Watershed

February 2020

Lower Minnesota River Watershed Restoration and Protection Strategy Report

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Contents

Key terms and abbreviations

Assessment Unit Identifier (AUID): The unique waterbody identifier for each river reach comprised of the U.S. Geological Survey (USGS) eight-digit HUC plus a three-character code unique within each HUC.

Aquatic life impairment: The presence and vitality of aquatic life is indicative of the overall water quality of a stream. A stream is 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.

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 and either chlorophyll-a or Secchi disc depth standards are not met.

Hydrologic Unit Code (HUC): A HUC is 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 Lower Minnesota River Watershed is assigned a HUC-8 of 07020012.

Impairment: Waterbodies 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 method for describing water quality using characteristics of aquatic communities, such as the types of fish and invertebrates found in the waterbody. It is expressed as a numerical value between 0 (lowest quality) to 100 (highest quality).

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

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

Source (or pollutant source): This term is distinguished from 'stressor' to mean only those actions, places or entities that deliver/discharge pollutants (e.g., sediment, phosphorus, nitrogen, pathogens).

Stressor (or biological stressor): This is a broad term that includes both pollutant sources and non-pollutant sources or factors (e.g., altered hydrology, dams preventing fish passage) that adversely impact aquatic life.

Total Maximum Daily Load (TMDL): A calculation of the maximum amount of a pollutant that may be introduced into a surface water and still ensure that applicable water quality standards for that water are met. A TMDL is the sum of the wasteload allocation for point sources, a load allocation for nonpoint sources and natural background, an allocation for future growth (i.e., reserve capacity), and a margin of safety as defined in the Code of Federal Regulations.

Executive summary

The Lower Minnesota River Watershed (LMRW) spans 1,835 square miles from east central Renville County to southwestern Ramsey County, encompassing a majority of Sibley, Le Sueur, Scott, and Carver counties, and portions of McLeod, Nicollet, Rice, Dakota, and Hennepin counties. With several metro cities in the northeast and extensive cropland in the remaining areas, this watershed is both diverse and greatly altered from its original land cover. As part of its transformation, many of the wetlands were drained and a majority of its streams were channelized.

This report does not directly address the main stem of the Minnesota River, nor lakes in the river's floodplain. Because it receives drainage from the entire Minnesota River Basin, the main stem of the Minnesota River is addressed in basin-scale studies/plans. Actions in the tributary streams of the LMRW will contribute to the improvement of the main stem, but will require additional actions upstream if all impairments of the Minnesota River main stem will be addressed.

A rich dataset for this watershed allowed an extensive assessment of water quality conditions, revealing a high incidence of impaired conditions. For streams, 84% of assessed streams showed impairments of aquatic life (e.g., suspended sediment, nutrient enrichment or eutrophication, and impaired biota) and 95% have impaired aquatic recreation (*E. coli*). Aquatic recreation impairment of lakes was less common, with 55% of those monitored indicating eutrophication impairment.

Following assessment, Total Maximum Daily Load (TMDL) studies were done on 98 waterbodies, and a stressor identification (SID) process was done on 82 waterbodies for biota (fish and/or macroinvertebrates) impairments.

The sources of suspended sediment identified were streambank erosion (primary source) and runoff from cropland, whereas eutrophication (phosphorus) sources were more varied. Phosphorus sources include cropland, altered wetlands, urban stormwater and internal loading in lakes (due to past loading of phosphorus, as well as carp and curly-leaf pondweed infestation). Livestock manure and fertilized fields are likely phosphorus source as well, in addition to being a primary *Escherichia coli (E. coli)* source. Failing septic systems and urban stormwater also appear to add to the *E. coli* levels.

Stressors to biota impairments include both the pollutant sources identified above and nonpollutant sources such as altered hydrology, insufficient/degraded habitat and connectivity issues (e.g., perched culverts).

Outcomes of this Watershed Restoration and Protection Strategy (WRAPS) project are the development of watershed-scale models and tools, detailed analyses and output from these work products, and a set of potential strategies for point and nonpoint source pollution that will cumulatively achieve, or otherwise make significant progress towards, water quality targets.

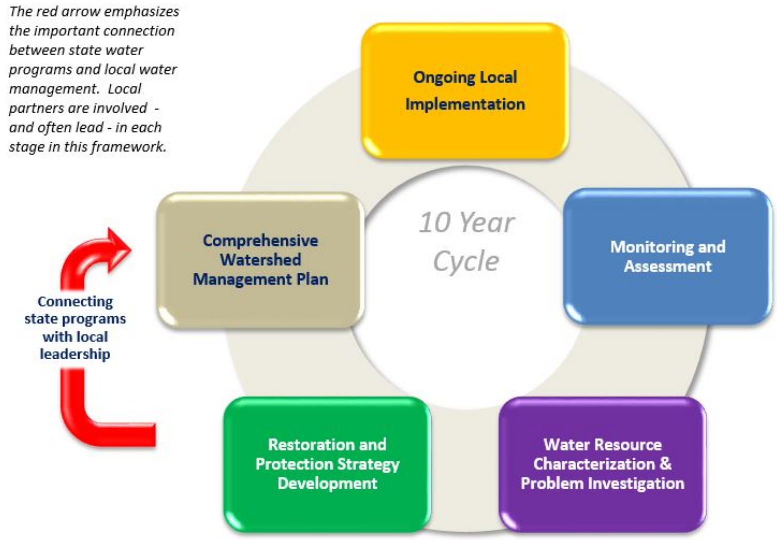
The strategies referenced in this report vary depending on the pollutant/source and nature of the problem. However, one very important strategy that would play a significant role for many of the impairments in the rural portions of this watershed is increased living cover. This strategy includes cover crops and use of perennial crops. Increased living cover provides multiple benefits—reducing phosphorus, sediment and nitrogen loading and improving hydrology and soil health.

Point sources are addressed under a regulatory structure by MPCA and others. For nonpoint source pollution, the information produced from this project is intended to inform local planning. Specifically, by providing an overall set of strategies needed to meet the goals (over some period of years or decades), local planners can focus on a subset of strategic actions to take on for their shorter-term (e.g., 10-year) planning cycle. It is important to note that implementation has been ongoing for decades. Much of this work is based on extensive monitoring, study and planning. It is the hope of the MPCA that this project adds to this existing body of work to further advance restoration and protection of waters by enabling better targeting and prioritization of implementation actions.

The relatively high overall percent load reduction needed for many of the waterbodies of this watershed represents a significant challenge. As such, restoration of waters will be a long-term undertaking requiring prioritization of efforts (e.g., which waterbodies to focus on first), and require a substantial outlay of financial resources. This sustained effort will also require a continued emphasis on civic engagement and public participation to motivate and encourage landowners and others to take action.

The farming community has been and continues to be a vital partner to conservation efforts in the Minnesota River Basin. Reducing sediment and nutrient impacts on water resources is important to Minnesota farmers who innovate new practices to improve the sustainability of their farms. Continued support from the State, local governments, and farm organizations will be critical to finding and implementing solutions that work for individual farmers and help achieve the goal of clean water.

What is the WRAPS Report?



Minnesota has adopted a watershed approach to address the state's 80 major watersheds. The Minnesota watershed approach incorporates **water quality assessment, watershed analysis, civic engagement, planning, implementation, and measurement of results** into a 10-year cycle that addresses both restoration and protection.

As part of the watershed approach, the Minnesota Pollution Control Agency (MPCA) developed a process to identify and address threats to water quality in each of these major watersheds. This process is called WRAPS development. WRAPS reports have two sets of strategies: impaired waters have strategies for restoration, and waters that are not impaired have strategies for protection.

Waters not meeting state standards are listed as impaired and TMDL studies are developed for them. TMDLs are incorporated into WRAPS. In addition, the watershed approach process facilitates a more cost-effective and comprehensive characterization of multiple waterbodies and overall watershed health, including both protection and restoration efforts. A key aspect of this effort is to develop and utilize watershed-scale models and other tools to identify strategies and actions for point and nonpoint source pollution that will cumulatively achieve water quality targets. For nonpoint source pollution, this report informs local planning efforts, but ultimately the local partners decide what work will be included in their local plans. This report also serves to at least partially address the U.S. Environmental Protection Agency's (EPA) Nine Minimum Elements of watershed planning, helping to qualify applicants for Clean Water Act Section 319 implementation funds.

It is important to further clarify the scope of this report by indicating what is and is not covered in this report. Regarding beneficial uses and pollutant types, this report focuses primarily on aquatic recreation and aquatic life uses and "conventional" pollutants (e.g., sediment, phosphorus, and *E. coli*) and, therefore, does not address aquatic consumption and toxic pollutants. Toxics include mercury, polychlorinated biphenyls (PCBs) and perfluorochemicals (PFCs), which provide a basis for aquatic consumption use impairment listings. Separate larger-scale efforts, studies and/or plans have been completed or are in progress to address these. One exception regarding toxics is chloride, which is briefly addressed in this report, though in terms of strategies we refer to two separate plans—the Twin Cities Metropolitan Area (TCMA) Chloride Management Plan and the Statewide Chloride Management Plan (in draft format).

In terms of waterbodies, this report does not directly address the main stem of the Minnesota River, nor lakes in the river's floodplain. Because it receives drainage from the entire basin, the main stem is addressed in basin-scale studies/plans. Actions in the tributary streams will contribute to improvement of the main stem. In addition, with limited exceptions, specific wetlands are not identified and addressed in this report. Rather, improvement of them in various subwatersheds is called for in the larger context of downstream impaired waters.

Lastly, in the interest of report length and avoiding duplication, this report focuses on impairments that have not already been the subject of previously completed TMDLs and TMDL implementation plans. These past studies covered 49 individual TMDLs and involved significant investment of time and resources. In spite of the limits to the scope, the remaining undertaking regarding impaired waters is extensive, encompassing 98 additional TMDLs, which were completed in three separate reports or parts:

- *Part I—Southern and Western Watersheds*. This part covers impairments south of the Minnesota River (Scott, Le Sueur, Rice, and Dakota Counties) as well as impairments in the western portion of the watershed (McLeod, Nicollet, Renville, and Sibley Counties). The impairments are many and include phosphorus for lakes and sediment (total suspended solids [TSS]), phosphorus, *E. coli*, and chloride for streams. TMDLs in this report were developed in two phases by Tetra Tech, Inc.
- *Part II—Northern Watersheds: Riley Purgatory Bluff Creek and Nine Mile Creek Watersheds.* This part addresses impairments in these largely urbanized Twin Cities Metro Area Watershed districts (WDs; Hennepin and Carver Counties). The impairments addressed include phosphorus-impaired lakes and *E. coli* in two streams. The TMDLs in this report were developed in two phases by Barr Engineering Company.
- *Part III—Northern Watersheds: Carver County Six Lakes.* This part addresses phosphorus-impaired lakes in a largely urbanized eastern part of Carver County. This part was developed in collaboration between the MPCA staff and Carver County Watershed Management Organization (WMO) staff.

Restoration strategies are provided in this report for these impairments, as well as a majority of the identified 120 impaired biota listings in the watershed.

Purpose	•Support local working groups and jointly develop scientifically-supported restoration and protection strategies to be used for subsequent implementation planning •Summarize watershed approach work done to date including the following reports: •*Lower Minnesota River Watershed Monitoring and Assessment* •*Lower Minnesota River Watershed Biotic Stressor Identification (streams and lakes reports)* •*Lower Minnesota River Watershed Total Maximum Daily Load (multiple reports)*
Scope	•Impacts to aquatic recreation and impacts to aquatic life in lakes and streams
Audience	•Local working groups (SWCDs, watershed districts, watershed management groups, etc) •State agencies (MPCA, DNR, BWSR, etc.)

1. Watershed background and description

The LMRW spans 1,835 square miles across southcentral Minnesota. The watershed stretches from east-central Renville County to southwestern Ramsey County, encompassing a majority of Sibley, Le Sueur, Scott, and Carver counties, and portions of McLeod, Nicollet, Rice, Dakota, and Hennepin counties. The watershed is divided by the Minnesota River, running its terminal course to the Mississippi River.

This report does not directly address the main stem of the Minnesota River, nor lakes in the river's floodplain. Because it receives drainage from the entire Minnesota River Basin, the main stem of the Minnesota River is addressed in basin-scale studies/plans. Actions in the tributary streams of the LMRW will contribute to the improvement of the main stem, but will require additional actions upstream if all impairments of the Minnesota River main stem will be addressed.

The Minnesota River flows north from Le Sueur, heading in a northeasterly direction through Belle Plaine, Jordan, Chaska, Chanhassen, Shakopee, Savage, and Bloomington before ultimately joining the Mississippi River in St. Paul at Fort Snelling State Park. In its final 25 miles, the river spreads out into a braid of backwater areas. During low flow, the lock-and-dammed Mississippi River can create lake-like conditions in the lower reach, favoring the production of algae from excess phosphorus loadings and increased residence time (the time it takes a volume of water to flow through a given system). The algae die, decompose and consume large quantities of dissolved oxygen (DO). Throughout its lower course the Minnesota River gains the flow of many small tributaries, including Rush River and High Island Creek to the west, Le Sueur Creek, Sand Creek, and Credit River to the east, and Bevens, Carver, and Nine Mile creeks to the north. Although the Minnesota River is generally not used for navigational purposes, the lower 15 miles from Savage downstream to the mouth have been dredged to provide a nine-foot-deep channel for commercial barge navigation.

