategies and BMPs on water quality.

To address the widespread water quality impairments in agriculturally-dominated watersheds such as the Yellow Medicine Watershed, comprehensive and layered BMP suites are likely necessary. A conceptual model displaying this layered approach is presented by Tomer et al. (2013; Figure 34). Another model to address widespread nutrients is presented in the *Minnesota Nutrient Reduction Strategy* (MPCA 2013c), which calls for four key strategies involving millions of acres statewide: 1) increase fertilizer use efficiencies, 2) increase and target living cover, 3) field erosion control, and 4) drainage water retention. A third example of a comprehensive, layered approach is being demonstrated with a "Treatment Train" approach in the Elm Creek Watershed (ENRTF 2013), which has demonstrated layered strategies including: 1) upland: cover crops and nutrient management, 2) tile treatment: treatment wetlands and controlled drainage, and 3) in-stream: woody debris and stream geomorphology restoration.

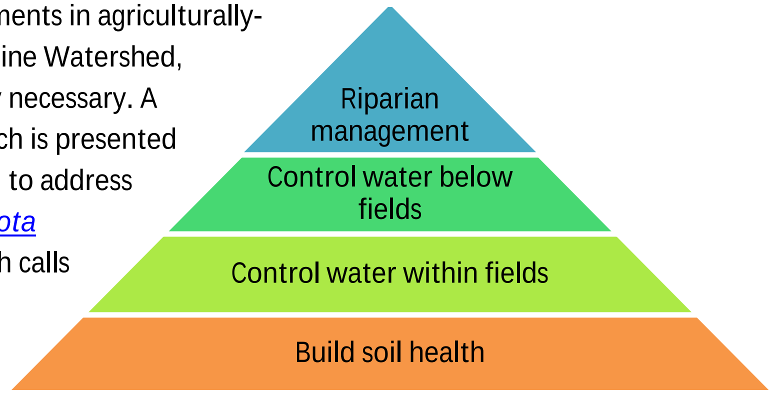


Figure 34: This conceptual model to address water quality in agricultural watersheds uses 1) soil health principles as a base: nutrient management, reduced tillage, crop rotation, etc., then 2) in-field water control: grassed waterways, controlled drainage, filter strips, etc., then 3) below-field water controls: wetlands, impounds, etc., and then 4) riparian management: buffers, stabilization, restoration, etc.

Agricultural BMPs

Since the Yellow Medicine Watershed land use and pollutant source contributions are generally dominated by agriculture, reducing pollutant/stressor contributions from agricultural sources is a high priority. A comprehensive resource for agricultural BMPs is the *The Agricultural BMP Handbook for Minnesota* (Miller et al. 2012). Hundreds of field studies of agricultural BMPs are summarized in the handbook, which has been summarized in Appendix 4.9. This summary table also contains a "relative effectiveness", which was estimated by conservation staff. For clarifications, the reader should reference the handbook.

The Minnesota Nitrogen Fertilizer Management Plan (MDA 2015) outlines strategies to minimize and prevent crop nitrogen contributions to groundwater; these strategies effectively address nitrogen contributions to surface waters, as well. Additional field data has been compiled by Iowa and Minnesota for review in their respective state nutrient reduction strategies. This information is included in Appendix 4.8.

Urban and Residential BMPs

Cities and watershed residents also impact water quality. A comprehensive resource for urban and residential BMPs is the *Minnesota Stormwater Manual* (MPCA 2014b). This resource is in electronic format and includes links to studies, calculators, special considerations for Minnesota, and links regarding industrial and stormwater programs. 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, widescale stabilization of eroding stream banks and ravines is cost-prohibitive. Instead, first addressing altered hydrology (e.g. excessive, concentrated flows) from the landscape can help decrease widescale 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 *How to Control Streambank Erosion* (IA DNR 2006). In some cases, however, high value property may need to be protected or a ravine/stream bank may be experiencing such severe erosion that stabilization of the stream bank 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 4.7). Strategies to minimize pollutant contributions from the watershed focus mostly on agricultural and/or stormwater BMPs, depending on the land use and pollutant contributions of 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 by the WRAPS workshop team. The table presented in Appendix 4.10 summarizes several model analyses of the Yellow Medicine Watershed and the Minnesota River Basin, generally. The reader is encouraged to refer to the linked reports (in table) for more details.

3.2 Social Dimension of Restoration and Protection

Communities and individuals ultimately hold the power to restore and protect waters in the Yellow Medicine Watershed. For this reason, the Clean Water Council (MPCA 2013b) recommended that agencies integrate civic engagement in watershed projects (MPCA 2010a).

Resident values of natural resources were collected through the Zonation (University of Helsinki 2015) analysis process. Generally, the results of this analysis show the highest participant support for the restoration of lake resources, as illustrated in the produced map (Figure 35). However, other high value regions were identified in the Spring Creek and Lower Yellow Medicine Watersheds. Additional public participation work included education. Watershed educational articles were written and provided to the public by the YMRWD (YMRWD 2014).

The WRAPS Workshop Team reviewed and summarized the opinions and values represented in the Zonation Analysis and 1W1P Kickoff meeting public comments in addition to their knowledge of the watershed citizens:

*Institutional **constraints** to increased BMP adoption*

- Policies (Farm Bill), rules, and funding perpetuate status quo

- Inability to guarantee income when making changes
- Ineffective/conflicting communication/messaging

*Individual and community **constraints** to increased BMP adoption*

- Lack of knowledge and/or ownership of problems and solutions
- Lack of trust in government/institutions
- Fear of unknown and/or unwillingness to differ from peers
- Financial risk avoidance and/or pursuit of higher agricultural productivity/yield

*Individual and community **priorities** that encourage increased BMP adoption*

- Local pride and stewardship ethic
- Leaving a legacy for future generations
- Clean surface water resources for outdoor recreation
- Clean ground water for drinking
- Education and continual learning/improvement

***Recommendations** for institutional leadership and programs to support increased BMP adoption*

- Policies and programs (e.g. Farm Bill) need to facilitate change, flexibility, and less bureaucracy
- Funding for more practices and to prevent income loss when transitioning farms to sustainable practices
- Identify and foster early sustainable farming BMP adopters to be leaders to community
- More/better education on sustainable practices, technologies, benefits, and progress
- Collaborate with ag professionals: co-ops, crop consultants, etc.

***Recommendations** for field-level conservation staff to support increased BMP adoption*

- Build trust to perpetuate cooperation and stewardship
- Increase messaging and education including advertisements, social media, billboards, documentaries
- Sponsor community events/education including clean-ups, banquets, citizen groups, school education
- Sponsor peer-leader and peer-to-peer networking events such as field days

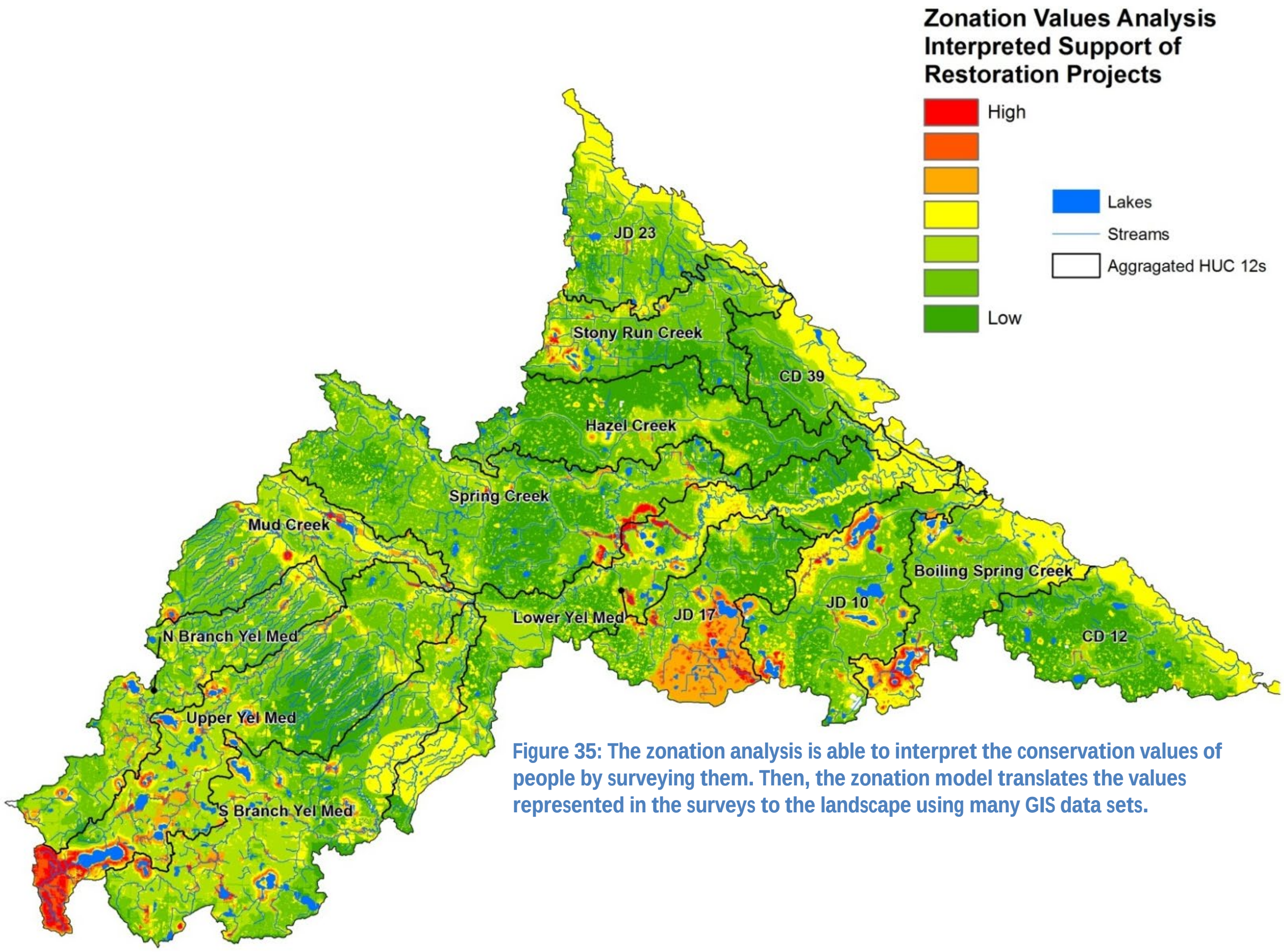


Figure 35: The zonation analysis is able to interpret the conservation values of people by surveying them. Then, the zonation model translates the values represented in the surveys to the landscape using many GIS data sets.

3.3 Restoration and Protection Strategies

Based on the scientifically-supported strategies, the social dimension of restoration and protection, the condition and pollutant source identification work, and professional judgment, a team of local and state conservation and planning staff selected restoration and protection strategies. This team is referred to as the "WRAPS Workshop Team" – see members on inside front cover. Table 12 illustrates the types and associated adoption rates of restoration and protection strategies estimated to meet the water quality goals (Table 12A) and 10-year targets (Table 12B).

Table 12A summarizes the pollutants and stressors, their sources and source contributions, and presents a narrative of the estimated changes necessary for all waters to meet the (long term) water quality goals. Data and models indicate that comprehensive and integrated BMP suites are necessary to meet the water quality goals. However, there are current limitations in BMP adoption, some technologies are not yet feasible, and the approximate time frame for these comprehensive changes is 50 years. For these reasons, recommending specific suites of strategies capable of cumulatively achieving all water quality goals is not practical and would likely need substantial future revision.

Table 12B summarizes the selected strategies to meet the 10-year water quality targets, the estimated effectiveness of the selected strategies on the identified pollutants and stressors, and the responsible parties for making these changes. These strategies and their relative adoption rates were selected by the WRAPS Workshop

Team. This table is most useful for immediate planning and other local needs, since local plans are typically re-done every 10 years. With the next iteration of the watershed approach, progress towards these targets can be assessed and new targets for the following decade can be created.

Table 12 illustrates "what" to do and "who" should do it, but should be refined in local planning processes to determine the "how" the strategies will get done and "where" the practices will be implemented. The presented strategies need to be implemented across the watershed at varying adoption rates due to regional differences in water quality conditions, pollutant and stressor sources, and in accordance with community priorities. Furthermore, not all strategies are appropriate for all locations. The strategies and regional adoption rates should be customized during locally-led prioritizing and targeting work (see Prioritizing and Targeting section below for more guidance).

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 12, set at the whole watershed scale, are intended to not only restore but also protect waters in the watershed. 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 region-specific considerations.

One of the primary concerns for watershed protection, or preventing further degradation, is to protect water bodies from the impacts of drainage improvements. Drainage improvements increase the amount and timing of water leaving the landscape. Subsurface drainage is one of the main causes of altered hydrology, which is the most commonly identified stressor in the watershed. Altered hydrology is also the primary driver of increased stream bank and ravine erosion, both large sources of sediment, and has devastating effects to habitat. Tile drainage water is also the largest source of nitrogen and a significant source of phosphorus. Because of the substantial impact from drainage projects, projects that increase flows present serious threats to the current water quality conditions. Mitigating the effects of these drainage projects is necessary to protect the current water quality conditions from further degradation.

Additional protection concerns in the watershed relate to groundwater protection. The main supply of drinking water to the residents and businesses in the Yellow Medicine River Watershed is groundwater: either from private wells, community wells, or a rural water supplier. Public water suppliers in the watershed that have undergone wellhead protection planning have identified that this groundwater supply is not directly influenced by surface water in the watershed. The public water supplies have low vulnerability to contamination which means that deep aquifers are fairly protected. However, there is still 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, especially in light of altered hydrology and the impacts on groundwater recharge.

Prioritizing and Targeting

Using the selected restoration and protection strategies, local conservation planning staff can prioritize areas and spatially target BMPs or land management strategies using GIS and other tools as encouraged by funding entities and Clean Water Legacy legislation on WRAPS (ROS 2013).

The objective in "prioritizing" and "targeting" is to identify locations to cost effectively implement practices to achieve the greatest improvement in water quality. A third concept, particularly related to funding, is "measuring", which means that implementation activities should produce measurable results. Figure 36Figure (BWSR 2014a) visually represents these concepts.

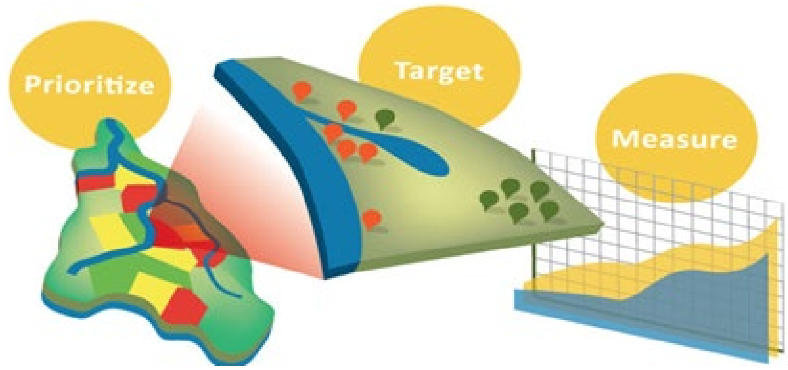


Figure 36: "Prioritized, targeted, and measurable" strategies and plans are more likely to improve water quality and have a better chance to be funded compared to those that are less strategic.

"Prioritizing" refers to the process of selecting priority areas or issues based on a justified water quality, environmental, or other concern. Within the Yellow Medicine Watershed, several prioritization criteria are identified in this report (Table 11). Priority areas within the watershed can be further refined by using these or other criteria either individually or in combination. Additional priority area selection criteria may include: 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.

Table 11: Priority areas are identified throughout this WRAPS report. Priority areas should be further customized and focused during local planning efforts.