Tributaries within the LMRW encompass 2,482 miles of flowing water including agricultural drainage ditches, streams and rivers. These waters are almost exclusively classified as warm-water. The western reaches of the watershed are generally flat showing little change in topography, and transition to a dramatic drop in elevation (1200 ft to 682 ft) from the top of the watershed to the lower reaches. on the western edges of the Minnesota River bluff. The eastern reaches of the watershed are more rolling in nature and show a similar shift towards high relief when reaching the eastern bluffs of the Minnesota River. This topographical shift in the lower reaches of the watershed give rise to coldwater springs that feed the regions few trout streams and calcareous fen wetlands. The watershed's lake-rich character in its northern and eastern reaches are a product of historical glacial activity and provide an important recreational resource for the watershed.

The watershed is also home to roughly 120 square miles of lakes; 133 lakes are greater than 10 acres in size. While a majority of lake basins within the watershed are shallow in nature, 25% are considered deep water basins. All waterbodies in the watershed maps in this report are depicted in a blue color unless otherwise noted in the legends.

Few features in the modern landscape of the LMRW have remained unaltered by agriculture and urban development, which are the predominant land uses (Figure 1). Figure 2 illustrates the extensive results of years of modifying, creating and rerouting watercourses and draining wetlands in this watershed to accommodate various aspects of human development. This, along with plowing of native prairies and forestlands, gave rise to its watershed-wide agricultural economies. The TCMA in the northern reaches of the watershed continues to expand southwest as there are greater demands for housing and development from a growing population.

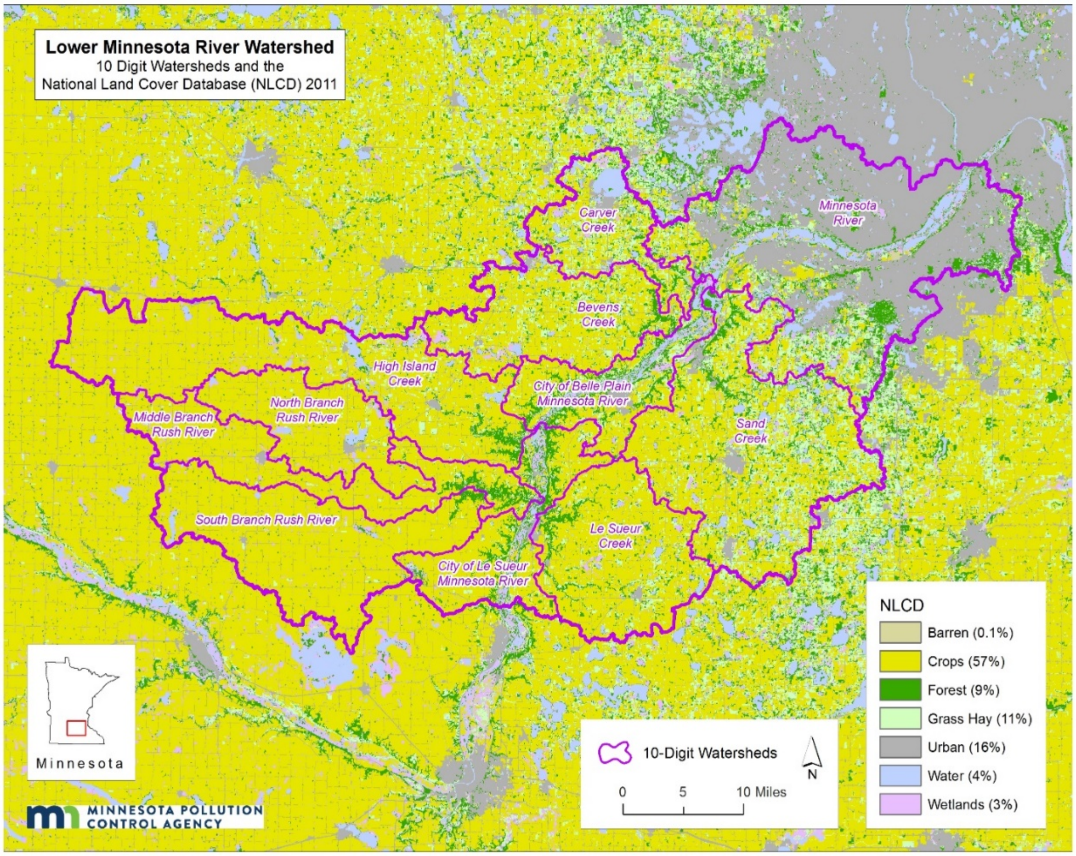


Figure 1 Land use in the Lower Minnesota River Watershed.

Remaining natural features in the watershed are predominately limited to protected areas that provide habitat to the region's wildlife, the most prominent being the protected corridor along the Minnesota River Valley that extends from Henderson to Bloomington, including the Minnesota Valley National Wildlife Refuge.

The western two-fifths of the LMRW falls within the northern boundaries of the Western Corn Belt Plains (WCBP) Ecoregion. The remainder of the watershed lies within the North Central Hardwood Forest (NCHF) Ecoregion. Today the ecoregion encompasses regrowth of what remains from forests historically cleared for commercial timber harvest and land cleared for agricultural use. Soils in the watershed are mainly comprised of the Central Iowa and Minnesota Till Prairie complex, consisting of rich organic glacial prairie soils that provide a rich medium for cultivation.

While the watershed is primarily rural, its northeastern reaches lie along the southern boundaries of the greater TCMA. The estimated population of the watershed is 616,832 and is expected to increase to the south and southwest of the Twin Cities (DNR 2017). Three counties in the watershed, Scott, Carver, and Hennepin, were among the state's five fasting growing counties from 2010 through 2015 (Scott County +8.4% (+51,400 residents); Carver +8.5% (+28,593 residents), Hennepin +6.0% (+105,503 residents)). Le

Sueur and Nicollet counties also having rising trends in growth while Sibley County has a declining trend (MSDS 2017).

From a water governance standpoint, much of the LMRW is led locally by WDs and WMOs taking on significant roles in terms of monitoring/study, planning and implementation (see Figure 3). Other local partners, particularly in the eastern half, include the Metropolitan Council Environmental Services, cities and other municipal separate storm sewer systems (MS4s). Soil and Water Conservation Districts (SWCDs) lead implementation efforts in the rural portions of counties.

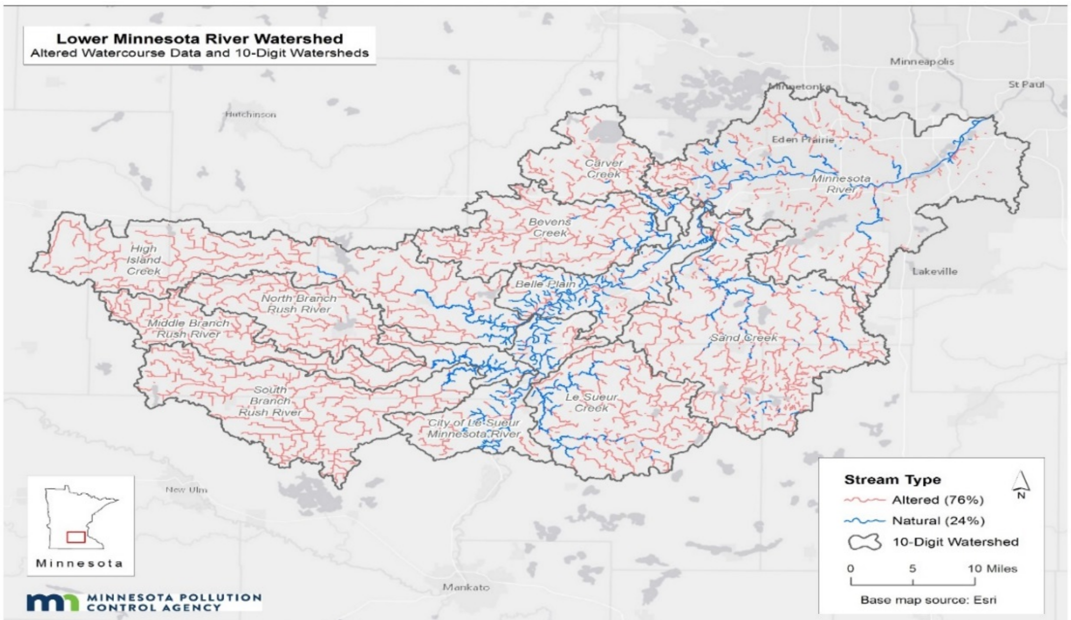


Figure 2 Altered watercourses in the Lower Minnesota River Watershed.

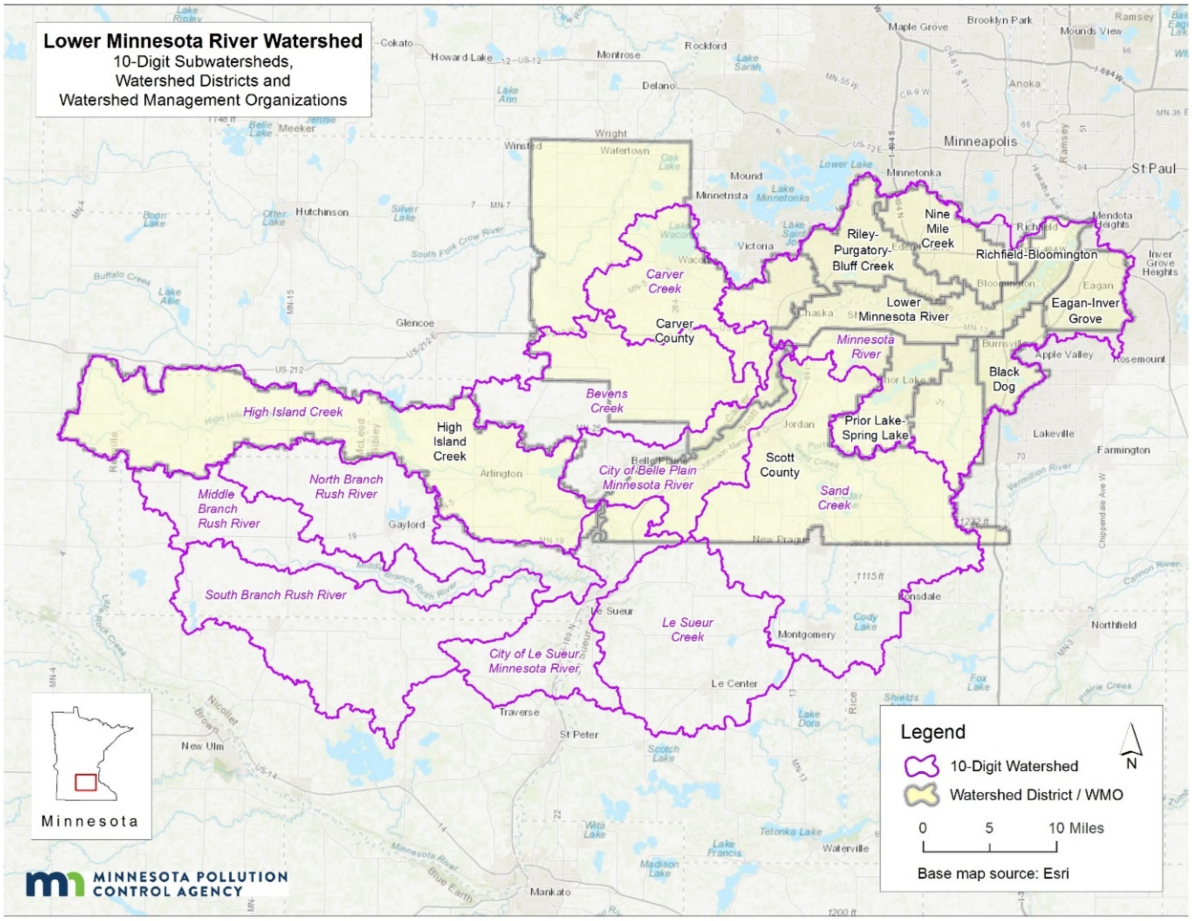


Figure 3 Watershed Districts and Watershed Management Organizations.

Additional Lower Minnesota River Watershed resources

U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Rapid Watershed Assessment for the Lower Minnesota River Watershed: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_023175.pdf

Minnesota Department of Natural Resources (DNR) Watershed Health Assessment Framework's Watershed Health Report Card for the Lower Minnesota River Watershed:
http://files.dnr.state.mn.us/natural_resources/water/watersheds/tool/watersheds/ReportCard_Major_33.pdf

2. Watershed conditions

In 2014 and 2015, the MPCA along with local partners conducted intensive watershed monitoring (IMW) in the LMRW to assess the aquatic life and aquatic recreational use status of a significant portion of the lakes and streams. The approach, methodologies and full results of this effort are provided in the LMR Monitoring and Assessment Report (see link on previous page). For assessment purposes, data collected by MPCA was pooled with water quality data collected by local partners and citizens within the previous 10 years.