Priority Areas	Refer to
Contributing areas of impaired streams and lakes, prioritized by needed parameter reductions, number of impairments, reduction goals or other	Goals maps: Figures 16, 20, 24, 28, 31
Highly hydrologically-altered subwatersheds	Figure 15, Appendix 4.4
High yielding HSPF-modeled subwatersheds or other data	Sources sections: Figures 19, 23, 26, 30

Some BMP priorities were selected by local partners (Appendix 4.15). These priorities were selected after reviewing the known impairments and stressors. Rather than prioritizing one region over another, this work selected prioritized strategies within regions of the watershed. This information can help customize the watershed-wide adoption rates for each subwatershed. For instance, strategies that are high priority in a region may be implemented at two to three times the selected watershed adoption rate, while those that have low or no priority may be implemented at one quarter to one half of the watershed adoption rate. Adoption rate customizations should also consider the pollutant/stressor reduction goals per region and any additional prioritizing and targeting work done.

"Targeting" refers to 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 intended to help target practices as part of the larger Watershed Approach, and should empower local partners in the 1W1P (BWSR 2014b) process to target practices that satisfy local needs. A summary of targeting tools and the applicability of tools for targeting specific practices are summarized in Appendices 4.13 and 4.14.

Table 12A: This portion of the strategies table summarizes the conditions discussed in Section 2 of the WRAPS report: the pollutants/stressors of concern, the current water quality conditions for each pollutant/stressor, and the watershed-wide water quality goals and targets. This table also presents the allocations of the pollutant/stressor goals and targets to the primary sources and the estimated years to meet the goal (both developed by the WRAPS Workshop Team) and an estimate of the strategies and adoption rates needed to meet water quality goals. This information will be revisited and revised in future iterations of the Watershed Approach. Specific practices, adoption rates, and responsibilities to meet the 10-year target are identified in table B.

Pollutant/ Stressor		Current Known Status	Goal at watershed outlet or average of individual reductions needed in context of current conditions	10-yr target to meet by 2025	Sources of Pollutant/Stressor: Land use	Sources of Pollutant/Stressor: Pathway	Allocation of goal to sources: Goal	Allocation of goal to sources: 10-yr target	General Strategies: Concept	General Strategies: Rough Estimate of Needed Adoption (All= >90% Most= >60% Many/much= >30% Some= >10% Few= <10%)	Years to goal from 2015
Altered Hydrology	High Flow	▪8 stream reaches stressed ▪Flow reductions needed to meet downstream needs ▪Increasing trend in river flow	20% reduction in annual river flow, 25% reduction in 2yr peak (annual yield from 7.4 to 5.9 in)	5% reduction	Crops, tiled	Tile drainage	10%	2.5%	Increase ET by making vegetation changes and by creating permanent water storage capacity in the landscape	All drainage projects are fully hydrologically mitigated to protect from further degradation. Most fields have landscape-scale vegetation including cover crops, buffers, grasses, etc.. Many fields have increased soil water holding capacity from increased soil organic matter due to improved tillage, increased vegetation,etc. Most field drainage incorporates conservation drainage principles and/or is intercepted by ponds, wetlands, etc. that ET and infiltrate. Some non-ag land use areas add wetlands, perennial vegetation, and urban/residential stormwater management.	50
					Crops, all	Surface runoff	8%	2%			
					Developed	All	2%	0.5%			
	Low Flow		increase dry season river base flow (groundwater)	3% increase	Crops, not tiled	Groundwater	N/A	0.3%	Shift flow timing to dry season by increasing infiltration and permanent water storage capacity in the landscape		40
					Crops, tiled	Groundwater		1.3%			
					All other land use	All		1.3%			
Sediment		▪7 stream reaches stressed/impaired ▪6 stream reaches supporting ▪Downstream waters impacted	20% reduction in river sediment concentrations/loads (FWMC from 77 to 65 mg/L)	8% reduction	Stream bank erosion		3%	0.5%	Address altered hydrology, stabilize where economically necessary	First, control hydrology in contributing areas as discussed above. Stabilize few stream banks/ravines - those that threaten high value property.	35
					Ravine erosion		3%	0.5%			
					Crops, not tiled	Surface runoff	7%	4%	1) Reduce concentration by improving treatment or management and/or 2) reduce polluted water volume	Most fields use surface sediment controls to prevent erosion including conservation tillage, removing open intakes, cover crops,etc. Many fields trap/settle eroded sediment at edge of field with buffers, sediment basins, etc.	
					Crops, tiled	Surface runoff & open tile intakes	6%	3%			
					Developed	All from land use	1%	0%			
Phosphorus		▪6 stream reaches and 8 lakes stressed/impaired ▪1 lake supporting ▪Downstream waters impacted	35% reduction in river 50% reduction in lake concentrations/loads (FWMC from 0.23 to 0.15 mg/L)	10% reduction for rivers, 12% reduction for lakes	Crops, all	Surface runoff	21%	6.5%	1) Reduce concentration by improving treatment or management and/or 2) reduce polluted water volume	All fields incorporate nutrient management principles for fertilizer and manure use. Sediment practices as discussed above are implemented. Many fields treat tile drainage water to remove phosphorus using treatment wetlands, vegetative filters, etc. Some ditch/stream water has improved treatment via stream/ditch vegetative improvements. Much of the urban/residential runoff is prevented or treated. Most failing SSTSs are fixed. Some WWTPs upgrades to reduce phosphorus are made.	30 for riverS, 40 for lakes
					Crops, all	Tile & groundwater	5%	1%			
					Pasture (overgrazed)	Surface runoff	1%	0.5%			
					Developed	Urban Stormwater	1.5%	0.5%			
					Developed	Failing SSTS	1%	0.5%			
					Developed	WWTPs	0.5%	0.0%			
					-	Stream Erosion	5%	1%	Address altered hydrology, stabilize where economically necessary	Sediment practices for stream banks/ravines as discussed above are implemented.	
Nitrogen		▪3 stream reaches stressed ▪1 stream reach not stressed ▪Downstream waters impacted	25% reduction in river concentrations/loads (FWMC from 6.4 to 4.9)	10% reduction	Crops, tiled	Tile drainage	15%	5%	1) Reduce concentration by improving treatment or management and/or 2) reduce polluted water volume	All fields incorporate nutrient management principles for fertilizer and manure use. Hydrology practices as discussed above are implemented, including design parameters for nitrogen removal. Sediment practices as discussed above are implemented , including design parameters for nitrogen removal. Much of the urban/residential runoff is prevented or treated.	30
					Crops, all	Groundwater	4%	2%			
					Crops, all	Surface runoff	5%	2%			
					Developed	City/Res Stormwater	1%	0.5%			
Bacteria		▪16 stream reaches impaired ▪1 stream reach supporting	65% reduction in river concentrations/loads (geomean from 190 to 126 cfu/100mL)	10% reduction	Crops w surface manure	Surface runoff	30%	4%	1) Reduce concentration by improving treatment or management and/or 2) reduce polluted water volume	All manured fields incorporate best manure management practices. Many manured fields incorporate infield and edge of field vegetative practices to capture manure runoff including cover crops, buffer strips, etc. Most manure feed lot pile runoff is controlled. Most failing SSTSs are fixed. Some WWTPs upgrades to reduce bacteria are made.	40
					Developed	Feedlot/stockpile runo	10%	3%			
					Pasture (overgrazed)	Pasture runoff	5%	1%			
					Crops w subsurface manure	Surface runoff	3%	1%			
					Developed	Failing SSTS	1%	1%			
					Developed	WWTPs	1%	0%			
Habitat		▪5 stream reaches stressed ▪4 stream reaches not stressed	40% increase in average MSHA score (score from 48 to 66)	5% increase	Degraded Riparian		N/A		Improve riparian	Hydrology practices as discussed above are implemented. All streams have adequate buffer size and vegetation to meet shading, woody debris, geomorph, and other habitat needs. Few channel restorations.	40
					Altered hydrology		see above		Address hydrology		
DO		▪16 stream reaches stressed ▪1 stream reach not stressed	increase, minimize fluctuation	Meet Q & P targets	Phosphorus, altered hydrology, and degraded riparian		see above		Address P, altered hydrology, riparian, and in-stream conditions	Address hydrology, phosphorus, and habitat practices as discussed above.	40

Table 12B: This portion of the table presents information most relevant for local planning efforts including the specific strategies and actions, adoption rates, and responsibilities. The strategies and relative adoption rates developed by the WRAPS workshop team were used to calculate the adoption rates needed to meet the pollutant/stressor 10-year targets. Information on the conditions, goals, and total timelines is presented in Table A. Refer to the key for notes and information.

Land use/Source Type	**Watershed Restoration and Protection Strategies** estimated to meet 10-year target at specified adoption rates	Adoption Rate		Pollutants/ Stressor addressed by strategy & relative effect of strategy on water quality goal per treated acre						Responsibility																							
		% watershed to newly adopt (treated area)	Acres to newly adopt (treated acres)	Flow	TSS	Phosphorus	Nitrogen	Bacteria	Habitat**	Farm Owners	Farm Operators	Residents	Organizations	Businesses	Municipalities	Ag Industry	YMWD	Area II	Drainage Auth	SWCD	P&Z/Environ.	Feedlot Staff	Elected Officials	Transportation Auth.	MPCA	DNR	BWSR	MDA	MDH	UofM Extension	USDA	USFWS	Corps of Engin.
Cultivated Crops	Nutrient management (for P & N)	10%	70,700			o	X			√	√					√				√					√		√	√		√	√		
	Cover crops	5%	35,400	x	X	o	X	X	-	√	√					√				√						√	√	√		√	√		
	Conservation tillage/residue management	5%	35,400	x	x	o	x	o	-	√	√					√				√							√	√		√	√		
	Buffers, border filter strips*	5%	35,400	-	o	o	-	o	x	√	√	√	√			√	√		√	√	√		√		√	√	√	√		√	√	√	
	WASCOBS, terraces, flow-through basins (for surface runof	5%	35,400	-	x	o	-	-	-	√	√							√		√					√		√	√			√		
	Grassed waterway*	2%	14,100	-	x	-	-		-	√	√									√					√		√	√			√		
	Treatment wetland (for tile drainage system)*	2%	14,100	-		-	X		-	√	√	√	√		√		√	√	√	√			√		√	√	√	√	√	√	√	√	
	Crop rotation (including small grain)	2%	14,100	o	o	-	o		-	√	√					√				√		√					√	√		√			
	Alternative tile intakes*	1%	7,100		x	o				√	√					√	√		√	√		√			√		√	√		√	√		
	Wood chip bioreactor*	1%	7,100			-	x			√	√						√		√	√							√				√		
	Saturated buffers*	1%	7,100	-		-	x		-	√	√						√		√	√							√	√			√		
	Controlled drainage, drainage design*	1%	7,100	-		-	x		-	√	√						√		√	√							√				√		
	Restored wetlands	0.5%	3,500	X	X	x	X	X	x	√	√		√				√	√	√	√						√	√				√	√	√
	Contour strip cropping (50% crop in grass)	0.5%	3,500	x	X	x	X	x	-	√	√					√	√			√							√	√		√	√		
	Improved manure application, better setbacks & training	0.5%	3,500	o		o	x	X	-		√					√						√			√					√	√		
	Conservation cover	0.1%	700	X	X	X	X	X	x	√	√		√				√			√			√		√	√	√				√	√	
	Extended retention (culvert design)*	0.1%	700	-	x	-	-		-	√	√		√		√	√	√	√	√	√				√		√	√				√	√	√
	Side inlet control to ditch (w serious erosion)*	0.1%	700		x	o				√	√		√		√	√	√	√	√	√							√				√		
	Two stage ditch*	0.1%	700	-	o	-	o	-	-	√	√		√						√	√	√					√	√				√		√
Pas-trues	Rotational grazing	0.1%	700			X		X		√	√						√			√											√		
	Livestock exclusion	0.1%	700			X		X	x	√	√						√			√											√		

* = strategy footprint is << treated area

Relative Effectiveness - at 1% watershed adoption, calculated % of goal addressed

X=extremely	x=very	o=somewhat	-= minimumly	<blank>=negligible
>2%	>1%	>0.5%	>0%	~0%

** Practices with some impact on flow are assumed to have a minimal impact on habitat, while those that are directly applicable to riparian areas are assumed very effective

Land use/Source Type	**Watershed Restoration and Protection Strategies** estimated to meet 10-year target at specified adoption rates	Adoption Rate	Pollutants/ Stressor addressed by strategy						Responsibility																							
			Flow	TSS	Phosphorus	Nitrogen	Bacteria	Habitat	Farm Owners	Farm Operators	Residents	Organizations	Businesses	Municipalities	Ag Industry	YMWD	Area II	Drainage Auth	SWCD	P&Z/Environ.	Feedlot Staff	Elected Officials	Transportation Auth.	MPCA	DNR	BWSR	MDA	MDH	UofM Extension	USDA	USFWS	Corps of Engin.
City & Residential	Urban and residential stormwater practices:	sufficient to reduce current city and residential contributions by 10%	√	√	√	√	√	√																								
	Street sweeping												√											√					√			
	Construction site erosion control										√		√	√																		
	Smart snow pile management										√		√																			
	Impervious disconnections													√									√									
	Municipal good house keepers										√			√																		
	Waterway buffers										√									√									√			
	Rain gardens										√		√	√					√													
	Golf course management											√	√						√										√			
	Innovative technologies													√																		
	Pave gravel surfaces												√										√									
	Pervious pavements										√		√	√																		
Failing SSTS	Maintenance and replacement/upgrades	sufficient to reduce current SSTS contributions by 10%			√		√		√		√									√												
	Enact ordinance to require compliant system sales																			√		√										
Feed lots	Feedlot runoff controls including: buffer strips, clean water diversions, etc.	sufficient to reduce current feedlot contributions by 20%			√	√	√								√	√					√											
Stream banks, Ravines	Streambank and ravine stabilization where needed to protect high value property, use bioengineered methods when possible, address hydrology first	as needed to protect high-value property		√	√			√	√	√		√		√	√	√		√	√				√		√	√				√		√
Lakes	Near lake veg & erosion restoration/maintenance	sufficient to reduce/consume P load to lakes by 2%			√						√					√				√					√				√			
	In-lake management and species control																															
Social Infrastructure	Ordinance & policy review/update		√	√	√	√	√	√	√	√	√							√		√	√	√	√	√	√	√				√		√
	Education, networking, and messaging including: Collaboration with ag professionals; Community events; Peer leader and peer to peer networking	sufficient to address barriers to adopting strategies at specified adoption rates	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	

Strategy Table Key& Notes

Ag BMP strategy NRCS project code

See the NRCS design guidance and/or the Ag BMP handbook for additional information. The Ag BMP practices and NRCS codes listed in the table may not be the only available practices in which to select from.