The MPCA's assessment process varies by parameter, but generally entails comparing chemical and biological monitoring results to state water quality standards and related indices to determine whether those levels are exceeded and, thus, considered impaired. (For a list of applicable state water quality standards for streams and lakes of this watershed see Tables 6 and 7 of LMR TMDL, Part I) Local knowledge and professional judgment are factored in during the assessment process. The specific parameters monitored and evaluated are as follows:

Beneficial use	Waterbody type	Monitoring category	Parameter(s)
Aquatic life	Streams	Biological	Fish, macroinvertebrates
		Chemistry	Total suspended solids (TSS), chloride, eutrophication parameters (total phosphorus (TP), chlorophyll-a, biological oxygen demand), dissolved oxygen, ammonia, pH
	Lakes	Biological	Fish, aquatic plants
		Chemistry	Chloride
Aquatic recreation	Streams	Chemistry	*E. coli* (indicator for pathogens)
	Lakes	Chemistry	Eutrophication (TP, chlorophyll-a, Secchi depth)

The scope of the 2014-2015 IWM effort in the LMRW included:

- 132 biological stream monitoring stations
- 22 IWM stream chemistry stations
- 17 lakes for eutrophication
- 23 lakes for biological integrity; for further general lake IBI information see: http://www.dnr.state.mn.us/waters/surfacewater_section/lake_ibi/index.html
- Fish contaminant sampling—this was done on a limited basis and included mercury, PCBs and PFCs and provides a basis for aquatic consumption use listings.

Data from this effort was combined with locally-collected data and resulted in assessment of 117 stream reaches and 103 lakes.

It should be noted that nitrogen is not currently among the parameters that is evaluated for aquatic life or aquatic recreation in Minnesota due to there being no nitrogen water quality standards for those beneficial uses. However, it has long been recognized that nitrogen from Minnesota contributes to the Gulf of Mexico hypoxia problem, and for this reason (and other nitrogen-related water quality concerns) Minnesota has established nitrogen reduction goals for the state's three major basins (MPCA 2014). In addition, at the individual stream reach level nitrate-nitrogen is among the potential stressors evaluated in the Minnesota River Basin for contributing to biological impairments (macroinvertebrates and fish).

2.1 Condition status

The primary outcome of assessment is a determination that the water either meets or exceeds water quality standards. If the water exceeds standards it is considered impaired. Some waterbodies were either not monitored or lacked sufficient data, and so were not assessed for some or all relevant parameters (and are signified as blank cells in the tables below). Table 1 and Figure 5 show results for the 2018 stream assessment cycle and past cycles, and Table 2 and Figure 7 for impaired lakes. (Note: entries with an * represent impairments that had TMDLs and TMDL implementation plans completed prior to this WRAPS project.) A waterbody index sorted by county and 10-digit HUC is available in Appendix 1.

Waterbodies that are impaired are subject to restoration. Those that are not impaired are subject to protection to prevent them from worsening.

Streams

The results of stream assessment are provided in Table 1 below with locations shown in Figure 6. Key findings and conclusions include the following:

- 84% of stream reaches assessed for aquatic life failed to meet standards
- Overall stream aquatic biology is poor in the watershed. Impairments were identified in all subwatersheds; 65 of the 87 reaches assessed for fish did not meet standards and 56 of the 70 reaches assessed for macroinvertebrates did not meet standards (Figure 4 and Figure 5).

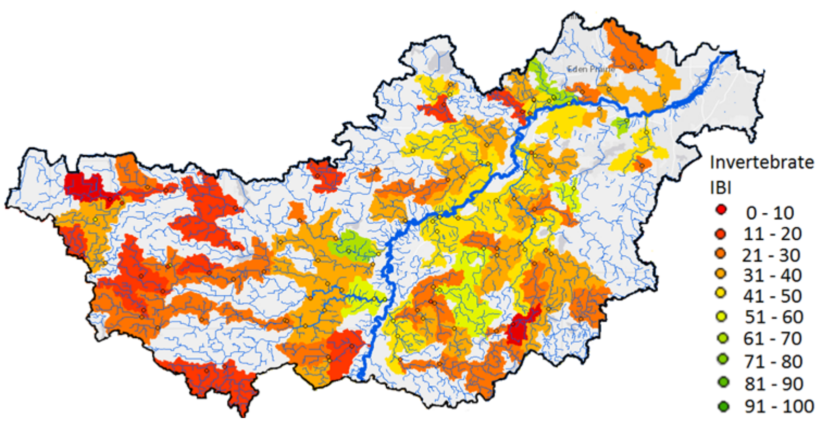


Figure 4 Macroinvertebrate Index of Biotic Integrity scores with DNR Stream Species Index scores

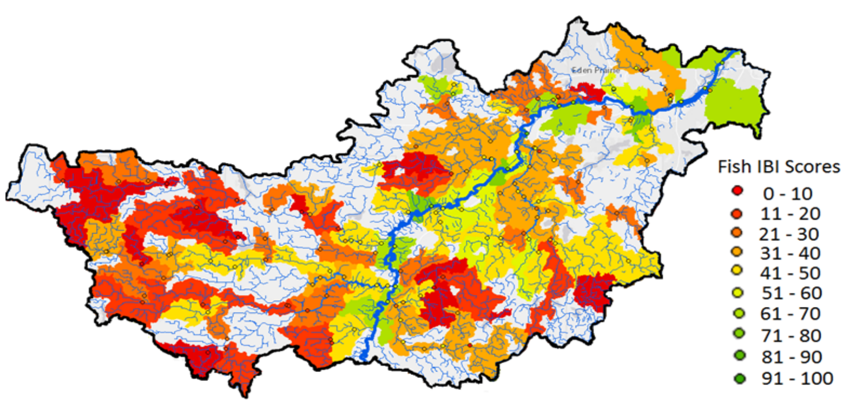


Figure 5 Fish Index of Biotic Integrity scores with DNR Stream Species Index scores

- Both TSS and TP (river eutrophication) impairments are prevalent, with 58% and 50% assessed reaches impaired for these parameters, respectively. While there are fewer river eutrophication impairments, this is a parameter that is evaluated mainly on larger streams (4th order and higher) since smaller streams may not have the residence time to grow algae (as measured by the response variable chlorophyll-a). Also, lack of complete response variable datasets limited the assessment of river eutrophication impairments.
- 24% of streams assessed for chloride are impaired. Those impaired primarily occur where urban stormwater runoff is significant or wastewater discharge occurs. Only one of the seven listings (Credit River) is a new listing (2018 assessment cycle).
- 55 of the 58 stream reaches assessed for aquatic recreation failed to meet standards. The three that were not impaired are either headwaters streams or receive most of their flow from a lake.

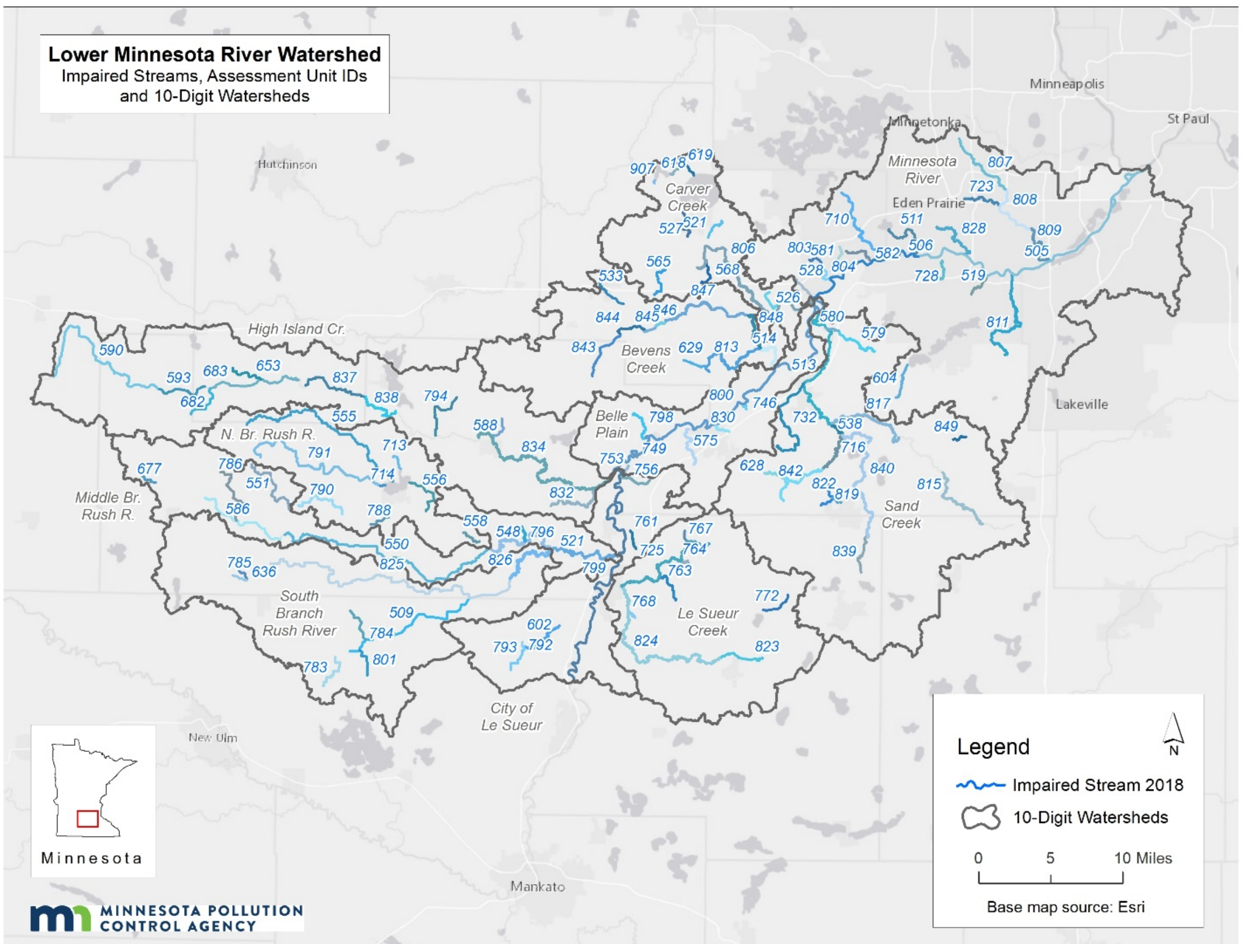


Figure 6 Impaired streams (by AUID); see Table 1 for types of impairments (Note: different impaired reaches denoted by different blue shades).

Table 1: Assessment status of stream reaches in the Lower Minnesota River Watershed (Imp = impaired; Mts = meets standard; * = TMDL and implementation plan previously completed).

HUC-10 Subwatershed	WD / WMO / County	Stream AUID	Aquatic Life						Aq Rec
			Fish Index of Biotic Integrity	Macroinvertebrate Index of Biotic Integrity	Dissolved Oxygen	Turbidity/TSS	River eutrophication	Chloride	*E. coli*
Minnesota R	Carver WMO	Chaska Creek, US Hwy 212 to Creek Rd07020012-803	Imp	Imp					
		Chaska Creek, Creek Rd to Minnesota R07020012-804							Imp
		Unnamed Creek, Gaystock Lk to Unnamed Cr07020012-835	Mts						
	LMRWD	Eagle Creek, Headwaters to Minnesota R07020012-519	Mts	Mts		Mts		Mts	Imp
		Unnamed creek, Headwaters to Minnesota R07020012-528							Imp
		Unnamed creek (Assumption Creek), Headwaters to Minnesota R07020012-582	Imp	Mts					
		Unnamed creek (East Creek), Unnamed Cr to Minnesota R 07020012-581	Imp	Imp		Imp			Imp
	NMCWD	Nine Mile Creek, Headwaters to Metro Blvd07020012-807	Imp						
		Nine Mile Creek, Metro Blvd to end of unnamed wetland 07020012-808	Imp	Imp					
		Nine Mile Creek, Unnamed wetland to Minnesota R 07020012-809	Imp	Imp		Mts		Imp*	Imp
		Nine Mile Creek, South Fork, Smetana Lk to Nine Mile Cr 07020012-723	Imp	Imp					
	PLSLWD	Unnamed creek (County Ditch 13), Unnamed ditch to Spring Lk (70-0054-00) 07020012-604	Imp	Mts					
		Unnamed creek (Prior Lake Outlet Channel), Dean Lk to Blue Lk07020012-728	Imp	Imp		Mts	Mts	Mts	Mts
	RPBCWD	Bluff Creek, Headwaters to Rice Lk07020012-710	Imp	Mts		Imp*		Mts	
		Purgatory Creek, Staring Lk to Minnesota R07020012-828	Mts	Imp				Mts	Imp
		Riley Creek, Riley Lk to Minnesota R07020012-511	Imp	Imp		Imp	Mts	Mts	Imp
	Scott WMO	Credit River, -93.3526 44.7059 to Minnesota R 07020012-811	Imp	Imp		Mts		Imp	Imp
Sand Creek	Le Sueur	Sand Creek, T112 R23W S23, south line to -93.5454 44.522607020012-839	Imp	Mts		Imp	Imp	Imp*	
	Scott WMO	County Ditch 10, CD 3 to Raven Str07020012-628	Mts	Imp		Mts		Mts	Imp
		County Ditch 3, Unnamed ditch to CD 1007020012-738	Mts	Mts					
		Porter Creek, Fairbanks Ave to 250th St E07020012-815				Imp		Mts	
		Porter Creek, Langford Rd/MN Hwy 13 to Sand Cr 07020012-817	Imp	Imp	Mts	Imp		Mts	Imp
		Raven Stream, E Br Raven Str to Sand Cr07020012-716	Imp	Imp				Imp*	Imp
		Raven Stream, East Branch, -93.6106 44.5532 to 255th St W07020012-819	Mts	Mts		Mts		Imp*	
		Raven Stream, West Branch, 270th St to E Br Raven Str 07020012-842	Imp	Imp		Mts		Mts	Imp
		Sand Creek, Porter Cr to Minnesota R07020012-513	Imp	Imp		Imp	Imp	Imp*	Imp
		Sand Creek, Raven Str to Porter Cr07020012-538	Imp			Imp			
		Sand Creek, -93.5454 44.5226 to Raven Str07020012-840	Imp	Imp		Imp	Imp	Imp*	