Ag BMP	NRCS code(s)	Additional Notes
Conservation cover	327, 643	Native vegetation including grasses, trees, shrubs
Conservation tillage	329,345,346	No till or strip till with very high residue to protect soil surface
Construction site erosion control	570	Silt fence, turf reinforcement, or similar to prevent sediment runoff
Cover crops	340	A key soil health principle. Learning curve to implement. Work with experienced users/professionals to implement.
Crop rotation	328	Consider in conjunction with cover crops and conservation tillage
Extended retention		See Ag BMP handbook (no NRCS code). Intended to slow discharge. Design must consider fish passage needs.
Feedlot runoff control	635, 362	Vegetated treatment area provides a controlled release of nutrient rich wastewater. Diverting runoff water.
Field buffers, borders, filter strips	393,386,332	Edge-of-field or within field
Grassed waterways	412, 342	Establishes permanent vegetation on flow pathways on erodible soils, slopes
In/near ditch retention and treatment	410, 587	Includes any practice where the ditch itself is incorporated in to practice: 2-state ditch, side inlet control, weirs and berms, etc.
In-lake management and species control		Prevention of invasive species, restore diverse fish populations to control rough fish, increase habitat diversity
Livestock exclusion	382, 472, 614	Exclusion from water bodies, can help to create watering station
Manure application setbacks	590	One specific component of nutrient management
Near-lake vegetative management		Leaving natural buffer zone at shoreline, using natural materials as wave breaks, restore/maintain emergent veg, woody debris
Nutrient (including manure) management	590	Considers amount, source, form, timing, etc..
Ravine (grade) stabilization	410	First address hydrology before costly stabilization
Restored wetlands	657, 643, 644	Restoring wetland (where one historically was located)
Rotational grazing	528	Managing for improved vegetation improves water quality
Saturated buffers	739	Vegetated subsurface drain outlet for nutrient removal
SSTS (Septic systems)	313	Maintenance and replacement when needed to ensure clean effluent
Streambank stabilization	580	Using bioengineering techniques as much as possible
Strip cropping	332, 585	Alternating erosion susceptible crops with erosion resident crops perpendicular to water flows
Tile system design; controlled drainage	554	Managing for less total runoff; includes alternative tile intakes
Treatment wetlands	656, 658	Specifically designed to treat tile drainage and/or surface runoff
Water and sediment basins, terraces	638, 600	Managing for extended retention and settling
Woodchip bioreactors	747	Reducing the level of nitrogen in drainage systems

***** The strategy footprint is only a fraction of the treated acres, which should be considered when comparing adoption rates. For example: grassed waterway will not take 14,100 acres out of production, but will treat 14,100 acres. It is intended to treat the water from many more acres than the strategy footprint. So the actual acres converted to grassed waterways would be a fraction (e.g. 1/20th or 1/100th) of the treated acres.

These strategies do not specify or supersede any permit requirements. MS4 and other permitted parties need to work with the MPCA program to ensure TMDL waste load allocations are met.

4 Appendix

4.1 Assessments by Stream Reach

AUID (last 3 digits)	Stream	Reach Description	Beneficial Use and Associated Parameters & Stressors Assessment														
			Aquatic Life											Aq Rec		Lim Use	
				Parameters				Stressors							Par		Par
			Assessment	F-IBI	M-IBI	DO	TSS	Q	P	N	DO	Hab	TSS	Assessment	Bacteria	Assessment	DO
538	Spring Creek	Headwaters to Yellow Medici	Imp	x	if	I	I							Imp	x	-	-
622	Judicial Ditch 17	CD 3 to Yellow Medicine R	IF	na	na	if	√							Imp	x		
502	Yellow Medicine River	Spring Cr to Minnesota R	Imp	√	√	√	x							Sup	√	-	-
513	Yellow Medicine River	S Br Yellow Medicine R to Spri	Imp	if	if	if	x							Imp	x	-	-
503	Yellow Medicine River	Headwaters to Yellow Medici	Imp	√	√	if	x							Imp	x	-	-
550	Judicial Ditch 29	T111 R44W S16, south line to S	IF	na	na	if	√							Imp	x	-	-
595	Unnamed creek	Headwaters to Unnamed cr	Imp	x	I	if	√	x	if	if	x	x	if	Imp	x		
597	Unnamed creek	Unnamed cr to Unnamed cr	IF			if	√							Imp	x		
599	Unnamed creek	Unnamed cr to S Br Yellow Me	IF			if	p							Imp	x		
600	Unnamed creek	CD 34 to CD 35	NA	na	na									Imp	x		
543	Mud Creek	Headwaters to T114 R43W S35	Imp	√	x	if	x	x	x	x	x	x	x	Imp	x	-	-
542	Yellow Medicine River	CD 8 to Yellow Medicine R	Imp	I	x	if	x	x	x	√	√	√	x	IF	if	-	-
564	Unnamed creek	Unnamed cr to Unnamed cr	Imp	√	x			x	if	if	if	√	if				
545	Unnamed creek	Headwaters to Yellow Medici	NA	na	na									Imp	x	-	-
584	Yellow Medicine River	Headwaters to Mud Cr	Imp	I	√	if	x							Imp	x		
694	Unnamed creek	Ash Lk to Yellow Medicine R	Imp	x	x			x	if	if	x	x	if				
536	Hazel Creek	Unnamed cr to Minnesota R	IF	√	if	if	√							Imp	x	-	-
707	Unnamed creek	Headwaters to CD 9	NA	na	na												
551	County Ditch 12	Headwaters to T113 R36W S8	NA	na	na									-	-	IF	if
552	County Ditch 12	T113 R 36W S5 to Mn River	IF	I												-	-
604	Echo Creek	Unnamed to Mn River	Sup	√													
673	Judicial Ditch 23	Unnamed to Unnamed	NA	na	na												
674	Judicial Ditch 23	Unnamed to MN River	Sup	√	√												
710	Unnamed Creek	Unnamed to MN River	NA	na	na												
711	CD90	Unnamed to Unnamed	NA	na	na												
713	County Ditch 39	CD 6A to Minnesota R	Imp	x	x			x	x	x	if	√	if				
714	County Ditch 6A	Unnamed to CD39	NA	na	na												
535	Stony Run Creek	T116 R40W S30, west line to M	IF	na	na	if	√							Imp	x	-	-
580	Stony Run Creek	Headwaters to T116 R41W S25	NA	na	na												
708	County Ditch 36	Unnamed to JD21	NA	na	na												
709	Unnamed Creek	Unnamed to JD21	NA	na	na												
554	Boiling Spring Creek	Unnamed ditch to T114	NA	na	na									-	-		
555	Boiling Spring Creek	T114 to Minnesota R	IF	√	√	IF	I							Imp	x		
620	Boiling Spring Creek	Headwaters to T113	NA	na	na												
717	County Ditch 2	Unnamed cr to Minnesota R	Imp	x	√			x	x	if	if	√	if				
718	Unnamed creek	Lone Tree Lk to Minnesota R	Imp	x	x			x	x	if	x	x	if				
518	JD10	Headwaters to Wood Lake Cr	NA	na	na											-	-
546	Judicial Ditch 10 (Woo	Timm Lk to Wood Lk outlet	NA	na	na											-	-
547	Judicial Ditch 10 (Woo	Wood Lk outlet to Minnesota	Imp	x	x	if	I	if	x	x	x	x	x	Imp	x	-	-
737	County Ditch 31	Headwaters to JD10	NA	na	na												

Beneficial Use Assessment*

Imp	=	impaired
NA	=	not assessed
IF	=	insufficient data
Sup	=	supporing

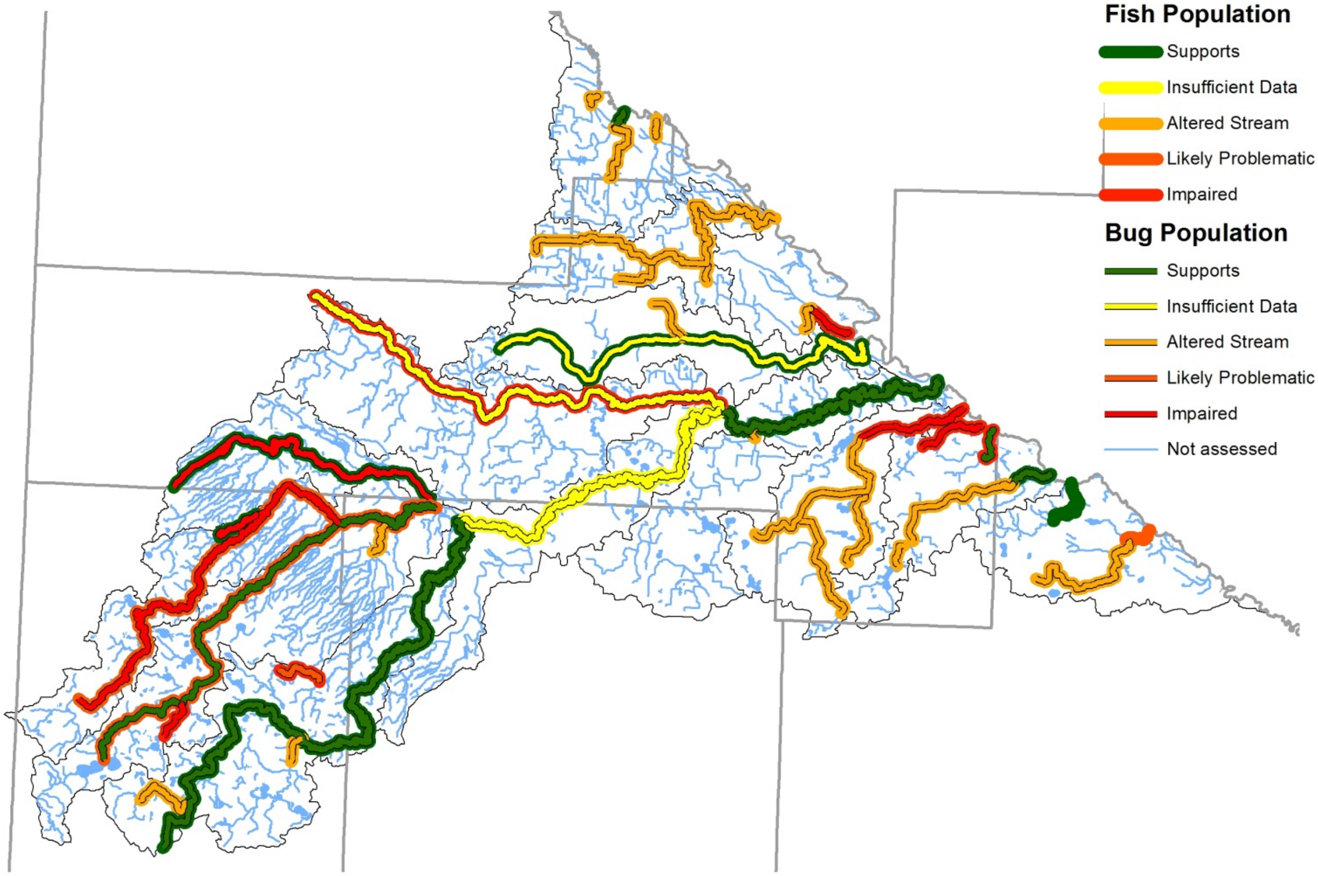
*benefical use assessment considers the status of multiple parameters and professional judgement

Parameter/Stressor Assessment

x	=	failing standard/ stressing	I	=	insufficient data but likely failing standard
if	=	insufficient data to make finding	√	=	supporting standard/ not stressing
na	=	data collected but not assessable until standards for channelized streams are developed			

4.2 Stream Biological Assessments

Streams assessed for aquatic life and the resulting assessment. Streams identified as impaired for low IBI scores are analyzed for the reason for the bio-impairment, referred to as stressors. The outside line color is the fish assessment and the inside color is the macroinvertebrate assessment.



4.3 TMDL Calculated % Reductions

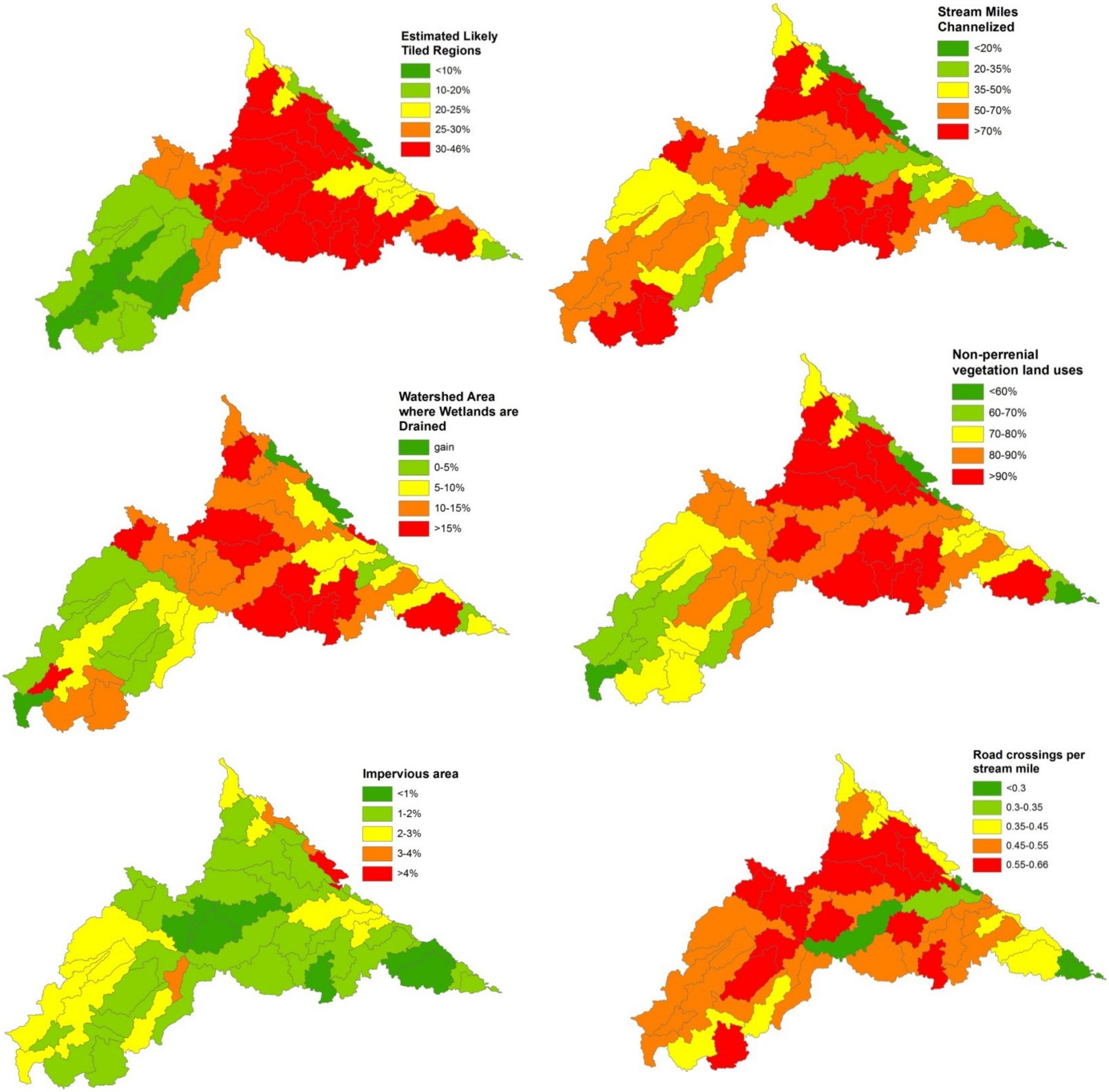
Aggregated HUC12 Watershed Stream AUID #	**Observed Load** (billion org) [# of samples]	**Load Set at 126 org /100mL Standard** (billion org)	**Estimated Reduction Needed To Get** **< 126 org/100 mL**
Hazel Creek- County Ditch No. 9 07020004-536	**4,663** [18]	**2,529**	**46%**
Wood Lake Creek – Judicial Ditch 10 07020004-547	**2,938** [15]	**769**	**74%**
Judicial Ditch 17 07020004-622	**2,940** [17]	**2,322**	**21%**
Lower Yellow Medicine River 07020004-513	**242,884** [17]	**44,803**	**82%**
Mud Creek 07020004-543	**5,903** [17]	**2,830**	**52%**
South Branch Yellow Medicine River 07020004-503	**1,284,040** [189]	**81,784**	**94%**
South Branch Yellow Medicine River 07020004-550	**55,845** [36]	**3,873**	**93%**
South Branch Yellow Medicine River 07020004-595 07020004-597 07020004-599	**59,047** [103]	**10,494**	**82%**
South Branch Yellow Medicine River 07020004-600	**4,629** [10]	**1,394**	**70%**
Spring Creek 07020004-538	**32,256** [17]	**14,617**	**55%**

Aggregated HUC12 Watershed Stream AUID #	Observed Load (billion org) [# of samples]	Load Set at 126 org /100mL Standard (billion org)	Estimated Reduction Needed To Get < 126 org/100 mL
Stony Run Creek 07020004-535	**4,388** [17]	**1,888**	**57%**
Upper Yellow Medicine River 07020004-545	**19,711** [17]	**2227**	**89%**
Upper Yellow Medicine River 07020004-584	**76,441** [51]	**18,866**	**75%**
Wood Lake Creek – MN River 07020004-555	**1,110** [15]	**294**	**74%**

Aggregated HUC12 Watershed AUID #	Observed Load (Tons TSS) [# of samples]	Load Set at 65 mg/L Standard (Tons TSS)	Estimated Reduction Needed To Get < 126 org/100 mL
Lower Yellow Medicine River 07020004-513	**15,761** [161]	**8,736**	**45%**
North Branch Yellow Medicine River 07020004-542	**1,319** [75]	**938**	**29%**
South Branch Yellow Medicine River 07020004-503	**4,127** [163]	**2,394**	**42%**
Upper Yellow Medicine River 07020004-584	**5,636** [160]	**2,919**	**48%**

Note: Information in these tables was updated after goals maps were created as a result of update HSPF model results for flow volumes. Some numbers many have changed slightly. Refer to final TMDL to ensure use of accurate numbers.