HUC-10 Subwatershed	WD / WMO / County	Stream AUID	Aquatic Life: Fish Index of Biotic Integrity	Aquatic Life: Macroinvertebrate Index of Biotic Integrity	Aquatic Life: Dissolved Oxygen	Aquatic Life: Turbidity/TSS	Aquatic Life: River eutrophication	Aquatic Life: Chloride	Aq Rec: *E. coli*
		Unnamed creek, Unnamed cr to Sand Cr07020012-684	Mts	Mts		Mts		Mts	
		Unnamed creek, Headwaters to Sand Cr07020012-732	Imp	Imp					
		Unnamed creek, RR bridge to E Br Raven Str07020012-822	Imp	Imp					
		Unnamed creek, Unnamed ditch to -93.4251 44.6206 07020012-849	Imp						
		Picha Creek, Unnamed cr to Unnamed cr 07020012-579	Imp	Imp					
		Picha Creek, Unnamed cr to Sand Cr07020012-580	Imp			Mts		Mts	
City of Belle Plain-Minn R	Scott WMO	Big Possum Creek, Unnamed cr to Minnesota R 07020012-749							Imp
City of Belle Plain-Minn R	Scott WMO	Robert Creek, Unnamed cr to Unnamed cr (at Belle Plaine Sewage Ponds)07020012-575	Imp	Imp		Imp		Mts	Imp
City of Belle Plain-Minn R	Scott WMO	Unnamed creek, Headwaters to Unnamed cr07020012-746				Mts	Mts		Imp
City of Belle Plain-Minn R	Scott WMO	Unnamed creek, Headwaters to Unnamed cr07020012-753							Imp
City of Belle Plain-Minn R	Scott WMO	Unnamed creek, Headwaters to Minnesota R07020012-756							Imp
City of Belle Plain-Minn R	Scott WMO	Unnamed creek (Brewery Creek), US Hwy 169 to Minnesota R07020012-830	Imp	Imp		Mts	Mts		Imp
City of Belle Plain-Minn R	Sibley	Unnamed creek, Unnamed cr to Minnesota R 07020012-798	Imp	Imp					
Carver Creek	Carver WMO	Carver Creek, Headwaters to MN Hwy 28407020012-805							Mts
Carver Creek	Carver WMO	Carver Creek, MN Hwy 284 to Minnesota R07020012-806	Imp	Imp		Imp*	Imp	Mts	Imp*
Carver Creek	Carver WMO	Unnamed creek, Headwaters to Carver Cr07020012-526							Imp
Carver Creek	Carver WMO	Unnamed creek, Benton Lk to Carver Cr07020012-568							Imp
Carver Creek	Carver WMO	Unnamed creek, Goose Lk (10-0089-00) to Unnamed wetland07020012-618							Imp
Carver Creek	Carver WMO	Unnamed creek, Reitz Lk to Unnamed cr07020012-621	Mts	Mts					Imp
Carver Creek	Carver WMO	Unnamed creek, Unnamed cr to Carver Cr (CD 2 & 3) 07020012-622	Mts	Mts					
Carver Creek	Carver WMO	Unnamed creek, Lk Waconia to Burandt Lk07020012-623							Mts
Carver Creek	Carver WMO	Unnamed creek, Gaystock Lk to Unnamed cr07020012-835	Mts						
Carver Creek	Carver WMO	Unnamed creek (Goose Lake Inlet), to Goose Lk (10-0089-00)07020012-907							Imp
Carver Creek	Carver WMO	Unnamed creek (Lake Waconia Inlet), Unnamed wetland to Lk Waconia07020012-619							Imp
Carver Creek	Carver WMO	Unnamed ditch, Burandt Lk to Unnamed cr07020012-527			Imp	Mts			Imp
Carver Creek	Carver WMO	Unnamed ditch, T115 R25W S16, west line to Winkler Lk 07020012-565							Imp
Bevens Creek	Carver WMO	Unnamed ditch, T115 R26W S14, north line to CD 4A 07020012-533							Imp
Bevens Creek	Carver WMO	Bevens Creek, Silver Cr to Minnesota R07020012-514	Imp	Imp		Imp*		Mts	Imp*
Bevens Creek	Carver WMO	Bevens Creek, 154th St to -93.8615 44.7265 07020012-844				Mts			Imp*

HUC-10 Subwatershed	WD / WMO / County	Stream AUID	Aquatic Life						Aq Rec
			Fish Index of Biotic Integrity	Macroinvertebrate Index of Biotic Integrity	Dissolved Oxygen	Turbidity/TSS	River eutrophication	Chloride	*E. coli*
		Bevens Creek, -93.8615 44.7265 to -93.8455 44.7327 07020012-845	Imp	Mts					
		Bevens Creek, -93.8455 44.7327 to unnamed cr 07020012-846				Imp*			
		Bevens Creek, Unnamed cr to -93.7156 44.7438 07020012-847				Imp*			Imp*
		Bevens Creek, -93.7156 44.7438 to Silver Cr07020012-848	Imp	Imp		Imp*			Imp*
		Judicial Ditch 22, Unnamed cr to Silver Cr07020012-629							Imp
		Silver Creek, -93.769 44.687 to Bevens Cr07020012-813	Imp	Imp		Imp*		Mts	Imp*
	Sibley	Bevens Creek, Headwaters (Washington Lk 72-0017-00) to 154th St07020012-843	Mts	Imp		Mts	Imp		Imp*
Le Sueur Creek	Le Sueur	County Ditch 34, Unnamed ditch to Forest Prairie Cr 07020012-764	Imp	Imp					
		County Ditch 42, School Lk to Clear Lk outlet07020012-772	Imp	Imp					
		County Ditch 8/53, Unnamed ditch to CD3407020012-766	Mts	Mts					
		Forest Prairie Creek, CD 29 to Le Sueur Cr07020012-725	Imp	Imp				Mts	Imp
		Judicial Ditch 4, Unnamed ditch to Forest Prairie Cr 07020012-767	Imp						
		Le Sueur Creek, CD 23 to W Prairie St07020012-823	Imp						
		Le Sueur Creek, W Prairie St to Forest Prairie Cr 07020012-824	Imp	Imp		Mts		Mts	Imp
		Unnamed creek, CD 56 to Le Sueur Cr07020012-768	Imp	Imp					
		Unnamed ditch, Unnamed ditch to Forest Prairie Cr 07020012-763	Imp	Imp					
City of Le Sueur-Minn R		Unnamed creek, Unnamed cr to JD 207020012-761						Mts	Imp
	Nicollet	Barney Fry Creek, CD 47A to CD 3507020012-602	Imp	Imp					Imp
		County Ditch 47A, Unnamed ditch to CD 75 07020012-792	Imp	Mts					
		County Ditch 75, Unnamed ditch to CD 47A 07020012-793	Imp	Mts					
High Island Creek	High Island WD	Buffalo Creek, 276th St /Co Rd 65 to High Island Cr 07020012-832	Imp	Imp		Imp			Imp
		Buffalo Creek (County Ditch 59), High Island Ditch 5 to 276th St /Co Rd 6507020012-831	Mts	Mts					
		County Ditch 39, Unnamed ditch to High Island Cr 07020012-683	Mts	Imp					
		High Island Creek, JD 15 to Bakers Lk07020012-653	Imp	Imp		Imp			Imp*
		High Island Creek, -94.0936 44.6181 to Minnesota R 07020012-834	Imp	Imp		Imp		Mts	Imp*
		High Island Creek, Bakers Lk to -94.2538 44.6574 07020012-837							Imp*
		High Island Creek, -94.2538 44.6574 to Unnamed cr 07020012-838	Imp	Imp				Mts	Imp*
		High Island Ditch 2, Unnamed cr to High Island Cr 07020012-588	Mts			Imp			Imp*
		Judicial Ditch 11, CD 103 to CD 1007020012-590	Imp						
		Judicial Ditch 11, CD 10 to JD 2407020012-593	Imp	Imp					
		Judicial Ditch 12, Headwaters to High Island Creek 07020012-794	Imp						
		Judicial Ditch 15, CD 31 to High Island Cr07020012-682	Imp	Imp					

HUC-10 Subwatershed	WD / WMO / County	Stream AUID	Aquatic Life						Aq Rec
			Fish Index of Biotic Integrity	Macroinvertebrate Index of Biotic Integrity	Dissolved Oxygen	Turbidity/TSS	River eutrophication	Chloride	*E. coli*
		Judicial Ditch 24, Headwaters to JD 1107020012-591	Mts						
		Unnamed creek (County Ditch 30), Headwaters to Bakers Lk07020012-594	Mts						
North Branch Rush R	Sibley	County Ditch 18, CD 40 to Titlow Lk07020012-714				Mts			Imp
		County Ditch 18, Headwaters to CD 4007020012-791	Imp						
		Rush River, North Branch (County Ditch 55), Titlow Lk to T113 R28W S35, south line07020012-556	Imp	Imp					
		Rush River, North Branch (County Ditch 55), Unnamed ditch to T112 R27W S17, east line07020012-558			Mts				Imp
		Rush River, North Branch (Judicial Ditch 18), Headwaters to Titlow Lk07020012-555	Imp	Imp					Imp
		Unnamed ditch, Headwaters to Titlow Lk07020012-713							Imp
		Unnamed ditch (County Ditch 55), Headwaters (Altnow Lk 72-0039-00) to N Br Rush R07020012-610	Mts						
Middle Branch Rush R	Sibley	County Ditch 11, Unnamed ditch to CD 2207020012-674	Mts						
		County Ditch 22, CD 49 to CD 1107020012-675	Mts	Mts					
		County Ditch 42, Headwaters to T113 R29W S31, south line07020012-551	Mts	Imp					
		County Ditch 44, Headwaters to M Br Rush R 07020012-786	Imp	Imp					
		County Ditch 49, Unnamed ditch to CD 2207020012-677	Imp	Imp					
		County Ditch 50, Co Rd 62 to Rush R07020012-796	Imp	Imp					
		County Ditch 56, Headwaters to Unnamed ditch 07020012-790	Mts	Imp					
		Rush River, S Br Rush R to Minnesota R07020012-521	Imp	Mts		Imp		Mts	Imp*
		Rush River, M Br Rush R to S Br Rush R07020012-548	Imp	Imp		Imp			
		Rush River, Middle Branch (County Ditch 23 and 24), CD 42 to Rush R07020012-550							Imp
		Rush River, Middle Branch (County Ditch 23 and 24), Unnamed ditch to T112 R30W S13, east line 07020012-586	Imp	Imp					
		Unnamed ditch, Unnamed ditch to Unnamed ditch 07020012-788	Mts	Imp					
South Branch Rush R	Nicollet	County Ditch 30A, Unnamed ditch to JD 1A07020012-801	Imp	Imp					
		County Ditch 32A, CD 32 to Unnamed ditch07020012-783	Imp	Imp					
		County Ditch 9, Unnamed ditch to JD 1A07020012-784	Imp						
		Judicial Ditch 1A, CD 40A to S Br Rush R07020012-509			Mts				Imp
	Sibley	County Ditch 13, Unnamed ditch to JD 107020012-636	Mts	Imp					
		Judicial Ditch 1, CD 4A to CD 1307020012-785	Mts	Imp					
		Judicial Ditch 6, Unnamed ditch to S Br Rush R 07020012-574	Mts						
		Rush River, South Branch, Unnamed ditch to -94.0478 44.476107020012-825	Imp	Imp					Imp*
		Rush River, South Branch, -94.0478 44.4761 to Rush R 07020012-826	Imp	Imp				Mts	Imp*

Lakes

The results of lake assessment are provided in Table 2 below with locations shown in Figure 7. The primary monitoring done on lakes is for TP—which is the cause of eutrophication, a condition that can result in unsightly algae blooms that could make swimming in them undesirable or unsafe. Key findings and conclusions of the lake assessment for both aquatic recreation and aquatic life include the following:

- 55% of lakes assessed for aquatic recreation failed to meet standards.
- Six lakes (Crystal, Fish (19-0057-00), McMahon, Mitchell, Red Rock, and Bryant) had previously been impaired by eutrophication, but due to successful restoration efforts are now meeting that standard and thus have been removed from the impaired waters list.
- 57% of lakes assessed for aquatic life/fish IBI failed to meet standards.
- All lakes with sufficient chloride data for assessment meet that standard.

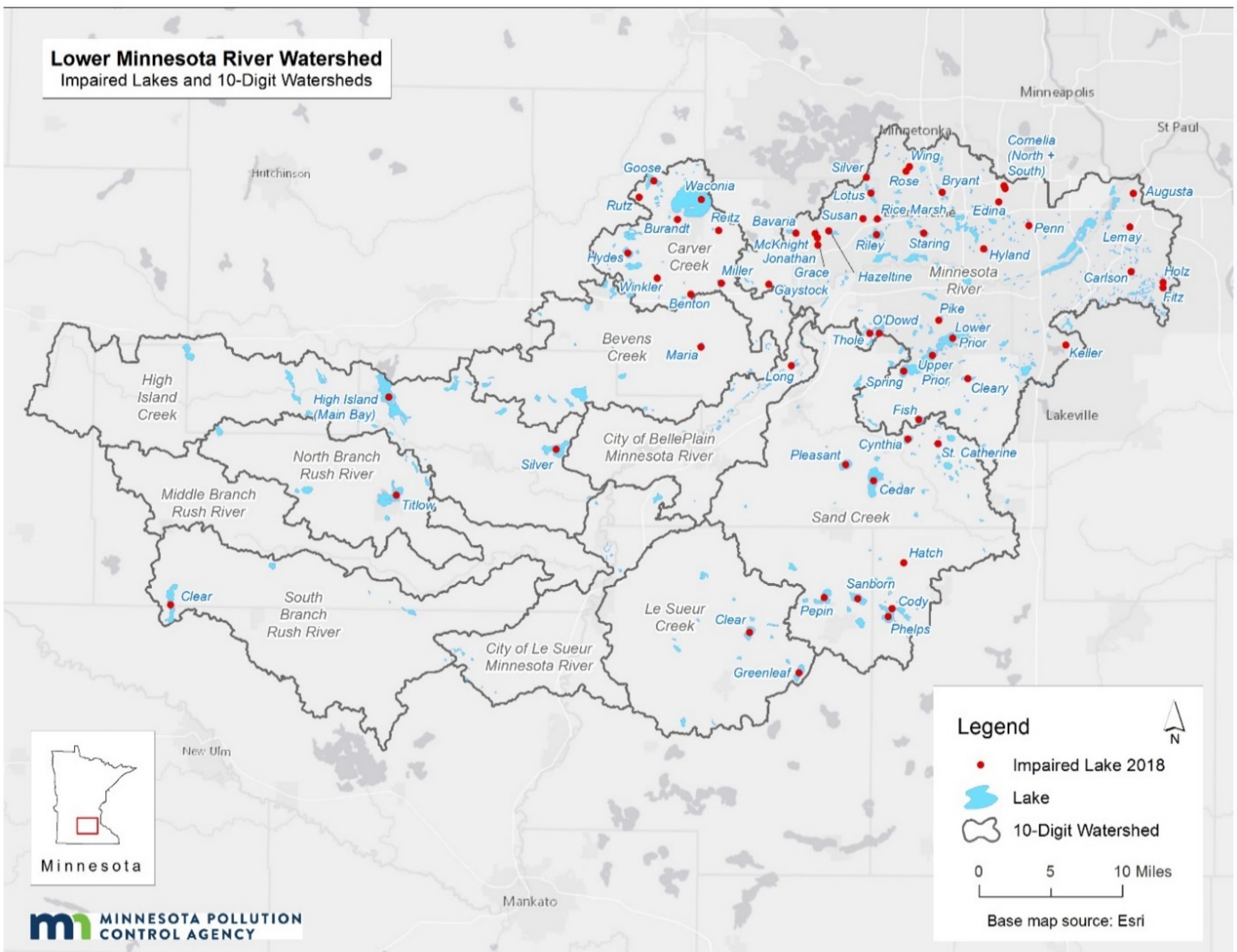


Figure 7 Impaired lakes; see Table 2 for types of impairments.

Table 2: Assessment status of lakes in the lower Minnesota River Watershed (Imp = impaired; Mts = meets standard; + = TMDL and implementation plan previously completed; * = close to TP standard (see section 2.5 for further information). For water clarity trend: ↗ = increasing; ↘ = declining; → = no apparent trend. Blank = insufficient information).

HUC-10 Subwatershed	WD / WMO / County	Lake	Lake ID	Aquatic Life: Fish Index of Biotic Integrity	Aquatic Life: Chloride	Aquatic Rec: Eutrophication	Aquatic Rec: Water clarity trend†
Minnesota R	BDWMO	Crystal	19-0027-00	Mts	Mts	**Mts**	↘
		Earley	19-0033-00			Mts	→
		Keller	19-0025-00		Mts	**Imp+**	↘
		Kingsley	19-0030-00			Mts	→
		Lac Lavon	19-0446-00			Mts	→
		Lee	19-0029-00			**Mts**	↗
		Orchard	19-0031-00	Mts	Mts	Mts	↗
		Twin	19-0028-00			Mts	→
		Wood Park	19-0024-00				→
	Carver WMO	Big Woods	10-0249-00				
		Firemen's Clayhole	10-0226-00			Mts	↘
		Gaystock	10-0031-00			Imp	
		Hazeltine	10-0014-00			Imp	↘
		Jonathan	10-0217-00			Imp	→
		McKnight	10-0216-00			Imp	↗
		Unnamed (Grace)	10-0218-00			Imp	↘
	EIGHWMO	Bald	19-0061-00			*	
		Blackhawk	19-0059-00			Mts*	→
		Bur Oaks Pond	19-0259-00			Mts	↘
		Carlson	19-0066-00			**Imp+**	↘
		East Thomas	19-0161-00			Mts	→
		Fish	19-0057-00		Mts	Mts	→
		Gerhardt	19-0069-00				↘
		Holland	19-0065-00		Mts	Mts	↗
		Jensen	19-0071-00			Mts	↘
		Lemay	19-0055-00			**Imp+**	→
		Lemay	19-0082-00			Mts	↗
		McDonough	19-0076-00			Mts	→
		O'Brien	19-0072-00			Mts	
		Pitts (Cliff)	19-0068-00				↗
		Thomas	19-0067-00			Mts	↗
		Unnamed	19-0036-00			Mts	
		Unnamed	19-0054-00			*	
		Unnamed (Fitz)	19-0077-00			**Imp+**	↗
		Unnamed (Hay)	19-0062-00			Mts	↗
		Unnamed (Heine)	19-0153-00			Mts	→
		Unnamed (Holz)	19-0064-00			**Imp+**	→
		Unnamed (LP-30)	19-0053-00			Mts	
		Unnamed (North)	19-0136-00			Mts	
		Unnamed (Schwanz)	19-0063-00			Mts	↗
	LMRWD	Brickyard Clayhole	10-0225-00			Mts	→
		Courthouse	10-0005-00		Mts	Mts	↗
		Unnamed	19-0128-00			Mts	
	LMRWMO	Augusta	19-0081-00			**Imp+**	↘
	NMCWD	Bryant	27-0067-00	Imp	Mts	Mts	↗
		Bush	27-0047-00			Mts	→
		Cornelia (North)	27-0028-01			Imp	
		Cornelia (South)	27-0028-02			Imp	
		Edina	27-0029-00			Imp	
		Glen	27-0093-00			Mts	
		Indianhead	27-0044-00				
		Lone	27-0094-00			Mts	
		Minnetoga	27-0088-00			Mts	
		Mirror	27-0055-00				→
		Normandale	27-1045-01			*	

HUC-10 Subwatershed	WD / WMO / County	Lake	Lake ID	Aquatic Life		Aquatic Rec	
				Fish Index of Biotic Integrity	Chloride	Eutrophication	Water clarity trend†
		North Anderson	27-0062-01			Mts	→
		Penn	27-0004-00			Imp	→
		Rose	27-0092-00			Imp	
		Shady Oak (middle bay)	27-0089-02			Mts	
		Smetana	27-0073-00				
		Southwest Anderson	27-0062-03				→
		Wing	27-0091-00			Imp	→
		Cate's or Hidden	70-0018-00			Mts	↗
		Crystal	70-0061-00				
		Fish	70-0069-00			Imp*	→
		Lower Prior	70-0026-00	Imp	Mts	Mts	↗
	PLSLWD	Pike	70-0076-00			Imp	→
		Spring	70-0054-00	Imp		**Imp+**	→
		Unnamed	70-0078-00				
		Unnamed	70-0085-00		Mts		
		Upper Prior	70-0072-00		Mts	**Imp+**	↗
		Ann	10-0012-00		Mts	Mts	→
		Duck	27-0069-00			Mts	
		Hyland	27-0048-00			Imp	↘
		Lotus	10-0006-00	Imp		Imp	↗
		Lucy	10-0007-00		Mts	Mts*	↘
		Mitchell	27-0070-00	Mts		Mts	↗
	RPBCWD	Red Rock	27-0076-00		Mts	Mts*	→
		Rice Marsh	10-0001-00		Mts	Imp	
		Riley	10-0002-00	Imp	Mts	Imp*	↗
		Round	27-0071-00			*	
		Silver	27-0136-00			Imp	
		Staring	27-0078-00	Mts	Mts	Imp	↗
		Susan	10-0013-00		Mts	Imp	→
		Cleary	70-0022-00			Imp	↗
		Hanrahan	70-0019-00				
		Keup's	70-0079-00		Mts		
		Krenz	70-0009-00				→
		Markley	70-0021-00				→
	Scott WMO	McColl Pond	70-0017-00				
		Murphy	70-0010-00			Mts	↗
		O'Dowd	70-0095-00	Imp		Mts	↗
		Thole	70-0120-01	Mts	Mts	Imp	→
		Unnamed (South Portion)	70-0011-02			Mts	→
	Le Sueur	Pepin	40-0028-00		Mts	Imp	
		Sanborn	40-0027-00			Imp	
		Cody	66-0061-00			Imp	
	Rice	Hatch	66-0063-00			Imp	
		LeMay	66-0056-00				
		Phelps	66-0062-00			Imp	
Sand Creek		Cedar	70-0091-00			**Imp+**	→
		Cynthia	70-0052-00			Imp	
		McMahon	70-0050-00	Mts		**Mts***	↗
	Scott WMO	Mill Pond	70-0113-00				→
		Mitchell	70-0128-00				
		Nash	70-0043-00				
		Pleasant	70-0098-00			Imp	
		St. Catherine	70-0029-00			Imp	
		Bavaria	10-0019-00	Imp		Mts*	↘
		Benton	10-0069-00			**Imp+**	↘
Carver Creek	Carver WMO	Burandt	10-0084-00			**Imp+**	→
		Goose	10-0089-00			**Imp+**	→
		Hydes	10-0088-00			**Imp+**	→

HUC-10 Subwatershed	WD / WMO / County	Lake	Lake ID	Aquatic Life: Fish Index of Biotic Integrity	Aquatic Life: Chloride	Aquatic Rec: Eutrophication	Aquatic Rec: Water clarity trend†
Bevens Creek		Meuwissen	10-0070-00				
		Miller	10-0029-00			**Imp+**	→
		Reitz	10-0052-00			**Imp+**	↗
		Rutz	10-0080-00			**Imp+**	→
		Waconia	10-0059-00	Imp	Mts	Mts*	↗
		Winkler	10-0066-00			**Imp+**	↗
		Maria	10-0058-00			**Imp+**	
	Sibley	Washington	72-0017-00				
Le Sueur Creek	Le Sueur	Clear	40-0079-00			Imp	
		Greenleaf	40-0020-00			Imp	
High Island Creek	High Island WD	High Island (main basin)	72-0050-01		Mts	Imp	↗
		Round Grove	43-0116-00		Mts	Mts*	
		Silver	72-0013-00		Mts	Imp	
North Branch Rush R	Sibley	Titlow	72-0042-00			Imp	
South Branch Rush R		Clear	72-0089-00		Mts	Imp	→

†Secchi disk trends using available data from 1972-2016 from MPCA's Citizen Lake Monitoring Program; see section 2.2 for further explanation.

2.2 Water quality trends

Statistical trends in stream and lake water quality can be difficult to identify because substantial data sets are required for trend analysis. Furthermore, year-to-year climatic variability can obscure gradual trends. In addition, several years of data are needed for trend analysis.

Streams

TSS and TP concentration data for impaired streams from LMR TMDL, Part I are shown in Figure 8 and Figure 9, respectively. Figure 8 shows aggregated data for 13 separate TSS-impaired streams. While no statistical test was conducted there appears to be no apparent trend of improvement or decline for either TSS or TP.

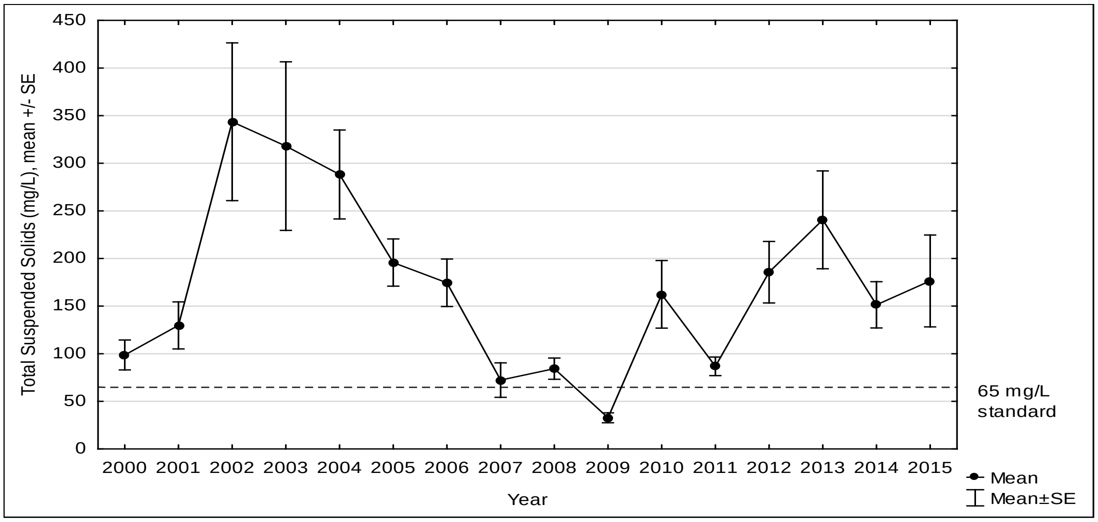


Figure 9 Average Apr–Sept total suspended solids concentrations in impaired streams from LMR TMDL, Part I.