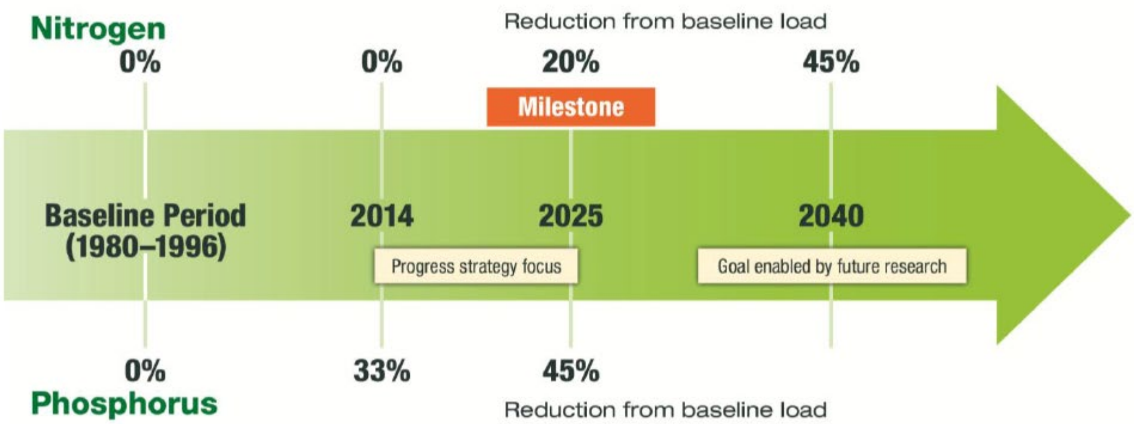
4.4 Altered Hydrology GIS Analysis



Analysis in report uses the following weights times each individual parameter (displayed in map): tile drained: 2, altered streams: 2, watershed area wetland loss: 8, non-perennial veg: 3, impervious: 10, road stream crossings: 20. Assumptions and analysis notes used to create above maps available upon request.

4.5 Minnesota State Nutrient Reduction Strategy

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



The phosphorus strategy calls for an additional 12% reduction (in addition to the already reached 33% reduction) between a 1980-1996 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 100units-45units=55 units. Since a 33% (33 units) reduction in baseline levels was already achieved, the 2014 load equals 100 units-33 units = 67 units. The reduction from 2014 to the final goal is (67 units - 55 units)/67units = 18% reduction. This goal is for the Mississippi River Basin as a whole, whereas the Minnesota River Basin is a much higher yielding area. Therefore, the total goals for major watersheds in the Minnesota River Basin will likely be higher than the Mississippi River Basin reduction goal.

4.6 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. MN Irrigation Scheduling Checkbook, Waseca station temp	NDSU (2012)	42 cm
4. MN Crop Coefficient Curve for Pan ET, Waseca station pan ET	Seeley and Spoden (1982)	39 cm

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

4.7 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 prevent phosphorus from getting to the lake and are a necessary basis for any restoration work.

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

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

- **Eco-friendly landscaping** – poor landscape design and impervious surfaces increase runoff and loading of nutrients into lakes.
  - Examples: aerate, rain barrels or cisterns, rain gardens, permeable pavers, sprinkler and drainage systems, maintain septic systems, etc.
- **Manage upland buffer zone vegetation** – Upland buffer zone vegetation selection can greatly affect nutrient absorbance, watering needs, erosion potential, need for drainage, etc.
  - Examples: properly landscape, maintain canopy and address terrestrial invasive species that may prevent re-generation of native trees, proper turf grass no mow lawns in highly utilized areas and planting native grasses and forbs with deep root systems in underutilized areas of lawn, reduce watering needs, controlled fertilization and grass clippings.

- **Naturalize transition buffer zone** – a natural transition buffer zone increases absorption of nutrients and decreases erosion potential of the water-shore interface.
  - Examples: balance natural landscaping by minimizing recreational impact area, utilize natural materials for erosion control bioengineering using wood or biodegradable materials in combination with stabilizing native vegetation to restore a shoreline, minimize beach blankets, draw down water levels for consecutive seasons to allow existing seed banks to develop deep rooted native vegetation or plant diverse mixes of grasses, sedges, forbs, shrubs and trees to create a complex root mass to hold the bank soils, preserve and restore native emergent aquatic vegetation sedges, rushes, forbs, shrubs and trees, do not remove natural wood features that supply cover and food sources for aquatic species and invertebrates while serving as a wave break along the shoreline.
- **Preserve aquatic buffer zone** – The aquatic buffer zone is difficult to restore, so the best approach is preservation and providing best opportunity for aquatic plants through watershed improvements to increase water quality. Draw down water levels to allow natural seed banks of emergent and aquatic vegetation to establish naturally, supplement more plant diversity with lower water levels as restoration of emergent and aquatic vegetation have higher success rates.
  - Examples: reduce recreational impact area, minimize control of all types of aquatic plants, reduce dock footprint, preserve and/or restore native emergent and floating-leaf aquatic plants.

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

- **Biomanipulation** – changing the fish population. Rough fish are generally bottom feeders and though feeding activity re-suspend sediments and decrease water clarity; thus, removing rough fish through mechanical or biological methods can improve water clarity, increase aquatic vegetation, and improve water quality overall.
  - Examples: commercial netting (not a standalone tool, implement in conjunction with other fisheries management methods to augment reduced populations for a short term period allowing desirable fish populations to develop adequate size to manage rough fish populations), balanced fish management increasing fish species diversity for a balanced fish population and introducing large predator fish populations, preserve and restore diverse spawning, cover, and feeding habitat that favors specific fish species that maintain a diverse fish population, reclamation (kill all fish and start over) inlets for rough fish should be considered when planning reclamation to prevent immediate re-introduction. In lake shore strategies are essential to incorporate to develop habitat for desirable species of fish once the rough fish population is removed.
- **Invasive species control of plants and/or animals** – invasive species alter the ecology of a lake and can decrease diversity of habitat when a healthy native diversity exists in a lake. Removing native vegetation or incorporating non-native vegetation into landscaping can allow for invasive species to establish and spread taking over larger blocks of native species that maintain the natural systems health, therefore reducing disturbance to near shore habitat is important.
  - Examples: prevention, early detection, lake vegetation management plan (LVMP)

- **Chemical treatment to seal sediments** – re-suspension of nutrients through wind action can cause internal nutrient loading.
    - Examples: alum treatments. Consider the long term effectiveness in shallow lakes that experience wind driven turning, where stratification of the lake does not occur. Incorporating establishment of lake shore habitat is important to absorb phosphorus in the lake as part of a long term approach to phosphorus level management.
- **Dredging** – Sedimentation after years of poor watershed practices increases nutrient laden sediments and decreases depth. Dredging should only be considered when the source of the sediment and the banks of the lake are stable to prevent sediment from redepositing. Dredging can: create channels for access, increase habitat diversity, and accommodate recreational use.

4.8 Nutrient BMP Summary Info from Minnesota and Iowa State Reduction Strategy Reports

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

MN: http://www.mda.state.mn.us/~/media/Files/chemicals/nfmp/nfmp2015.pdf

IA: http://www.nutrientstrategy.iastate.edu/sites/default/files/documents/NRS2-141001.pdf

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%**
	Randall et al. (2003)	Minnesota	13%
Split applications	Jaynes et al. (2004)	Iowa	30%
	Range of % reduction		**13 to 30%**

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

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

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

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

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

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

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

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

\+ A positive number is nitrate concentration or load reduction and a negative number is increased nitrate.

++ A positive corn yield change is increased yield and a negative number is decreased yield. Soybean yield is not included as the practices are not expected to affect soybean yield.

* SD = standard deviation.

‡ Reduction calculated based on initial application rate for each Major Land Resource Area (MLRA).

‡‡ Calculated based on the Maximum Return to Nitrogen (MRTN) relative yield at the given rates.

** Based on 1 study with 3 years of corn and 2 years of soybean.

*** This number is based on the Land Retirement number – there are no observations to develop a SD.

^ These numbers are based on load reduction since there is no impact on concentration with these practices

† Based on one report looking at multiple wetlands in Iowa (Helmers et al., 2008a).

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

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

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

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

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

c - SD = standard deviation.

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

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

f - Indicates no impact on yield should be observed.

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

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

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

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

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

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

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

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

Name	Practice/Scenario**	Nitrate-N	Phosphorus	Cost of N Reduction from baseline ($/lb)	Initial Investment (million $)	Total EAC* Cost (million $/year)	Statewide Average EAC Costs ($/acre)
		% Reduction from baseline					
NCS1	Combined Scenario (MRTN Rate, 60% Acreage with Cover Crop, 27% of ag land treated with wetland and 60% of drained land has bioreactor)	42	30	2.95	3,218	756	36
NCS2	Combined Scenario (MRTN Rate, 100% Acreage with Cover Crop in all MLRAs but 103 and 104, 45% of ag land in MLRA 103 and 104 treated with wetland, and 100% of tile drained land in MLRA 103 and 104 treated with bioreactor)	39	40	2.61	2,357	631	30
NCS3	Combined Scenario (MRTN Rate, 95% of acreage in all MLRAs with Cover Crops, 34% of ag land in MLRA 103 and 104 treated with wetland, and 5% land retirement in all MLRAs)	42	50	4.67	1,222	1,214	58
NCS4	Combined Scenario (MRTN Rate, Inhibitor with all Fall Commercial N, Sidedress All Spring N, 85% of all tile drained acres treated with bioreactor, 85% of all applicable land has controlled drainage, 38.25% of ag land treated with a wetland)	42	0	0.88	4,810	225	11
NCS5	Combined Scenario (MRTN Rate, Inhibitor with all Fall Commercial N, Sidedress All Spring N, 65% of all tile drained acres treated with bioreactor, 65% of all applicable land has controlled drainage, 29.25% of ag land treated with a wetland, and 15% of corn-soybean and continuous corn acres converted to perennial-based energy crop production)	41	11	5.58	3,678	1,418	67
NCS6	Combined Scenario (MRTN Rate, 25% Acreage with Cover Crop, 25% of acreage with Extended Rotations, 27% of ag land treated with wetland, and 60% of drained land has bioreactor)	41	19	2.13	3,218	542	26
NCS7	Combined Scenario (MRTN Rate, Inhibitor with all Fall Commercial N, Sidedress All Spring N, 70% of all tile drained acres treated with bioreactor, 70% of all applicable land has controlled drainage, 31.5% of ag land treated with wetland, and 70% of all agricultural streams have a buffer)	42	20	0.95	4,041	240	11
NCS8	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 a wetland, and 70% of all agricultural streams have a buffer) - Phosphorus reduction practices (phosphorus rate reduction on all ag land, Convert 90% of Conventional Tillage CS & CC acres to Conservation till and Convert 10% of Non-No-till CS & CC ground to No-Till)	42	29	***	4,041	77	4

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.

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

4.9 Agricultural BMP Summary Table

Conservation Practice			Relative Effectiveness, Summarized Effectiveness Data, and Level of Study - by Pollutant/Stressor							
Practice "group"		Individual Practices (Ag BMP Handbook page#)	Sediment (from upland/field)	Phosphorus (Total, dissolved, or particulate)	Nitrogen (Total, nitrate, or dissolved)	Pesticides (one or more)	Bacteria (fecal and/or e. coli)	Hydrology	Habitat	Sediment (from bank, bluff, channel or ravine)
Restore to natural/ minimal management		Conservation Cover (22) land out of production, into vegetation	*	*	10mg/L in streams with 3% of watershed in practice **					
		Restored Wetland (151) (previously drained; typically larger)	>75% reduction *	0-50% TP reduction *	68- >85% TN reduction *					
Improve soil health and/or vegetation	General (can do anywhere)	Cover Crops (36)	32-92% reduction	54-94% TP reduction 7-63% dP reduction	13-64% TN reduction 66% TN reduction**	40% reduction		11% reduction in volume of tile drainage		
		Conservation Tillage (94) (no-till or high residue)	90% reduction 6-99% reduction **	57% dP reduction 59-91% TP reduction **	-3-91% TN reduction **			56%-99% reduction in surface runoff		
		Nutrient Management (48)	15-65% reduction after adding manure**	50% dP reduction 14-91% TP reduction**	10-40% TN reduction**			2-62% reduction in runoff volume after adding manure		
		Crop Rotation (26) including perennial or small grains	32-92% reduction	53-67% TP reduction	59-62% TN reduction 66-68% TN reduction *					
		Pest Management (60)				17-43% reduction 40-50% (5 years) 70-80% (10 years)*				
	Site-specific	Contour Buffer Strips (28) applies only to steep fields	83-91% reduction 30-94% reduction*	49-80% TP reduction 20-50% dP reduction	27-50% TN reduction 18-49% dN reduction	53-77% reduction*	43-74% reduction			
		Grassed Waterway (84) for concentrated surface flows/gullies	94-98% reduction 77-97% reduction **			70-96% reduction **		2-20% reduction in surface runoff (modeled)		
		Contour Stripcropping (72) 50% or more of field in grass, etc..	43-95% reduction	70-85% TP reduction 8-93% TP reduction	20-55% TN reduction					
		Terrace (113) applies only to steep fields	80-95% reduction	70-85% TP reduction	20-55% TN reduction					
		Contour Farming (33) applies only to steep fields	28-67% reduction	10-62% TP reduction	25-68% TN reduction					
Improve water manage-ment (retention and filtration)	Tile drainage /subsurface water	Alternative Tile Intakes (67) replacing open intakes	70-100% reduction*	*						
		Tile System Design (63) shallower and wider pattern			40-47% NO_3 reduction					
		Saturated Buffers (not in handbook) intercepting tile drainage water								
		Controlled Drainage (75)		50% TP reduction 63% dP reduction *	20-61% NO_3 reduction *			15-50% reduction in volume of tile drainage		
		Woodchip Bioreactor (156) (for tile drainage water)		*	30-50% NO_3 reduction *	*	*			
	Surface water	Treatment Wetland (146) (constructed; typically smaller)	75% reduction in urban settings *	59% TP reduction * 49-56% dP reduction 71-74% TP	40-43% TN reduction 64% TN reduction					
		Filter Strips, Field Borders (125)	76-91% reduction 0-99% reduction **	38-96% TP reduction 50% dP reduction 2-93% TP	27% TN reduction 1-93% NO_3 reduction **	45-78% reduction *	*			
		Sediment Basin (134)	60-90% reduction 77% reduction	34-73% TP reduction 72% TP reduction	30% TN reduction 82% NO_3 reduction		70% reduction			
		Side Inlet Control to Ditch (137) for grade stabilization and retention								
		Extended Retention (80) created by culvert/road design						11-41% reduction i 10-yr peak flow for drainage area		
		Water & Sediment Basin (143)	64 (modeled) - 99% reduction	74% organic P 80% sediment-bound P (modeled)						
Improve riparian areas		Riparian and Channel Veg (99) intercepting surface runoff	53-99.7% reduction 55-95% reduction	41-93% TP reduction 63% pP reduction	58-92% TN reduction 37-57% TN reduction					
		Streambank Stabilization (109) using bioengineering techniques								
		Two Stage Ditch (115) replacing trapezoidal ditch			5-15% TN reduction*					*
		Grade Stabilization (40) of headcut in ravine or small channel								75-90% reduction
Improve livestock and/or manure management		Rotational Grazing (103) replacing row crops/continuous graze	49% reduction compared to row crop	75% reduction compared to row crop	62% reduction compared to row crop		consistently lower than continuous graze			
		Livestock Exclusion (45) applies only to livestock operations		75% TP reduction	62% TN reduction 32% NO_3 reduction					49% reduction 82-84% reduction
		Waste Storage Facility (91) improved from leaky structure		25-90% TP reduction	29-80% TN reduction*					
		Feedlot Runoff Control (121) improvements to system with runoff	79% reduction 35-95% reduction *	83% TP reduction * 30-85% TP reduction	84% TN reduction 10-45% TN reduction *		Up to 99% removal *	67% reduction in surface runoff		

Notes: Numeric effectiveness and level of study from the MN Ag BMP Handbook (Miller et al., 2012). Relative effectiveness (shades) estimated by local conservation professionals. Refer to the handbook for additional details and before selecting a BMP to ensure its applicability, siting and design criteria. Rev date: 4/29/14 JB

Relative Effectiveness
- very effective BMP
- somewhat effective BMP
- minimally effective BMP
- not effective BMP

Level of Study in Upper Midwest
- ** well studied
- * some study

4.10 Modeled BMPs

Model(s) & Report	Summary & Notes	Scenario	Modeled Landscape/BMP(s)	Parameter Load Reduction: Sediment	Phosphorus	Nitrate/N	Cost
Nitrogen BMP Spreadsheet Minnesota Watershed Nitrogen Reduction Planning Tool (Lazarus et al., 2013)	The BMPs outlined here were developed using the N-BMP spreadsheet tool with inputs specifically for the Hawk-Yellow Medicine Watershed. This represents just one of endless scenarios than can be analyzed with this tool. Total cumulative nitrogen reduction for all BMPs applied is 25%. Reductions for individual BMPs are listed under the Parameter Reductions columns. Parameter Reductions do not add up to the cumulative reduction because some practices are mutually exclusive and therefore, less acres are available for practices.	Individual or All (see notes)	40% of area (67% of corn fields) receives target N application rate (30% less)			12.9%	**$-4.6/lb N**
			10% of area (50% of fall appliers) switches to spring N application			5.1%	**$-0.4/lb**
			10% of area (50% of fall appliers) switches to 70% side-dress, 30% preplant			5.5%	$2.0/lb N
			10% or area (50% of fall appliers) use N inhibitor			2.3%	$0.6/lb N
			13% of area (14% of corn and beans) plants rye cover crop (90% success)			3.9%	$22/lb N
			3.6% of area (50% of short season crops) uses cover crops on short season crops			1.2%	$20/lb N
			1.4% of area is in riparian buffer (50% of 100' on all streams in watershed)			1.2%	$23/lb N
			1% of area restored to (treatment) wetlands			0.5%	$2/lb N
			1.8% of area converted to perennial grass			1.5%	$6/lb N
			1.1% of area has bioreactors			0.1%	$20/lb N
			1.1% of area has saturated buffers			0.4%	$3.2/lb N
			1.1% of area has controlled drainage			0.3%	$4.3/lb N
Phosphorus BMP Spreadsheet (Lazarus et al. draft version of tool used)	The BMPs outlined here were developed using the P-BMP spreadsheet tool with inputs specifically for the Hawk-Yellow Medicine Watershed. This represents just one of endless scenarios than can be analyzed with this tool. Total cumulative phosphorus reduction for all BMPs applied is 25%. Reductions for individual BMPs are listed under the Parameter Reductions columns. Parameter Reductions do not add up to the cumulative reduction because some practices are mutually exclusive and therefore, less acres are available for practices.	Individual or All (see notes)	39% of area (80% of feasible area) receives target/reduced P fertilizer rate		5.1%		
			15% of area (80% of fall appliers in wheat/corn) switch to preplant fertilizer		0.5%		
			45% of area (80% of fields not currently using) adopt reduced tillage with >30% residue		7.0%		
			1.4% of area is in riparian buffer (50% of 100' on all streams in watershed)		5.9%		
			34% of area uses cover crops		3.5%		
			1% of area uses controlled drainage		2.2%		
			16% of area (80% of open intakes) use conservation/alternative intakes		0.0%		
			3.4% of area (80% of fields not currently doing so) inject or incorporate manure		1.5%		
HSPF Scenarios Tetra tech Report (2015)	Three different scenarios were selected by the local work group and modeled. Analysis on Yellow Medicine River mouth for year 1996-2012.	1	Water basins to store 1" of runoff per rain event from ag land surface runoff and tile drainage	20.8%	14.2%	5.7%	
		2	Reduce N application from 165 to 111 lb/ac, reduce soil test P to 16, agronomic rate for manure appl.	-0.9%	8.0%	20.7%	
		3	25% of area adopts fall/winter cover crops and 50' stream buffers increased from 70% to 80%	4.0%	2.1%	2.1%	
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.	2025 Milestone	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 Minnesota River tributaries and mainstem. Scenarios 1, 2 were minimally effective. HSPF capable of modeling stream dynamics. Load reductions are either reported specifically for the Le Sueur River Watershed where possible or generally for the Minnesota River Basin, depending on how the report summarized those numbers. 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), 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 Medicine)	26% (MN basin)		
		5	All BMPs in Scenario 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)		

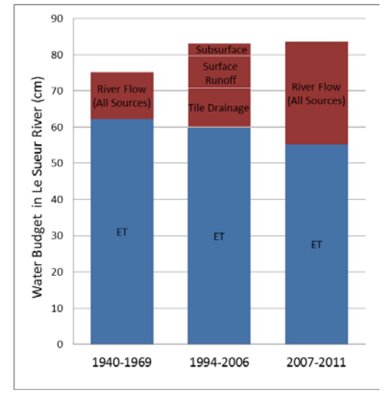
Model(s) & Report	Summary & Notes	Scenario		Normal til	Cons til	1/2 P fert	Pasture	Grass	Forest	Wetland	Water	Urban	Sediment	Phosphorus	Nitrate/N	Cost
SWAT, InVEST, Sediment Rating Curve Regression, and Optimization Lake Pepin Watershed Full Cost Accounting (Dalzell et al., 2012)	Models 6 BMPs in the 7-mile Creek Watershed either: **1**) placed by rule of thumb recommendations (not optimal) or **2**) to maximize TSS reduction for dollars spent (optimal). Completed economic analyses including: **A**) current market value only (using 2011 $) and **B**) integrated, which adds a valuation of ecosystem services (relatively modest value). Does not allow multiple BMPs on same pixel of land. Scenarios are described by percentages of land in each land use. Analysis of 2002-2008 data.	Land uses:		Normal til	Cons til	1/2 P fert	Pasture	Grass	Forest	Wetland	Water	Urban				
		Baseline		83%	0%	0%	2%	0%	4%	5%	1%	5%	0%	0%		0%
		2A	A	3%	14%	64%	3%	1%	5%	5%	1%	5%	4%	-1%		**-4%**
			B	35%	1%	38%	10%	1%	4%	5%	1%	5%	25%	22%		4%
			C	8%	0%	35%	32%	10%	4%	5%	1%	5%	50%	46%		21%
			D	2%	0%	10%	43%	29%	4%	5%	1%	5%	76%	69%		51%
		2B	a	30%	1%	44%	2%	0%	11%	5%	1%	5%	15%	19%		-8%
			b	26%	0%	41%	13%	1%	7%	5%	1%	5%	25%	28%		-7%
			c	13%	0%	29%	38%	2%	7%	5%	1%	5%	50%	48%		0%
			d	3%	0%	8%	68%	3%	6%	5%	1%	5%	76%	70%		19%
		1A	F	25m grass buffers around waterways									3%	3%		4%
			G	250m grass buffers around waterways									15%	15%		28%
			H	Converting highly erodible lands to grasslands									15%	17%		10%

4.11 Source Assessment Summary

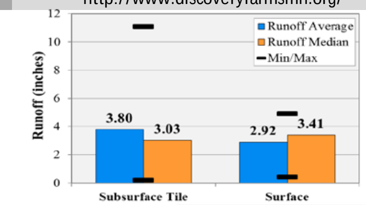
	Specific Source Assessment Analyses (including source and applicable area)	Discovery Farms Data (for corroboration) http://www.discoveryfarmsmn.org/	Watershed Pollutant Load Monitoring Network Data (for general condtions, corroboration)	HSPF Source Assessment (6/22/15 model update)	Professional Judgement Source Assessment

Q

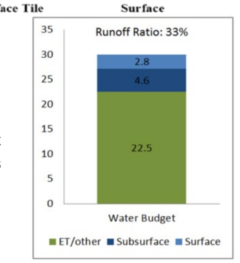
DNR doing baseflow separation to estimate GW component

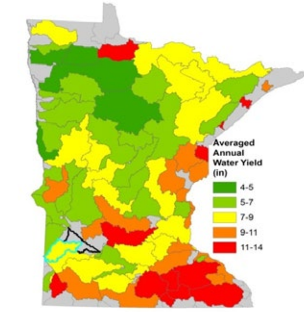


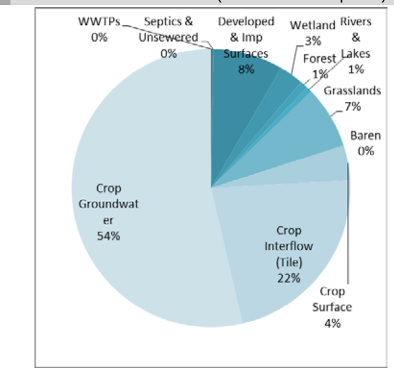
Middle bar: SWAT modeling of water budget by Folle

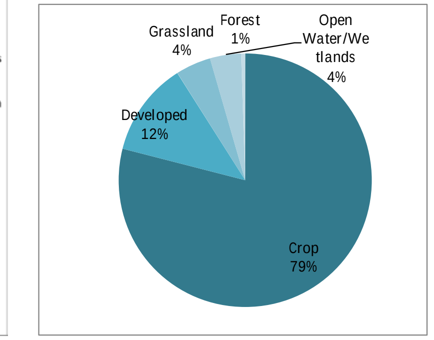


Simple water Budget for the 4 tiled farms

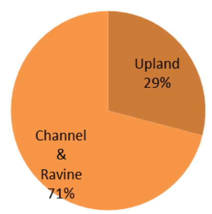




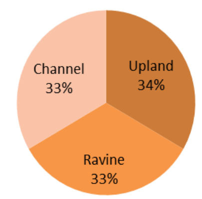




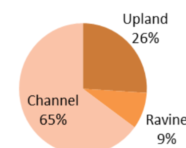
TSS



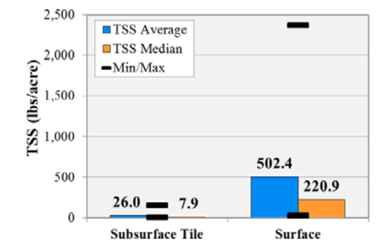
Schottler Finger-printing, MN River tribs US from mid mn

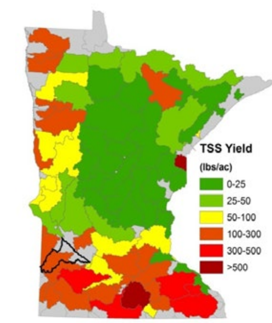


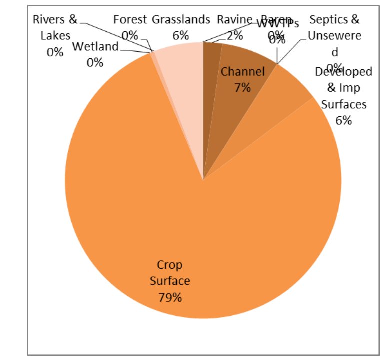
Generic Source Assessment for MN Basin (P Baskfield)

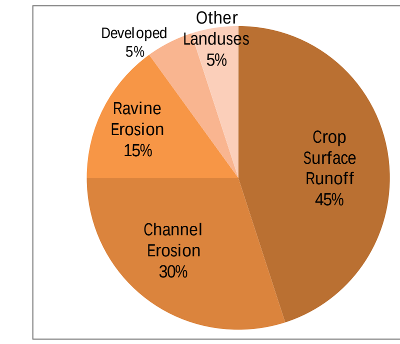


Gran Sediment Budget for Le Sueur River









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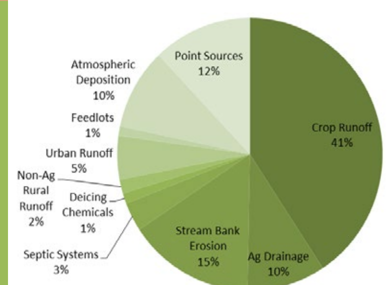
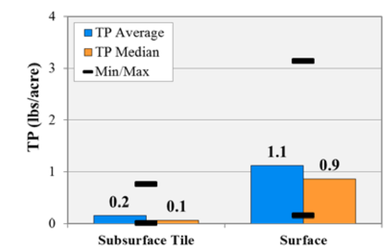
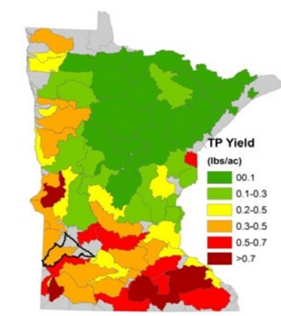
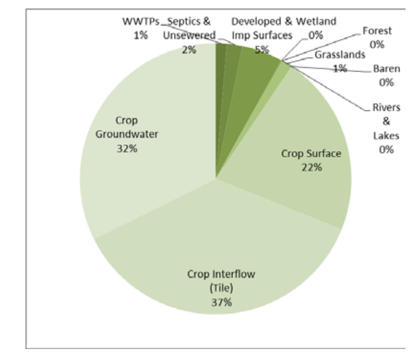
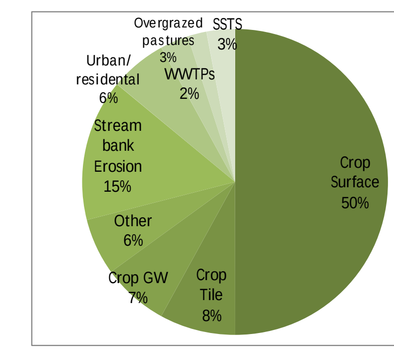


[Detailed Assessments of Phosphorus Sources to Minnesota Watersheds](#) Barr Engineering and the PCA (2003 with 2007 update)