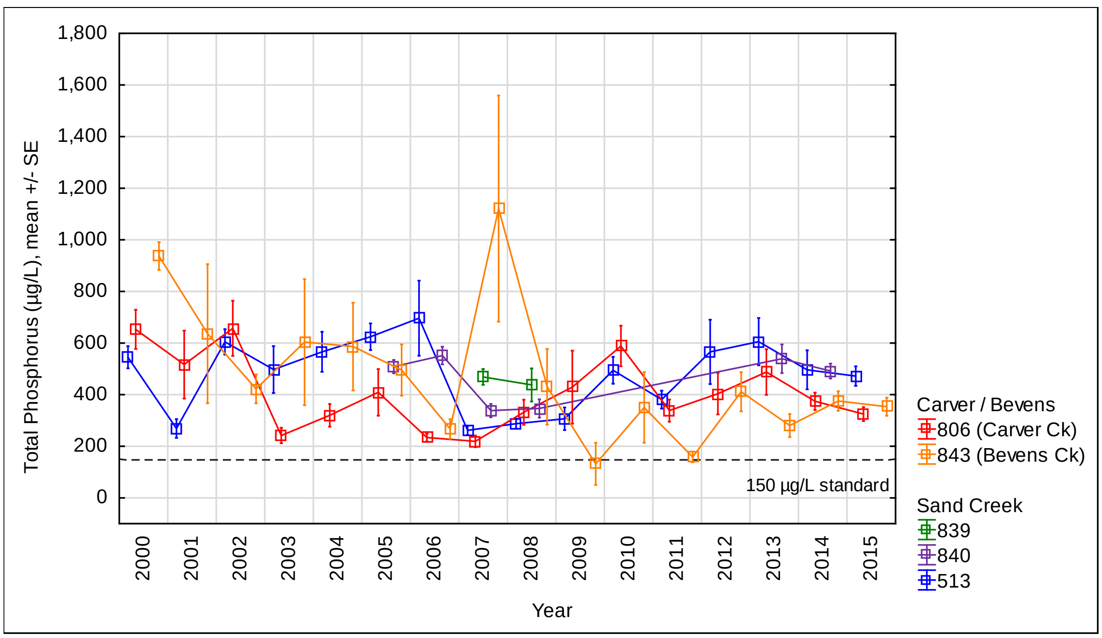


Figure 8 Average Jun–Sept TP concentrations in impaired streams (means and error bars are shifted within year to facilitate comparison among streams).

Lakes

The MPCA routinely analyzes lake clarity (Secchi disk) data generated from the MPCA's Citizen Lake Monitoring Program for those lakes with a minimum of eight years of this transparency data. A Seasonal Kendall statistical test is used for this analysis. A summary of results is shown in the last column of Table 2 and indicates that 27 lakes have an increasing trend in water clarity, 14 have a decreasing trend and 38 show no apparent trend. The MPCA report *A review of Secchi transparency trends in Minnesota lakes* (MPCA 2016) identifies phosphorus as the primary driver of transparency, but also indicates that some invasive species can have a marked, though potentially temporary, effect. An important example is increased clarity from phytoplankton filtration by zebra mussels, until the point a possible crash in population of that species occurs. (Lakes with confirmed zebra mussel infestation in the LMRW per the

Minnesota DNR are Burandt, Lower Prior, Miller, Riley, Upper Prior, and Waconia.) Again, climatic variability may be governing the trends for some of the lakes as well.

2.3 Stressors and sources

In order to develop appropriate strategies for restoring or protecting waterbodies, the stressors and/or sources impacting or threatening them must be identified and evaluated. Biological SID is done for streams with either fish or macroinvertebrate biota impairments and lakes with either fish or aquatic plant biota impairments. SID encompasses both evaluation of pollutants and non-pollutant-related (e.g. altered hydrology, connectivity, habitat) factors as potential stressors.

Pollutant source assessments are done as part of SID work and TMDLs. This section summarizes the various pollutant sources and, where possible, their relative magnitude in terms of contribution to impairments. Section 3 provides further detail on the sources' geographic extent.

Stressors of biologically-impaired stream reaches

The report *Lower Minnesota River Watershed Stream Stressor Identification Report* (MPCA 2018) provides the full results for the evaluation of the individual stream reaches. A summary of those results is provided in Table 3 below. This analysis identifies both pollutant and non-pollutant stressors. Pollutant stressors include eutrophication (phosphorus), nitrate, TSS, chloride and possibly low DO (where a separate evaluation shows causation by a pollutant). Non-pollutant stressors include degraded or insufficient habitat, connectivity and altered hydrology. Connectivity problems are most commonly human-made structures like culverts (that are improperly sized or unaligned with the stream bottom) or dams, which prevent or limit fish passage. Altered hydrology can result in more flashy flows (i.e., greater frequency of both higher and lower flows) caused by changes to the stream's watershed.

The analysis in Table 3 also provides general source-related information for each stressor. For example, for the stressor 'low DO' two potential sources (or causes/pathways)—plant respiration and lack of flow—were evaluated and are shown. (In some cases this analysis could not determine a source and so is depicted as 'unidentified'. Also, various other sources were evaluated or considered as part of this process, but are not shown in this table since the analysis either ruled them out or there was insufficient information to adequately evaluate them. See the footnote for this table for the specific additional sources evaluated/considered.) More detailed TSS and TP source analyses are provided in Table 7 and Table 9, respectively, for any stream reaches that were separately assessed as impaired for those specific parameters. Watershed-wide maps of stream reach stressors and pollutants by parameter are shown in their respective section.

Those reaches without identified pollutant stressors are not subject to TMDLs (and are designated as EPA category 4C). Those reaches that are impacted by pollutant stressors are generally subject to TMDL requirements. For this project there are some reaches that are impacted by a pollutant stressor that have an accompanying TMDL completed for that pollutant, e.g., some TSS or eutrophication TMDLs (and are thus designated as EPA category 4A to reflect completion of the needed TMDLs). There are more reaches; however, that are impacted by a pollutant stressor that do not yet have a completed TMDL and will be deferred to a later date (and thus will remain as EPA category 5, TMDL needed).

Key overall findings and conclusions from the SID work include the following:

- Nearly all reaches have multiple stressors. In only three of the 74 reaches evaluated are no conclusive stressors identified.
- Insufficient/degraded habitat is the most prevalent stressor, occurring in 76% of the reaches. Altered hydrology is next highest at 65%. These findings are not surprising given the large extent of stream alteration that has occurred in this watershed, as shown in Figure 2.
- The pollutant-related stressors were also significant with eutrophication (phosphorus) affecting 62% of the reaches and nitrate and TSS affecting 54%. Low DO, which may in some cases be pollutant-driven, occurs in 32% of the reaches.
- Nitrate, which is most prevalent as a stressor in streams of intensely agricultural areas, is the only stressor that appears to vary in occurrence geographically.

Information about specific stressors are listed below.

Altered Hydrology

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

Altered hydrology was a commonly identified stressor to aquatic life in the LMRW, found to affect most of the investigated stream reaches (Table 3). Both high and low river flow conditions were identified as problematic in the watershed. Since altered hydrology is not a pollutant by itself, it is only investigated when a bio-impairment is identified. The sources of altered hydrology are common across the watershed. Therefore, altered hydrology is likely negatively impacting water quality watershed-wide.

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

Long-term stream flow monitoring in the Minnesota River at Jordan indicates there was a significant change in flows beginning in the early 1980s. The DNR, utilizing a double mass curve, evaluated the relationship between precipitation and discharge data over time (DNR 2017). The evaluation shows that for every inch of precipitation, more water is entering the river via runoff (Figure 10). While the Minnesota River at Jordan receives water from the entire basin, similar results are seen in High Island Creek.

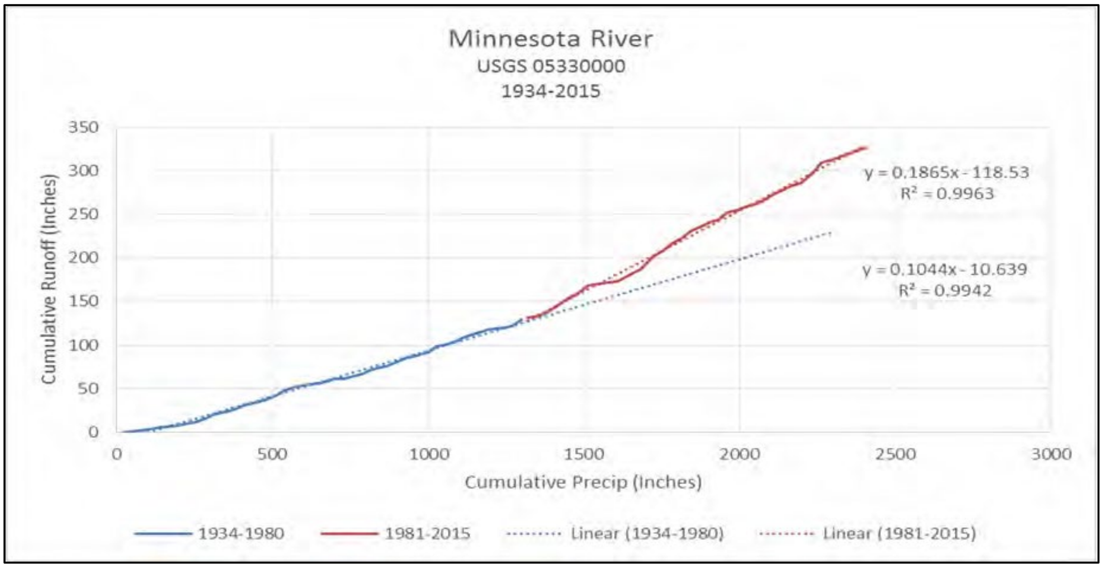


Figure 10 Double Mass curve analysis for the Minnesota River – Jordan. A distinct increase in the amount of runoff per inch of precipitation is noted starting in 1981 (figure prepared by DNR).

Stream flow monitoring in High Island Creek only dates back to 1973, but changes starting in the early 1980s is also noted (Figure 11). When evaluating flows in High Island Creek on a monthly scale, this change is more pronounced in certain months (Figure 12).

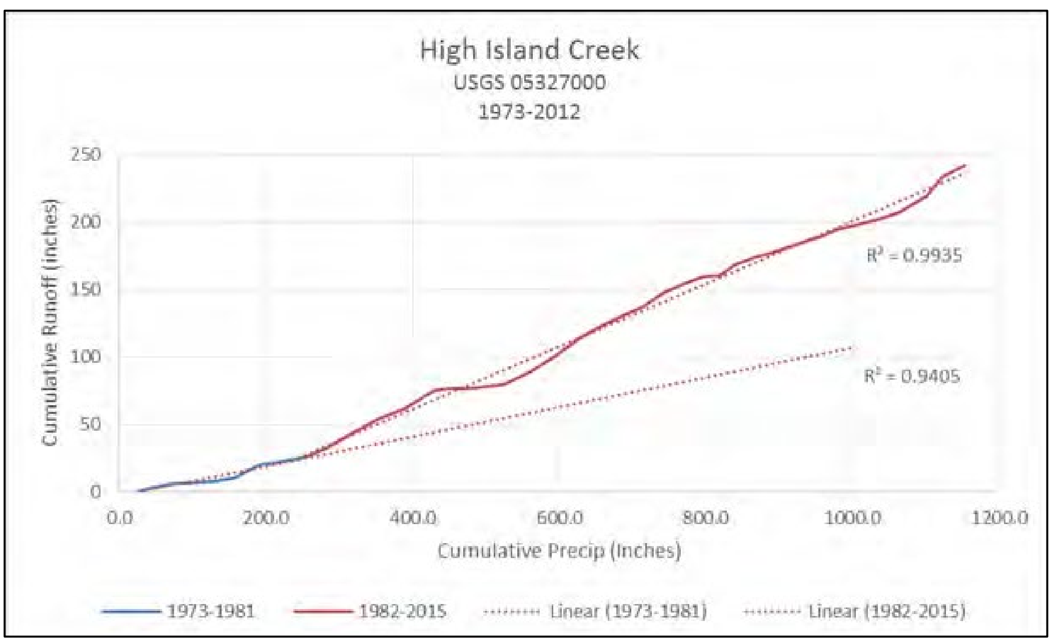


Figure 11 Double mass curve analysis for High Island Creek. Similar to the Minnesota River – Jordan an increase in runoff is noted starting in the early 1980s (figure prepared by DNR).

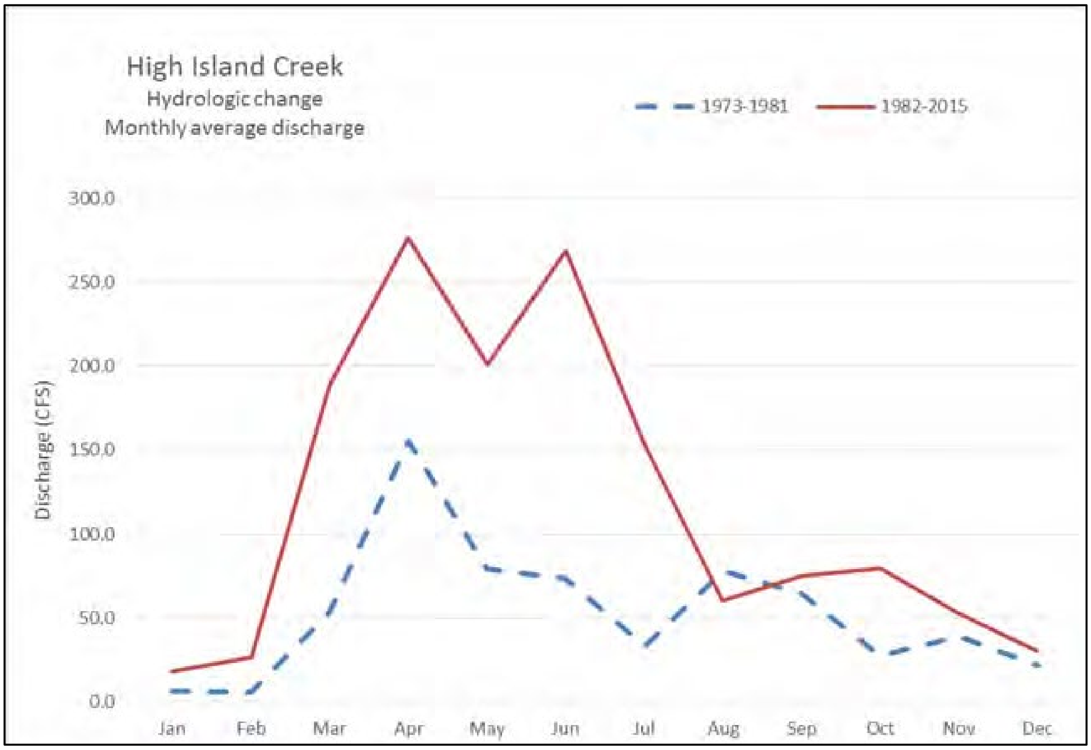


Figure 12 Comparing monthly average discharges for High Island Creek from the time periods 1973 through 1981 and 1982 to present (DNR).

While increase in precipation is one reason for the increase in runoff, Lehart et al. (2011) have concluded that the increase in annual precipitation alone cannot explain the large increase in the average annual stream flows. Changes in soil organic matter (SOM), cropping rotations, drainage and imprevious surfaces all have a significant contrubition to the increase in runoff.

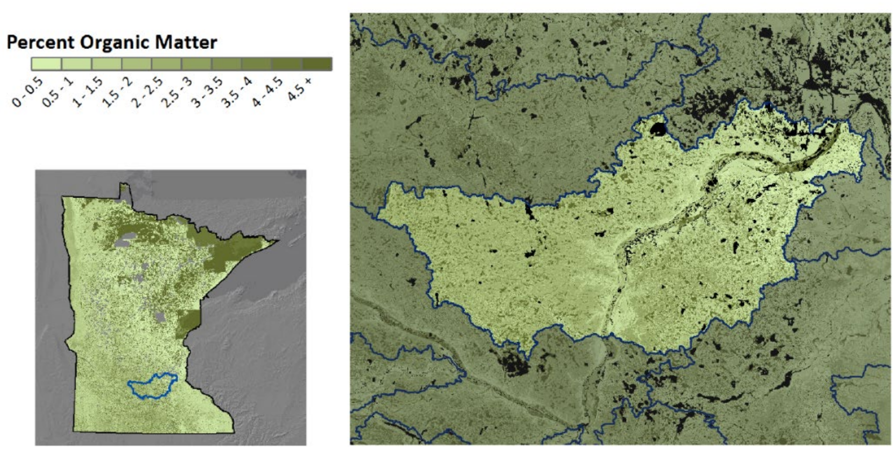


Figure 13 Percent soil organic matter, DNR Watershed Health Assessment Framework
Historically, SOM levels in the LMRW were between 4% and 7%. Intense historical tillage has resulted in many areas of the LMRW to now average between 1% and 3% SOM.

SOM plays a significant role in the ability of the soil to allow water infiltration and to hold water. The National Resource Conservation Service (NRCS) estimates that for every 1% increase in SOM in the top six inches of soil, an additional 27,000 gallons of water per acre could be held in the soil profile (USDA-NRCS Beman Hudson 2013). This equates to roughly 1" of water per acre per 1% of SOM. Soils in southern Minnesota and within the LMRW have some of the highest SOM levels of all mineral soils, historically ranging from 4% to 7% of the total soil mass (Overstreet & DeJong-Hughes). Agricultural practices, such as tillage, crop rotation and fertilization all have an effect on SOM. Aggressive tillage has a considerable effect on SOM, and most organic matter losses in soil occurred in the first decade or two after land was cultivated. In some cases more than 50% of the SOM was lost in the first 25 years of aggressive land cultivation (i.e. moldboard plowing) (Lewandowski 2000). GIS analysis completed for the DNR Watershed Health Assessment Framework (WHAF) provides a current estimation of SOM in the LMRW (Figure 13).

Since European settlement, the diversity of vegetation and crops on the landscape has continued to decline. Grasslands were replaced by diverse crops and cities. Then between the mid- to late-20th centuries, the diverse crops - including substantial amounts of small grains and hay - were replaced by a dominance of corn and soybeans (Figure 14).

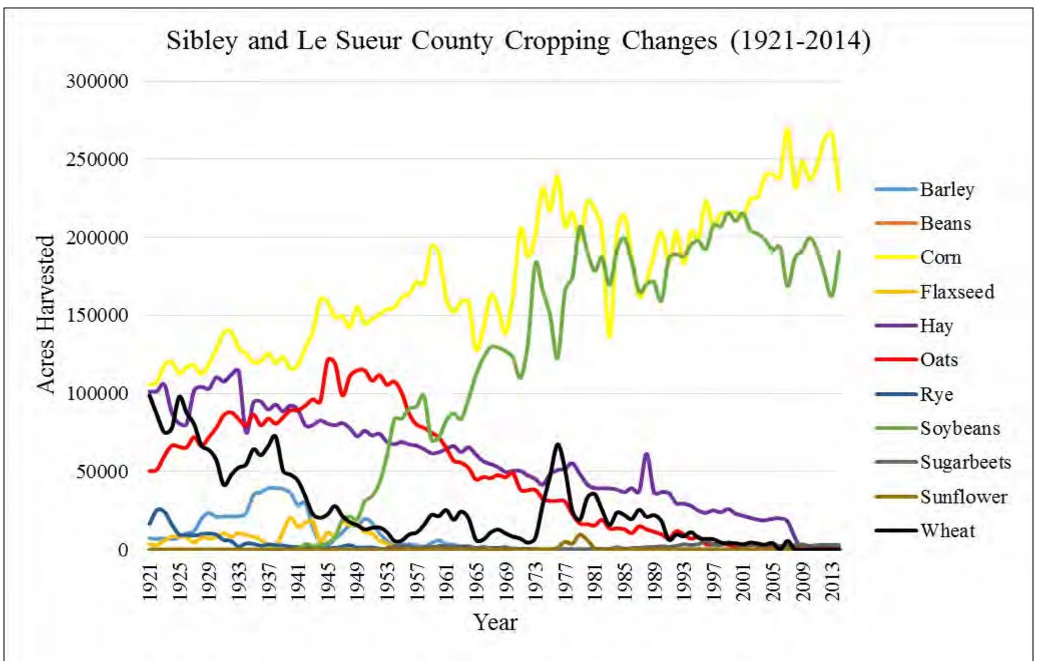


Figure 14 Acres harvested, by crop, 1921 through 2014 for Sibley and Le Sueur Counties (DNR).

The DNR analysis of crop history in Sibley and Le Sueur Counties shows that in 1921 the three main crops were corn at 15.36% of the total land use followed by hay at 14.73% and wheat at 14.37%, for a total of 44.46% of the total land use. In 2014, corn still remained the most planted crop at 33.39% and soybeans the second most at 27.76% of the total land use. All other crops together only added up to less than 1% for a total land use of 61.2%. The changes in land use and crops have resulted in impacts to hydrology. While corn and soybeans have similar total ET rates as small grains and perennials, when the ET occurs is significantly different. ET for small grains and perennials begins in early spring, in some cases several months before corn and soybeans. In mid-summer corn and soybeans have a significant higher

ET than small grains and perennials. Corn and soybean are less in sync with monthly precipitation amounts than small grains and perennials (Figure 15; NRCS 1977), resulting in more precipitation entering rivers in spring as runoff and less entering in mid-summer as baseflow.

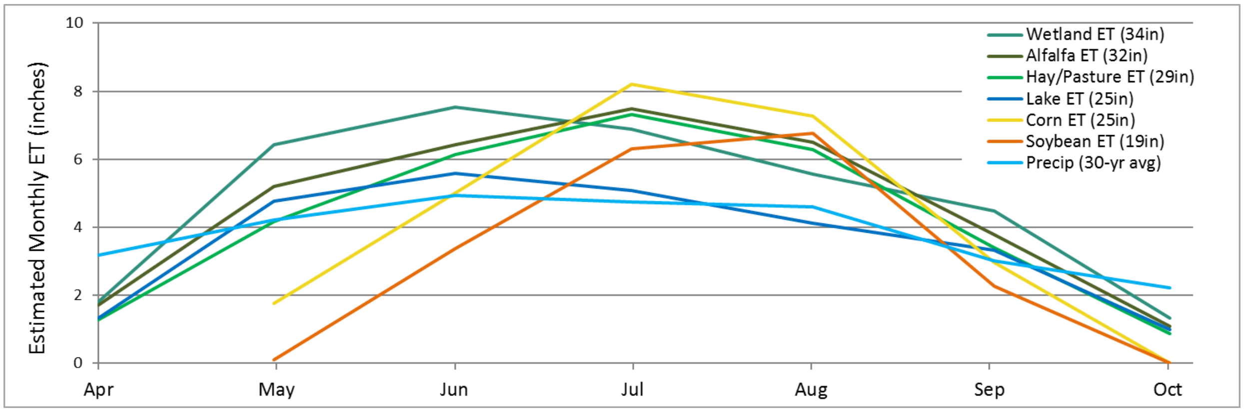


Figure 15 Estimated monthly evapotranspiration rates of various land covers. While there is some difference in the total yearly ET of alfalfa/hay/pasture and corn/soybeans, the biggest effects of changing crop patterns is the timing of the ET. Alfalfa, hay and pasture have significantly higher ET in spring (April, May and June) when compared to corn and soybeans. See Appendix 2 for information on how ET was calculated for various categories.

A significant amount of watercourses, in the LMRW, have been ditched or straightened for agricultural drainage. This altering of watercourses leads to an increase of the speed at which water leaves the landscape, creating more near channel erosion. In its work for the Minnesota Statewide Altered Watercourse Project the MPCA, Minnesota Geospatial Information Office and DNR determined that 63.2% (1,623.1 miles) of the watercourses in the LMRW are considered altered, 1.2% (29.9 miles) are considered impounded, and 19.4% (499.0 miles) remained natural. The remaining 16.2% (416.6 miles) had no definable channel. Figure 16 provides a GIS interpretation of locations of streams, lakes and wetland prior to settlement of the LMRW. Figure 16 also depicts the current state of watercourses in the LMRW, showing significant watercourse alterations.

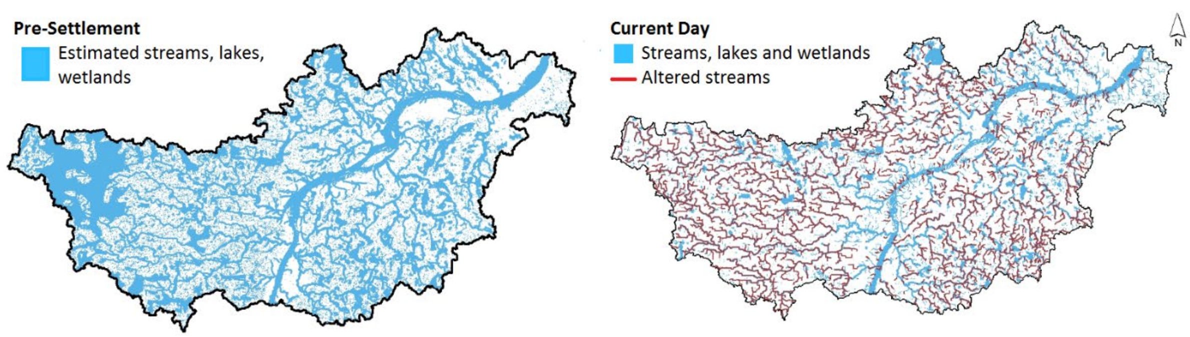


Figure 16 Pre-settlement (estimation) and current location of streams, lakes and wetlands in the LMRW.