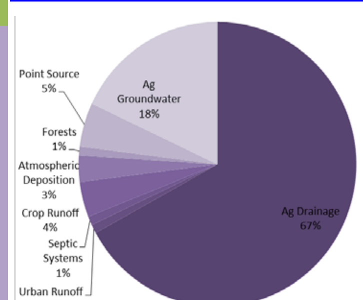




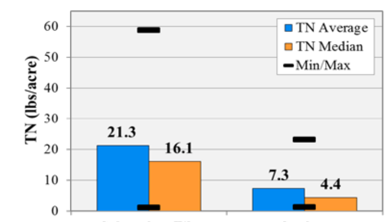


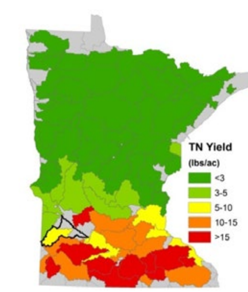


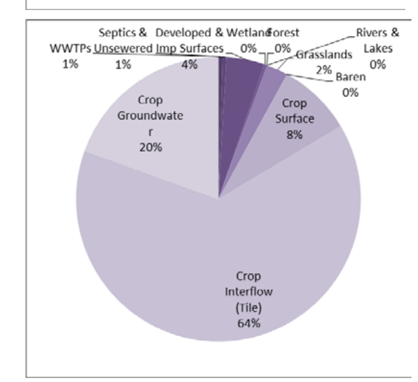
TN

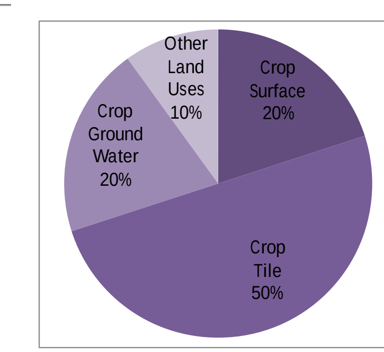


PCA Assessment for MN Basin, avg yr

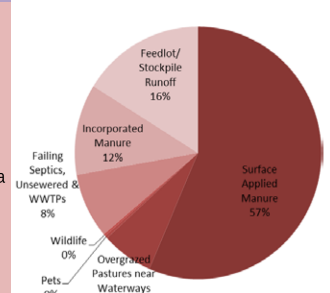








Bacteria



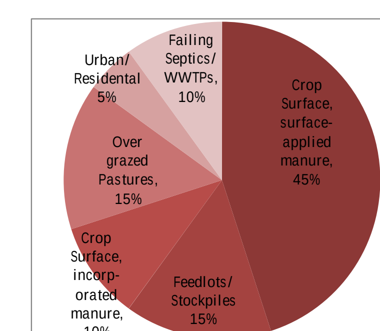
Strong relationship to fecal bacterial contamination in water	**Weak** relationship to fecal bacterial contamination in water
· High storm flow (the single most important factor in multiple studies) · % rural or agricultural areas greater than % forested areas in the landscape (entire watershed area)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

[South Branch Yellow Medicine River Fecal Coliform TMDL](#)

Bacteria "producers" in watershed
150,000 livestock animal units
2,000 wildlife animal units
15,000 people

note: animal unit is a roughly 1000 lb animal



4.12 Water Portioning Calculator

Key

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

Landuse		
	% of crops	% of watershed
tiled ag	45%	35.6%
not tiled ag	55%	43.5%
all ag	100%	79%

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

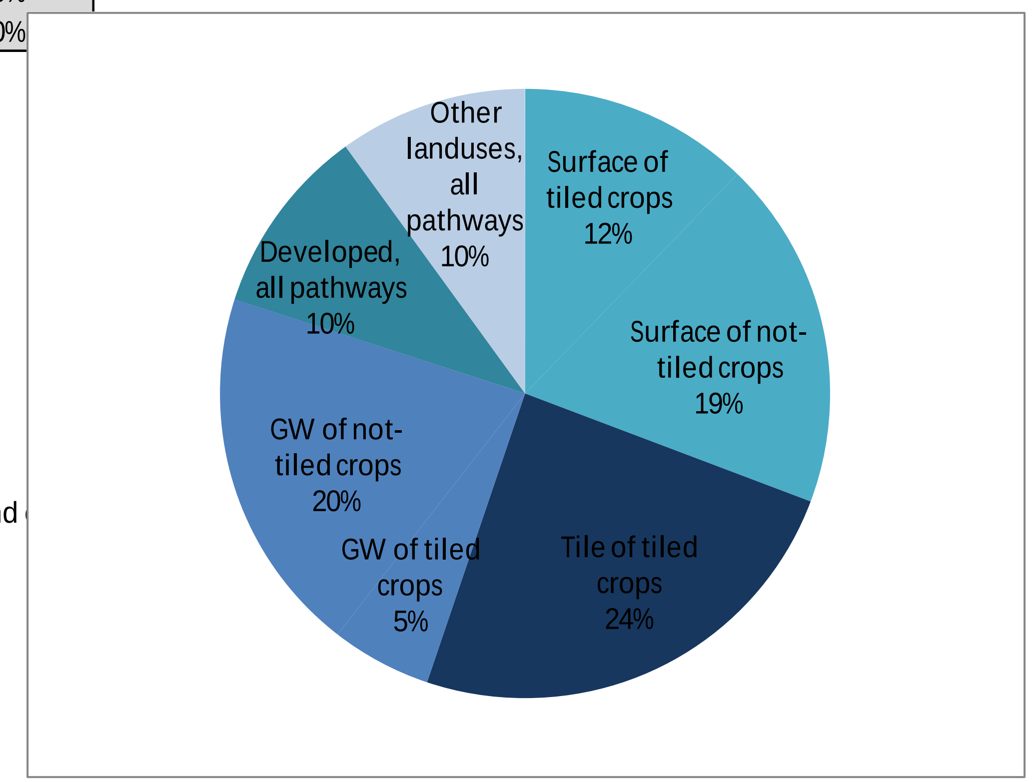
% of water yields by flow path between tiled and untiled land					
	% of ag water tile yields	% of ag water surface yields	% of ag water GW yields	% of total water from ag	% of total watershed
tiled land	100%	40%	21%	52%	42%
not tiled land	0%	60%	79%	48%	38%
all ag land	100%	100%	100%	100%	80%

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	0.80	:	1.0	see check numbers below (yellow)
Assume that in a tiled field, the tile:surface water yeild ratio is	2.0	:	1.0	see check numbers below (blue)
Assume that the GW:total ratio of river water for watershed = that of ag ar	0.31	:	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	:	3.0	see check logic below (light pink)
Assume that the per acre yield for all flowpaths ratio for a tiled:not tiled fi	1.35	:	1.0	see check logic below (pink)

Flow contributions by flow path toward total watershed contributions			
	tiled ag	not tiled ag	all ag land
% from tile	24%	0%	24%
% from surface	12%	19%	31%
% from GW	5%	19%	25%
% from all ag paths	42%	38%	80%

Use Solver to look at effects of inputs/assumptions (peach cells), especially cells B11:D14, by setting J18=J9

40%



Data and Estimates for Checks in Calculator		
Watershed Yield (in) (WPLMN data)	7.4	
Change in River flow due to drainage (in) (Schottler Study)	1.6	
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)	2.1	
Average surface runoff ratio for a tiled:not tiled (ratio) (Discovery Farms)	0.8	
Average Tile Runoff from Tiled sites (in) (Discovery Farms)	4.6	
Average Surface Runoff from Tiled sites (in) (Discovery Farms)	2.8	
Average Tile:Surface water yield ratio in a tiled field (ratio) (Discovery Farn	1.6	
Estimated Tile Runoff from Tile Drained Areas (in)	4.4	Assume Schottler's number is all tile from the watershed, use this and
Estimated Surface Yield from Tile Drained Areas (in)	3.0	Above number and disc farm
Estimated tile:surface ratio for a tiled field	1.5	Above 2 numbers
DNR baseflow seperation for watershed		56%, but this includes some of the tile water contribution

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

4.13 Available GIS Targeting Tools/Data Layers

This information was compiled as a quick resource for GIS users. Sources are not technically referenced but are associated with the provided link.

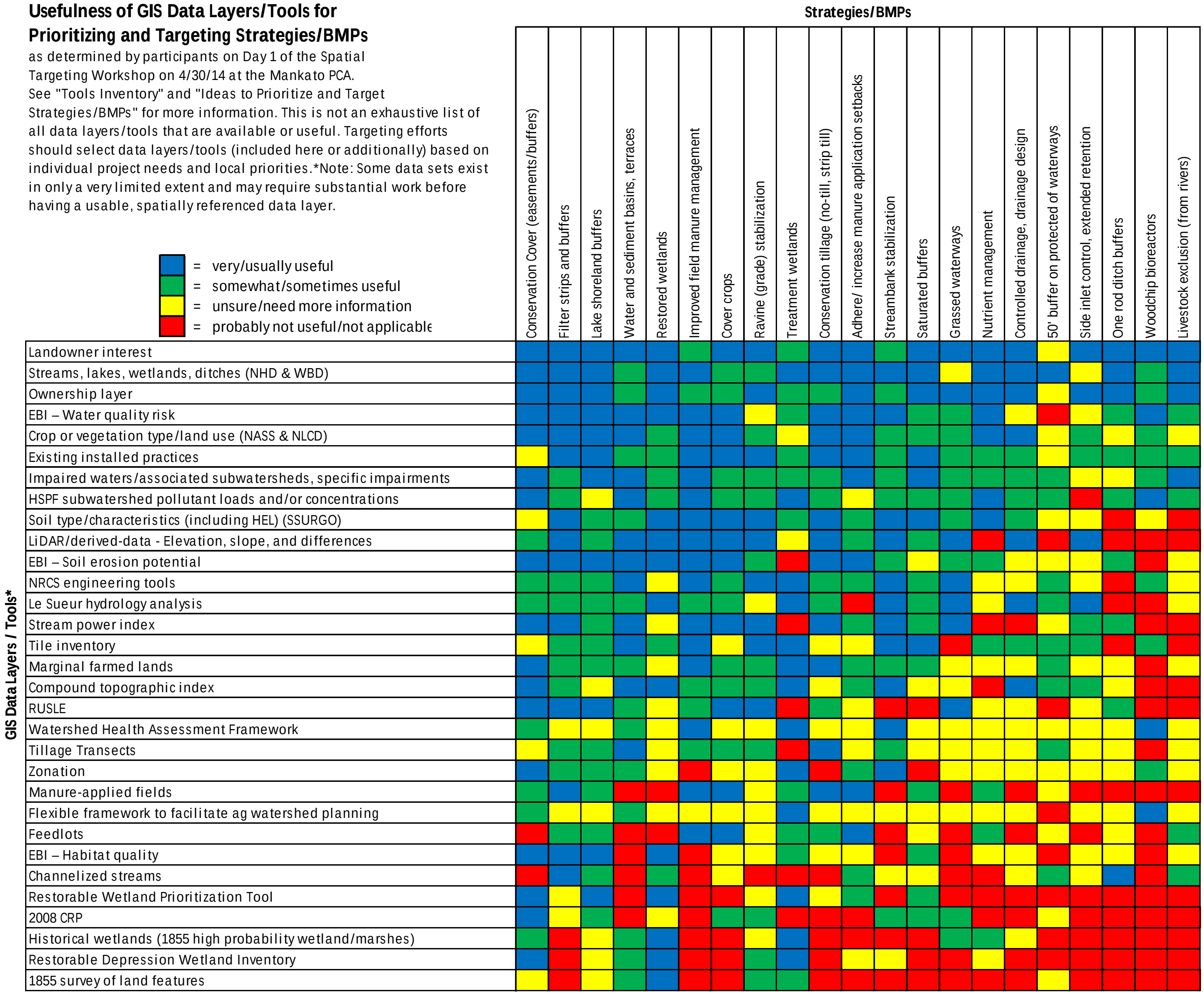
Tool	Description	Example Uses	Notes for GIS Use	Link to Data/Info
Hydrological Simulation Program – FORTRAN (HSPF)	Simulation of watershed hydrology and water quality. Incorporates point and non-point sources including pervious land surfaces, runoff and constituent loading from impervious land surfaces, 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 seperately. 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/
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 priortization 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
1855 Land Survey Data	Data originally created by land surveyors in the mid-to-late 1800s. Surveys were conducted in one-mile grid and indicatecd the land cover at the time of the survey. This data has been georeferenced and is availble 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/
Historical Wetlands (PCA Analysis)	Data was created for the GBERB by PCA staff. Created using a combination of techniques including using the 1855 digitized features and a terrain and soils-based analysis.	This data can be used to identify locations to target wetland restorations. Areas with high % of lost wetlands may be prioritized.	Data available from PCA staff (in the GBERB only).	
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 perrenial 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 calcuator) to prioritize subwatersheds to target conservation practices intended to mitigate altered hydrology.	GIS layers (in the Le Sueur Watershed only) 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 Inventory	Data exists in a very limited extent at the County level. The data layer can be created by digitizing visible tile lines from imagery.	Knowing the location, extent, and spacing of tile can help define priority areas or target fields to implement practices that address altered hydrology.	Contact you County to see if any data exists.	
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 caluclation 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 analysese have been done with different resulting qualitites 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 conditoning 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 basedon 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 orthigonal to the flow direction. CTI was desigined 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 controllign 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 availble.	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 residental 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 th 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 coridors 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

Tool	Description	Example Uses	Notes for GIS Use	Link to Data/Info
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 erosivity.	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
Manure-applied Fields	Data on which fields received manure (and possible the rate in which manure is applied). This data exists in a spatial format in a very limited extent based on the County Feedlot record keeping. This information could be created from manure management plans and/or annual reports. Martin County has created this layer.	Identifying areas of heavy manure usage. This can be helpful when prioritizing or targeting areas to address E. coli.	Contact County feedlot staff to inquire	
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"
Marginal (Farmed) Lands	Data exists in a limited extent and perhaps not at all in the GBERB. This data can be made using other data layers. There are several ways to define marginal (farmed) lands, but criteria usually include either high levels of environmental sensitivity or areas that make little net profit when farmed.	Useful for identify areas that would be most beneficial to take out of crop production to place a BMPs that cannot occur on an actively farmed footprint. Commonly used to identify locations targeted for perennial (biofuel) crops.	Can be created using one of many established definitions or marginal land (see link).	http://kellylab.berkeley.edu/storage/papers/2014-LewisKelly-IJGI.pdf
Tillage Transect Survey	Data regarding the observed tillage or residue cover. Data exists in a very limited extent. MSU WRC will be doing a survey in the Le Sueur River watershed.	Prioritizing areas or targeting specific fields based on the type of tillage used.	Contact Rick Moore at WRC	: http://mrbdc.mnsu.edu/minnesota-tillage-transect-survey-data-center
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
Landowner Interest	Data exists in only a very limited extent at this time. The data exists in areas (e.g. County SWCDs) that have tracked this information themselves. Other entities may consider tracking this information.	Having information on interested landowners (including interest in specific projects) increases chances of being funded. An area with many interested landowners could be high priority.		
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 (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://www.jswconline.org/content/68/5/113A.extract
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/
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/
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.	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

4.14 Usefulness of GIS Data Layers/Tools

Usefulness of GIS Data Layers/Tools for Prioritizing and Targeting Strategies/BMPs

as determined by participants on Day 1 of the Spatial Targeting Workshop on 4/30/14 at the Mankato PCA. See "Tools Inventory" and "Ideas to Prioritize and Target Strategies/BMPs" for more information. This is not an exhaustive list of all data layers/tools that are available or useful. Targeting efforts should select data layers/tools (included here or additionally) based on individual project needs and local priorities.*Note: Some data sets exist in only a very limited extent and may require substantial work before having a usable, spatially referenced data layer.



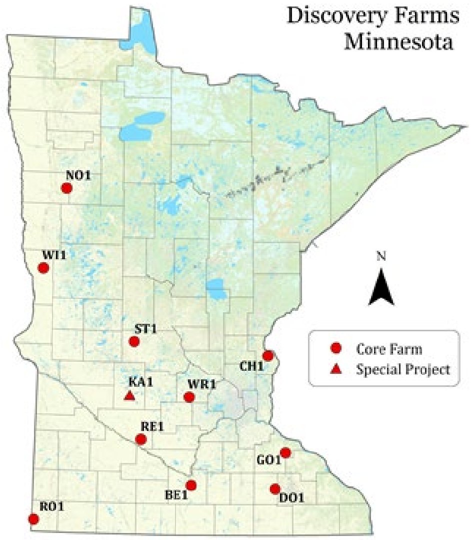
4.15 Locally selected priorities

Aggregated HUC-12

Strategies	Upper YM River	No. Br. YM River	So. Br. YM River	Lower YM River	JD 17	Mud Creek	Spring Creek	Stony Run Creek	JD 23, CD 39	JD 10	Boiling Spring Creek	Hazel Creek/ CD9
Buffer/Filter Strips	H	H	H	H	H	H	H	H	H	H	H	H
Shoreland Management	M	L	L	M	M		M			M		
Livestock Management	M	M	M-H	M		M-H		L		M		M
Nutrient Management	H	H	H	M-H	M	M	M-H	M-H		M	M	M-H
Manure Management	M	M	M-H	M	M	M		L		M		M
Wetland Restoration	H	H	H	H	H	H	H	M-H	M-H	H		H
In Stream Practices	M-H	M	M	M						M	M	
Septic System Compliance	M-H	M	M-H	M	M-H	H	M	M	M	M	M	M
Riparian Protection	H	H		H		M	M-H	M-H	M	M-H	M-H	H
Gully Restoration/Protection/Stabilization	M	M	M	M			M	M	M	M-H	M-H	M
Control/Reduced Drainage	M	M	M	M	M	H				H	M	M-H
Reduce flows	M				M	M-H	M-H	M		M		M
Stream bank Stabilization	M	M	M	H					M-H	M	M-H	M
Blind Intakes	L	L	L	M	M	M	M	M	L	M	L	L
Upland Erosion Control-WSCB,Terr., GW	M	M	M	M	M	M		M-H	M	M	M	
Fertilization, Lawn Care Education	M	L	M		M				M	L	M	L
Cover Crops	M	M	M	M	M	M	M-H	M	M	M	M	M
City Discharge management	L	L	L	M	L	L	L		L	L	L	L
Shallow Lake Management	M	M	L				M	L		M	L	
In Lake Management	L			M	M					M	L	
No increase in flows										M		
Flood Control					L	M						

Priorities per region: H high priority; M medium priority; L low priority

4.16 Discovery Farms Information



Site	Water Year	Precip (in)	Combined Runoff (in)	Combined Runoff (%)	Subsurface Runoff (in)	Subsurface Runoff (%)
BE1	2012	22.55	4.00	18%	3.58	16%
	2013	28.67	3.36	12%	1.45	43%
	2014	30.08	11.67	39%	8.28	71%
ST1	2012	21.65	5.63	26%	4.82	86%
	2013	23.54	4.56	19%	3.75	82%
	2014	35.15	9.35	27%	6.70	72%
WR1	2012	34.58	6.84	20%	1.94	28%
	2013	25.59	6.80	27%	3.03	45%
	2014	37.25	10.38	28%	5.77	56%
DO1	2013	35.01	9.98	29%	6.00	60%
	2014	35.61	9.20	26%	5.77	63%
Average		29.97	**7.43**	**24%**	**4.64**	**62%**

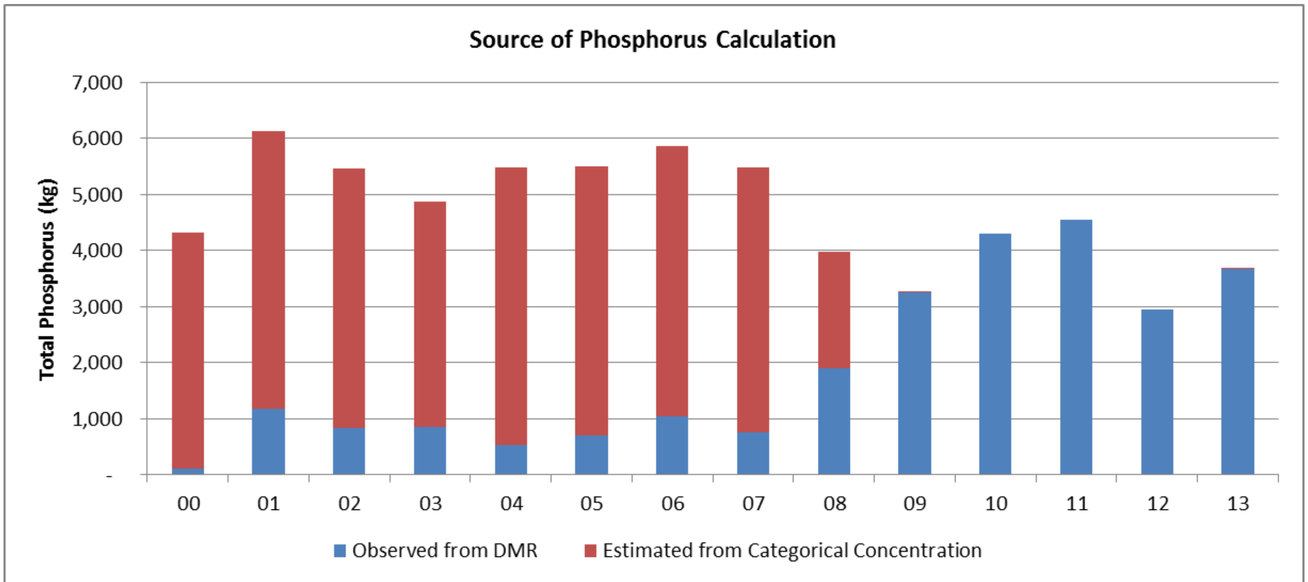
SURFACE

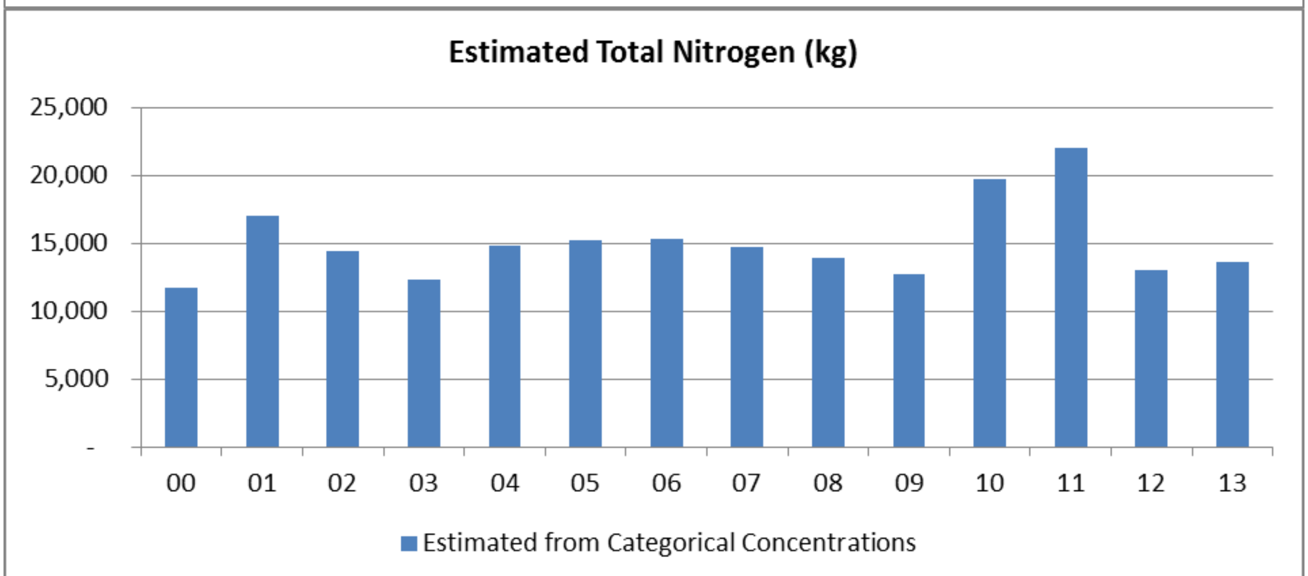
Site	Water Year	Runoff	TSS	TP	Dissolved P	Particulate P	TN	NO3-N	Organic N	NH3-N	Runoff Duration	# Events
		inches	YIELD (lbs/acre)								days	
BE1-F	WY2012	0.42	74.0	0.1	0.0	0.1	1.1	0.1	1.0	0.0	6.40	7
	WY2013	1.91	76.0	0.4	0.2	0.1	3.3	0.7	1.0	1.6	12.12	19
	WY2014	3.39	479.8	0.6	0.2	0.4	4.2	1.5	2.7	0.1	25.55	19
BE2-F	WY2012	0.63										
CH1-F	WY2011	4.20	82.0	1.2	0.7	0.6	3.9	0.5	2.9	0.5	14.01	17
	WY2012	2.28	128.0	0.9	0.5	0.4	2.9	0.7	2.0	0.2	10.44	14
	WY2013	4.53	55.9	1.1	0.8	0.3	10.0	1.1	7.1	1.8	10.08	20
	WY2014	4.10	141.9	1.0	0.7	0.3	3.3	0.9	2.1	0.3	15.23	37
DO1-F	WY2013	3.99	220.9	1.6	1.0	0.6	7.9	2.2	3.4	2.3	11.82	12
	WY2014	3.43	260.6	0.8	0.6	0.2	3.8	1.8	1.9	0.1	12.38	11
GO1-F	WY2011	4.31	47.2	0.6	0.2	0.4	8.7	0.5	4.5	3.7	14.23	13
	WY2012	1.71	21.9	0.5	0.3	0.1	2.1	0.3	1.4	0.4	5.89	16
	WY2013	4.78	205.2	0.9	0.5	0.4	6.6	2.2	2.7	1.7	13.58	20
	WY2014	2.12	307.1	0.8	0.3	0.5	4.4	1.2	2.7	0.5	8.66	25
RO1-F	WY2014	0.72	47.2	0.4	0.2	0.2	1.8	0.6	1.0	0.2	2.99	8
ST1-F	WY2011	4.09	395.6	0.9	0.4	0.4	5.9	2.6	3.1	0.1	20.84	17
	WY2012	0.81	665.4	1.2	0.1	1.2	10.9	0.5	10.1	0.4	2.87	14
	WY2013	0.81	327.2	0.4	0.1	0.3	3.1	0.6	2.3	0.2	6.45	14
	WY2014	2.65	1,747.7	1.6	0.3	1.3	14.8	1.2	13.3	0.3	10.16	23
WR1-F	WY2012	4.90	2,366.9	3.1	0.5	2.6	17.1	1.1	15.5	0.5	9.11	20
	WY2013	3.77	976.0	2.2	0.8	1.4	14.5	3.2	9.5	1.8	4.55	9
	WY2014	4.61	1,923.2	3.1	0.7	2.4	23.0	5.0	17.0	1.0	7.52	18

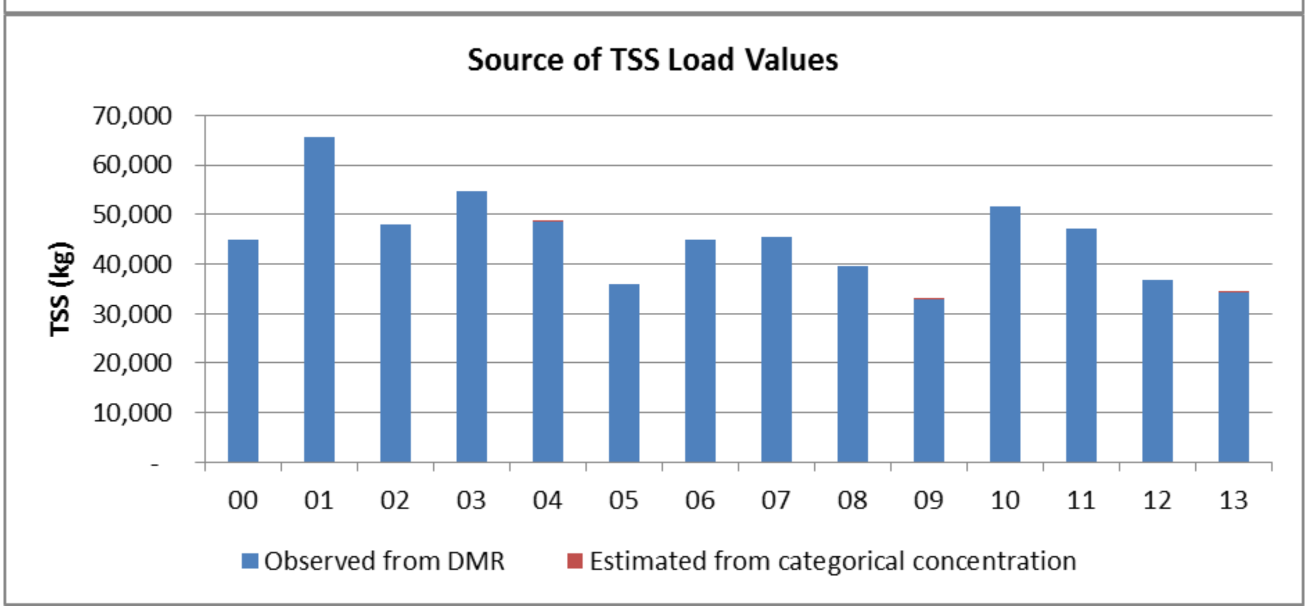
SUBSURFACE

Site	Water Year	Runoff	TSS	TP	Dissolved P	Particulate P	TN	NO3-N	Organic N	NH3-N	Runoff Duration	# Events
		inches	YIELD (lbs/acre)								days	
BE1-T	WY2011	11.08	5.3	0.1	0.1	0.1	42.9	40.7	1.9	0.2		
	WY2012	3.58	7.9	0.1	0.0	0.0	13.7	12.3	1.3	0.1	118.92	
	WY2013	1.45	0.8	0.0	0.0	0.0	8.9	8.5	0.3	0.0	55.48	
	WY2014	8.28	13.3	0.1	0.1	0.0	22.5	20.3	2.0	0.2	113.85	
BE2-T	WY2012	1.70	108.9	0.2	0.0	0.1	17.3	14.8	2.4	0.1	74.97	
DO1-T	WY2013	6.00	7.3	0.1	0.0	0.0	38.7	36.5	2.1	0.1	110.92	
	WY2014	5.77	3.1	0.1	0.1	0.0	27.9	26.7	1.1	0.2	131.59	
NO1W-T	WY2013	0.18	0.9	0.0	0.0	0.0	1.0	0.9	0.1	0.0		
	WY2014	1.98	6.8	0.0	0.0	0.0	11.4	10.5	0.9	0.0		
NO1E-T	WY2014	0.93	3.3	0.0	0.0	0.0	2.4	2.1	0.2	0.0	124.28	
RE1-T	WY2012	0.90	10.7	0.0	0.0	0.0	3.4	3.0	0.4	0.0	40.92	
	WY2013	1.62	7.1	0.1	0.0	0.0	10.2	9.5	0.6	0.0	84.68	
	WY2014	2.62	145.1	0.3	0.1	0.2	12.8	10.8	1.9	0.1	74.59	
ST1-T	WY2012	4.82	61.9	0.2	0.1	0.1	36.9	32.9	3.9	0.1	326.38	
	WY2013	3.75	6.4	0.2	0.1	0.1	44.3	42.8	1.4	0.1	133.16	
	WY2014	6.70	38.7	0.4	0.3	0.2	58.8	54.7	3.4	0.7	204.19	
WI1-T	WY2013	2.01	2.5	0.0	0.0	0.0	7.8	7.0	0.8	0.0		
	WY2014	5.81	10.6	0.0	0.0	0.0	25.6	23.2	2.2	0.1		
WR1-T	WY2012	1.94	46.0	0.2	0.1	0.1	9.0	7.8	1.2	0.0	52.54	
	WY2013	3.03	11.3	0.4	0.2	0.1	16.1	13.6	2.1	0.4	86.28	
	WY2014	5.77	48.9	0.8	0.5	0.2	35.0	31.1	3.6	0.3	107.63	

4.17 Point Source Data Summary







4.18 Point Source Pollutant Loads versus Watershed Outlet Loads

	Point Source Loads (Kg) data from locations or categorically calculated			Watershed Outlet Loads (Kg) data from WPLMN		
Year	**TP**	**TSS**	**TN**	**TP**	**TSS**	**TN**
2008	938	11,287	3,354	16,846	7,494,896	903,454
2009	886	15,273	3,111	14,721	5,352,815	368,984
2010	1,583	28,079	7,237	148,151	43,212,043	3,782,689
2011	1,478	23,017	7,249	113,372	39,809,610	3,254,884
2012		12,631	1,557		9,112,051	311,260
Total	4,885	90,287	22,508	293,090	104,981,415	8,621,271

4.19 NPDES Permit Holders in the Yellow Medicine Watershed

Type	Name	County
Feedlot	Forsman Farms Inc - Montevideo	Lac Qui Parle
Feedlot	Sundlee Pork Inc	Lac Qui Parle
Feedlot	Christensen Farms Site F068	Lincoln
Feedlot	Prairieview Pork Inc	Lincoln
Feedlot	Kevin R Leibfried Farm	Lincoln
Feedlot	Steve Citterman Farm	Lincoln
Feedlot	Buysse Inc - Crestview Farm	Lyon
Feedlot	E & P Farms	Lyon
Feedlot	L & N Hog Farms	Lyon
Feedlot	Plainview Farms Inc	Lyon
Feedlot	Hentges Family Farm	Lyon
Feedlot	Guy Jeremiason Farm - North	Lyon
Feedlot	Guy Jeremiason Farm - South	Lyon
Feedlot	John Wambeke Farm	Lyon
Feedlot	Jordan Hog Finishing Site	Redwood
Feedlot	Christensen Farms Site F148	Redwood
Feedlot	Hentges Finisher	Redwood
Feedlot	John Citrowske Farm - Sec 28	Yellow Medicine
Feedlot	Allied Dairy LLP	Yellow Medicine
Feedlot	Kvistad Farms Inc	Yellow Medicine
Feedlot	Patrick W McCoy Hog Barns	Yellow Medicine
Feedlot	Paul Syring Farm	Yellow Medicine
Feedlot	Pederson Pork Farm	Yellow Medicine
Feedlot	Rob Hill Farms Inc	Yellow Medicine
Feedlot	Stevens Farms LLP	Yellow Medicine
Feedlot	Mike Verhelst Farm	Yellow Medicine
Feedlot	Richard Nuytten Farm	Yellow Medicine
Feedlot	Tim Schlenner Farm 17	Yellow Medicine
Feedlot	Dave Schwerin - Site 3	Yellow Medicine
Feedlot	Ben and Mike Hinz Farm	Yellow Medicine
Feedlot	Christensen Farms Site C073	Yellow Medicine
Feedlot	Christensen Farms Site C071	Yellow Medicine
Feedlot	Christensen Farms Site C072	Yellow Medicine
Industrial Stormwater Permit	Norcraft Companies Inc - SW	Lyon
Industrial Stormwater Permit	HiRel Systems Minneota - SW	Lyon
Industrial Stormwater Permit	Minneota Maintenance Building - SW	Lyon
Industrial Stormwater Permit	Cottonwood city of Municipal Bldg - SW	Lyon
Industrial Stormwater Permit	Mid Continent Cabinetry - ISW	Lyon
Industrial Stormwater Permit	Central Bi-Products - Redwood Falls - SW	Redwood
Industrial Stormwater Permit	Northern Con-Agg Pit 9115 & 9119 - SW	Redwood
Industrial Stormwater Permit	Progressive Contractors Plant 95-102 - SW	Steele
Industrial Stormwater Permit	Yellow Medicine Co Landfill - SW	Yellow Medicine
Industrial Stormwater Permit	Plews Edelmann Div- Stant Co - SW	Yellow Medicine
Industrial Stormwater Permit	Echo city of Fire Hall Bldg - SW	Yellow Medicine
Industrial Stormwater Permit	Echo city of Street Maintenance Bldg - SW	Yellow Medicine
Industrial Stormwater Permit	Veblen Protein Inc - SW	Yellow Medicine
Industrial Stormwater Permit	Wood Lake City Maintenance Shop - SW	Yellow Medicine
Industrial Stormwater Permit	Hazel Run city of - SW	Yellow Medicine
Industrial Stormwater Permit	Rural Tool & Machining Co - ISW	Yellow Medicine
Industrial Stormwater Permit	Martin Marietta Materials Yellow Medicine - SW	Yellow Medicine
Industrial Stormwater Permit	Yellow Medicine Cty Hwy Clarkfield - SW	Yellow Medicine
Industrial Stormwater Permit	Yellow Medicine Cty Hwy Granite Falls - SW	Yellow Medicine
Industrial Stormwater Permit	Yellow Medicine Cty Hwy Wood Lake - SW	Yellow Medicine
Industrial Stormwater Permit	Yellow Medicine Cty Hwy Dept Porter - SW	Yellow Medicine
Industrial Stormwater Permit	Ray's Auto Parts - SW	Yellow Medicine
Permitted Facility, General Permit	Ivanhoe WWTP	Lincoln
Permitted Facility, General Permit	Lincoln County Highway Department	Lincoln
Permitted Facility, General Permit	Cottonwood WWTP	Lyon

Permitted Facility, General Permit	Minneota WWTP	Lyon
Permitted Facility, General Permit	Taunton WWTP	Lyon
Permitted Facility, General Permit	Belview WWTP	Redwood
Permitted Facility, General Permit	Granite Falls WTP	Yellow Medicine
Permitted Facility, General Permit	Magellan Pipeline Co LP - Cottonwood	Yellow Medicine
Permitted Facility, General Permit	Echo WWTP	Yellow Medicine
Permitted Facility, General Permit	Porter WWTP	Yellow Medicine
Permitted Facility, General Permit	Wood Lake WWTP	Yellow Medicine
Permitted Facility, General Permit	Hanley Falls WWTP	Yellow Medicine
Permitted Facility, General Permit	Clarkfield WWTP	Yellow Medicine
Permitted Facility, Individual Permit	Belview WTP	Redwood
Permitted Facility, Individual Permit	Lake Redwood Restoration Dredge	Redwood
Permitted Facility, Individual Permit	Delhi WWTP	Redwood
Permitted Facility, Individual Permit	Redwood Falls WWTP	Redwood
Permitted Facility, Individual Permit	Saint Leo WWTP	Yellow Medicine
Construction Stormwater Permit	Ivanhoe Reconstruction Project CSW	Lincoln
Construction Stormwater Permit	Lake Stay Twp New Road Construction CSW	Lincoln
Construction Stormwater Permit	CSAH 12 - Lincoln County CSW	Lincoln
Construction Stormwater Permit	SAP 41-599-14 CSW	Lincoln
Construction Stormwater Permit	County Road 101 Bridge Project CSW	Lincoln
Construction Stormwater Permit	CSAH 17 - Lincoln County CSW	Lincoln
Construction Stormwater Permit	CSAH 3 - Lincoln County CSW	Lincoln
Construction Stormwater Permit	CSAH 14 Grading & Agg Surfacing CSW	Lincoln
Construction Stormwater Permit	CSAH 17 Shoulder Widening CSW	Lincoln
Construction Stormwater Permit	SAP 41-605-19; 41-605-20 - CSW	Lincoln
Construction Stormwater Permit	CSAH 7 Snow Sloping - CSW	Lincoln
Construction Stormwater Permit	Lincoln Co Landfill Building Site Prep - CSW	Lincoln
Construction Stormwater Permit	Lincoln Co Hwy Truck Station/Office Com - CSW	Lincoln
Construction Stormwater Permit	CSAH 7 Snow Sloping N Phase 2 - CSW	Lincoln
Construction Stormwater Permit	SAP 41-599-21 & 41-599-24 - CSW	Lincoln
Construction Stormwater Permit	Earth Shoulder Widening CSAH 1 CSW	Lincoln
Construction Stormwater Permit	SAP 41-601-22 CP 97-01-02 CSW	Lincoln
Construction Stormwater Permit	SAP 41-613-20 CP 97-13-04 CSW	Lincoln
Construction Stormwater Permit	Lakota Ridge Wind Farm CSW	Lincoln
Construction Stormwater Permit	Shaoakatan Hills Wind Farm CSW	Lincoln
Construction Stormwater Permit	SAP 41-599-19, CP 98-127-44 - CSW	Lincoln
Construction Stormwater Permit	SAP 41-617-27 CSW	Lincoln
Construction Stormwater Permit	SAP 41-599-28 box culverts-CSW	Lincoln
Construction Stormwater Permit	SAP 41-599-32 Box Culverts-CSW	Lincoln
Construction Stormwater Permit	SAP 41-599-30 Box Culverts-CSW	Lincoln
Construction Stormwater Permit	SAP 41-599-35 Box Culverts-CSW	Lincoln
Construction Stormwater Permit	CSAH 15-CSW	Lincoln
Construction Stormwater Permit	SAP 41-618-14 (CSAH 18) - CSW	Lyon
Construction Stormwater Permit	SAP 42-598-38 CSW	Lyon
Construction Stormwater Permit	SAP 42-609-29 CSW	Lyon
Construction Stormwater Permit	SAP 87-640-03 CSW	Lyon
Construction Stormwater Permit	Ousman Addition - CSW	Lyon
Construction Stormwater Permit	SP 4210-36 CSW	Lyon
Construction Stormwater Permit	Sanitary Sewer and Storm Sewer Imp - CSW	Lyon
Construction Stormwater Permit	Minnesota Recreational Trail - CSW	Lyon
Construction Stormwater Permit	2004 WW Treatment Facility - Cottonwood - CSW	Lyon
Construction Stormwater Permit	2006 Athletic Facility Cottonwood - CSW	Lyon
Construction Stormwater Permit	SAP 87-603-26 / SP 87-603-27 - CSW	Lyon
Construction Stormwater Permit	Sanitary Sewer/Storm Sewer Imp Ph 2 - CSW	Lyon
Construction Stormwater Permit	CP 04:80 - CSW	Lyon
Construction Stormwater Permit	SAP 64-619-09 CSW	Redwood
Construction Stormwater Permit	Central Bi-Products WW Storage Pond P4 - CSW	Redwood
Construction Stormwater Permit	T-132 CSW	Yellow Medicine
Construction Stormwater Permit	CP 00-34 -CSW	Yellow Medicine
Construction Stormwater Permit	CP 00-51 -CSW	Yellow Medicine
Construction Stormwater Permit	CP 00-58 -CSW	Yellow Medicine

Construction Stormwater Permit	CP 01-71 CSW	Yellow Medicine
Construction Stormwater Permit	CP 08-20 CSW	Yellow Medicine
Construction Stormwater Permit	CP 98-57 CSW	Yellow Medicine
Construction Stormwater Permit	Lone Tree Dairy CSW	Yellow Medicine
Construction Stormwater Permit	SAP 87-618-17 CSAH 18 CSW	Yellow Medicine
Construction Stormwater Permit	T-125 - csw - CSW	Yellow Medicine
Construction Stormwater Permit	T-130 CSW	Yellow Medicine
Construction Stormwater Permit	Skyline Vista CSW	Yellow Medicine
Construction Stormwater Permit	2004 Athletic Field Yellow Med East H.S. - CSW	Yellow Medicine
Construction Stormwater Permit	CP 05-47 (CR A-1) - CSW	Yellow Medicine
Construction Stormwater Permit	CP 04-57 - CSW	Yellow Medicine
Construction Stormwater Permit	Granite Falls Runway Extension - CSW	Yellow Medicine
Construction Stormwater Permit	Fertilizer Building and Grain Storage Expansion	Yellow Medicine
Construction Stormwater Permit	Proposed Process Water System - CSW	Yellow Medicine
Construction Stormwater Permit	CP 97-50 - CSW	Yellow Medicine
Construction Stormwater Permit	CP 97-65 CSW	Yellow Medicine
Construction Stormwater Permit	CP 97-68 CSW	Yellow Medicine
Construction Stormwater Permit	CP 98-60 CSW	Yellow Medicine
Construction Stormwater Permit	CP 98-62 CSW	Yellow Medicine
Construction Stormwater Permit	CP 98-76 CSW	Yellow Medicine
Construction Stormwater Permit	CP 99-33 CSW	Yellow Medicine
Construction Stormwater Permit	SAP 87-602-18 - CSW	Yellow Medicine
Construction Stormwater Permit	SAP 87-609-08 -CSW	Yellow Medicine
Construction Stormwater Permit	SAP 87-612-09 -CSW	Yellow Medicine
Construction Stormwater Permit	SAP 87-618-18 - CSW	Yellow Medicine
Construction Stormwater Permit	SAP 87-633-05 CP 96-68 CSW	Yellow Medicine
Construction Stormwater Permit	SAP 87-635-07 CSAH 35 CSW	Yellow Medicine
Construction Stormwater Permit	SP 87-613-10 CSW	Yellow Medicine
Construction Stormwater Permit	T-123 CSW	Yellow Medicine
Construction Stormwater Permit	T-138 - CSW	Yellow Medicine
Construction Stormwater Permit	Canby Airport Sewer Ext. CSW	Yellow Medicine
Construction Stormwater Permit	Diversion Channel Clean Out & Repair CSW	Yellow Medicine
Construction Stormwater Permit	Granite Falls Municipal Airport - CSW	Yellow Medicine
Construction Stormwater Permit	BNSF Siding Project CSW	Yellow Medicine
Construction Stormwater Permit	SAP 41-618-09 - CSW	Yellow Medicine
Construction Stormwater Permit	620th St - CSW	Yellow Medicine
Construction Stormwater Permit	12-599-72 - CSW	Yellow Medicine
Construction Stormwater Permit	SaP 87-617-12 (CSAH 17) - CSW	Yellow Medicine
Construction Stormwater Permit	CP 01-74 - CSW	Yellow Medicine
Construction Stormwater Permit	CP 07-03, CSAH 13, CSW	Yellow Medicine
Construction Stormwater Permit	SP 6402-21 - CSW	Yellow Medicine
Construction Stormwater Permit	Clarkfield Industrial Park - CSW	Yellow Medicine
Construction Stormwater Permit	SAP 87-624-03 (CSAH 24) - CSW	Yellow Medicine
Construction Stormwater Permit	Granite Falls 2002 Utility Improvements - CSW	Yellow Medicine
Construction Stormwater Permit	140th Ave Echo - CSW	Yellow Medicine
Construction Stormwater Permit	Minnesota Valley Substation-CSW	Yellow Medicine
Construction Stormwater Permit	Minnesota Falls Landfill Expansion - CSW	Yellow Medicine
Construction Stormwater Permit	SAP 87-599-94 - CSW	Yellow Medicine
Construction Stormwater Permit	2007 Airport Improvements - Granite Falls - CSW	Yellow Medicine
Construction Stormwater Permit	CP 08-03 - CSW	Yellow Medicine

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4.21 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. 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 life impairment: Streams are considered impaired for impacts to aquatic life if the fish Index of Biotic Integrity (IBI), macroinvertebrate IBI, dissolved oxygen, turbidity, or certain chemical standards are not met. The presence and vitality of aquatic life is indicative of the overall water quality of a stream.

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

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 describes water quality using characteristics of aquatic communities.

Knick Zone: An area carved much deeper than the surrounding area by a river that drops elevation drastically in attempt to meet the lower elevation of the outlet. Knick zones are common in the Minnesota River basin due to glacial River Warren carving the deep Minnesota River valley.

Non-point source pollutants: Pollutants that are from diffuse sources; most of these sources are not regulated. Non-point 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.

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.

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 2013f)), and storm water runoff from construction activity (construction storm water permit (MPCA 2013g)).

Polychlorinated Biphenyls (PCBs): A group of toxic, man-made organic chemicals sometimes found as a pollutant in water bodies, formerly used in the US 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 broad term that includes both pollutants and non-pollutants or factors (e.g., altered hydrology, dams preventing fish passage) that adversely impact aquatic life.

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 non-point 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)