Agricultural drainage, by design, modifies the hydrology of a given area. The University of Minnesota outlines the potential impacts agricultural drainage may have on a watershed in the publication Fields to Streams, Managing Water in Rural Landscapes (Lewandowski 2015):

- ***Reduces time that water is being stored in the soil.*** *Only drainable water is removed by tile and ditches. The amount of plant available water (i.e., water held by soil particles against the pull of gravity) is not affected by artificial drainage systems.*
- ***Changes the pathway of water over land.*** *Some ditches and tile link streams to depressions (potholes) that were previously not connected, which could increase peak flows.*
- ***Reduces overland flow*** *(and soil erosion) if water instead moves through soil and subsurface tile. Overland flow still occurs on tiled land if surface soil structure is poor, blocking infiltration, or if the soil is saturated.*
- ***Decrease evaporation*** *by removing areas of standing water.*
- ***Increase annual transpiration*** *if rooting depth and productivity increase.*
- ***Increase the total amount of water that reaches streams*** *(annual yield). Models show that tiling increases the annual amount of water leaving the field.*
- ***Reduce, delay, and extend the peak flow in a stream*** *after a precipitation or snowmelt event (if water is moving through tile systems instead of overland). Water takes longer to travel through soil to a tile system than to move overland or through ditches. This means rainfall will reach a stream later than if it only flowed overland. Soil continues to drain long after an event, so elevated stream flow lasts longer than if the rain all reached the stream overland.*

The publication notes that while tile impacts within the field or at the field edge are understood, extrapolating to the watershed scale increases uncertainty of the overall impact of tile drainage. The hydrology of a watershed involves complex variables that under certain circumstances tile may increase and at other times may moderate. With so many variables, the overall impact of agricultural drainage systems on watershed hydrology are site specific and vary greatly based on the interplay of six important factors as identified in the publication:

- ***Type of drainage.*** *For example, drainage ditches may increase the rate of overland flow, while subsurface tile may reduce the amount of overland flow in favor of subsurface flow.*
- ***Scale of impacts.*** *The hydrologic impact at the edge of a field may not add up to the same effect in a stream. Watershed-wide impacts on a stream are much more complex than field-edge impacts and vary with different runoff events.*
- ***Precipitation patterns.*** *The amount of water in the soil before a snowmelt or rain event will determine the downstream impact of a drainage system – the more water in the soil before an event, the more surface runoff and tile flow. The size of the event also matters. Even with drainage tile, a short, heavy rainfall will generate more runoff than the same amount of precipitation in several lighter events.*
- ***Field conditions.*** *The soil management practices in a tiled field will affect flow to the tile.*
- ***The rest of the watershed.*** *The impact of ditches and tile may be large or small relative to other influences on hydrology in the watershed including the amount of lakes, wetlands, and other water storage; the amount of impervious surfaces; channelization of streams; the presence of dams and culverts; and climatic patterns.*

- ***System design and landscape details.*** *The type of soil and the capacity of the system – determined by tile size, spacing, depth, and outlet characteristics – have known hydrologic effects. Sands and Canelon (2013) modeled significant variation in ET, water yield, and surface runoff depending on the type of soil, precipitation, and drain spacing and depth*.

Impervious surfaces are areas that covered by roads, roofs or other materials that prevent water from entering the soil profile. As the amount of impervious surfaces increase, both the quantity of stormwater and the speed at which the runoff arrives in the streams increases. Impervious surfaces also negatively affect rivers flows by not allowing the precipitation to soak into the soil profile to recharge ground water to supply river base flows. This results in lower low flow conditions. The DNR considers a watershed that has 4% or more impervious surfaces as being highly impacted. Impervious surfaces are prevalent in the eastern portions of the LMRW. Figure 17, adapted from the DNR WHAF, compares impervious areas from 2001 and 2011.

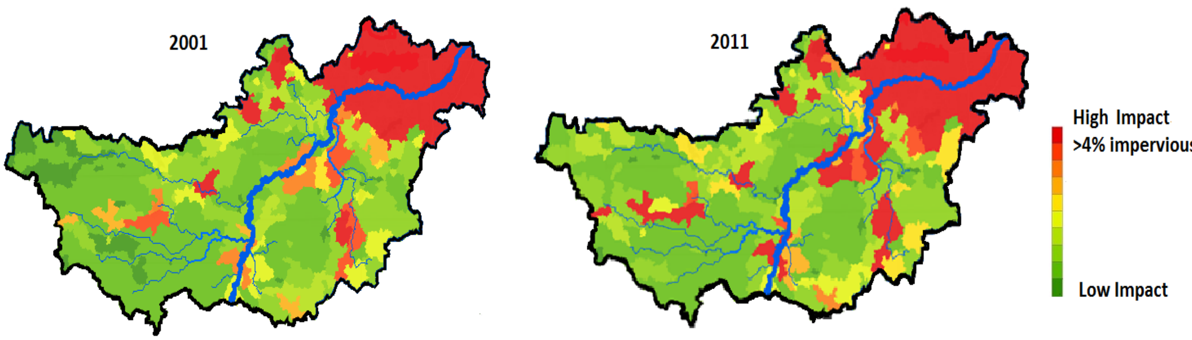


Figure 17 Changes in the impact of impervious surfaces between 2001 and 2011. The DNR considers a subwatershed with more than 4% impervious surface as being highly impacted. Figure adapted from the DNR WHAF.

Figure 18 and Table 3 identify areas within the LMRW that are affected by altered hydrology.

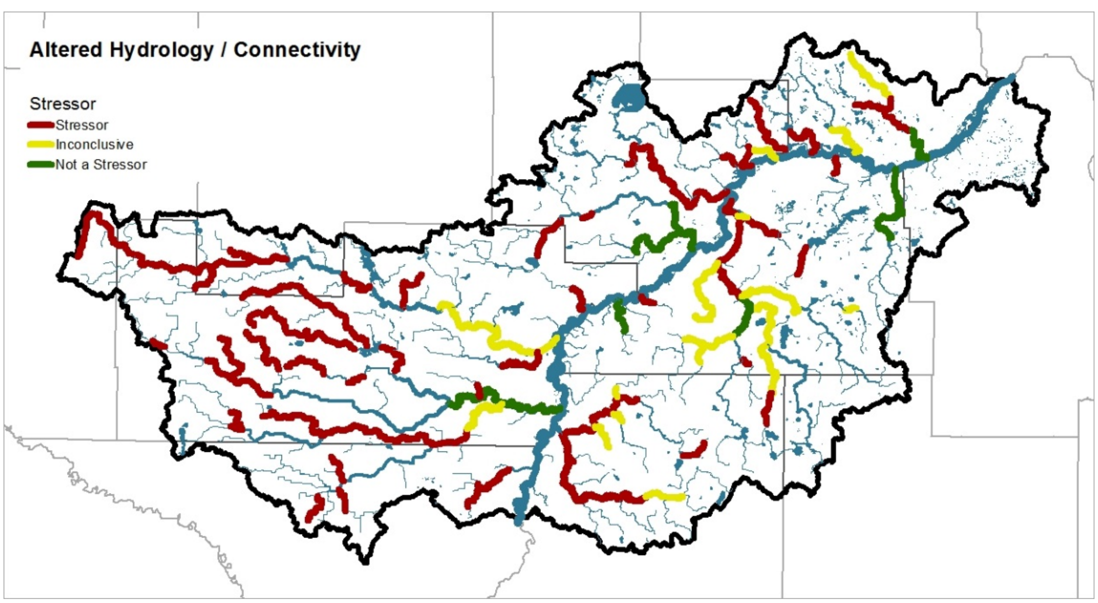


Figure 18 Locations where altered hydrology was identified as a stressor to aquatic life.

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

Connectivity

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

Connectivity was identified as conclusive stressor in 18 stream segments and as potential source in two other segments (Table 3). A Minnesota Department of Transportation (MnDOT) bridge and culvert inventory was completed in the LMRW. The DNR WHAF used this information along with dam locations to develop a connectivity index for the LMRW (Figure 19).

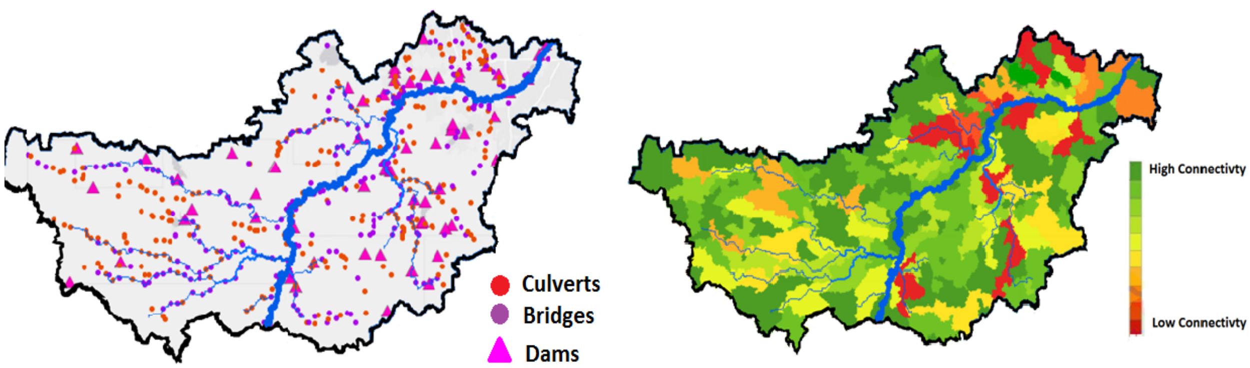


Figure 19 Culvert and dam locations on streams within the LMRW. DNR combined the locations of culverts and dams to develop a connectivity index for the LMRW. Maps developed utilizing DNR WHAF.

Habitat

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

Of the bio-impaired stream reaches, degraded habitat was identified as a stressor in 60, ruled out in 8, and inconclusive in 6 stream reaches. The habitat assessment results are illustrated in Figure 20. Assessment results show that generally, degraded habitat is stressing upstream and headwater reaches. The downstream reaches (closer to the Minnesota River) tend to have better habitat. Red indicates a stressor (habitat is problematic in that stream reach.

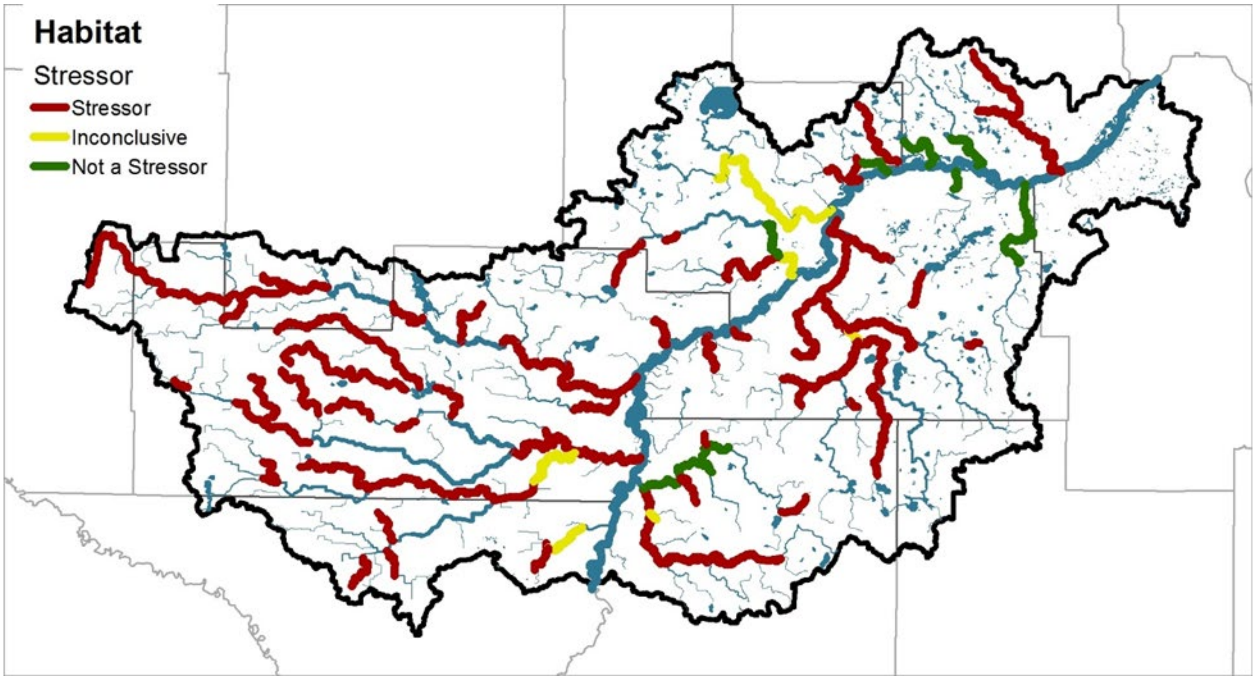


Figure 20 Locations where habitat was identified as a stressor or an impairment in the LMRW.

Dissolved Oxygen

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

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

DO was identified as conclusive stressor in 25 stream segments and as potential, inconclusive source in 25 other segments (Table 3 and Figure 21).

Because DO is primarily a response of other stressors, the practices used to address DO are the same practices as altered hydrology, phosphorus, and habitat.

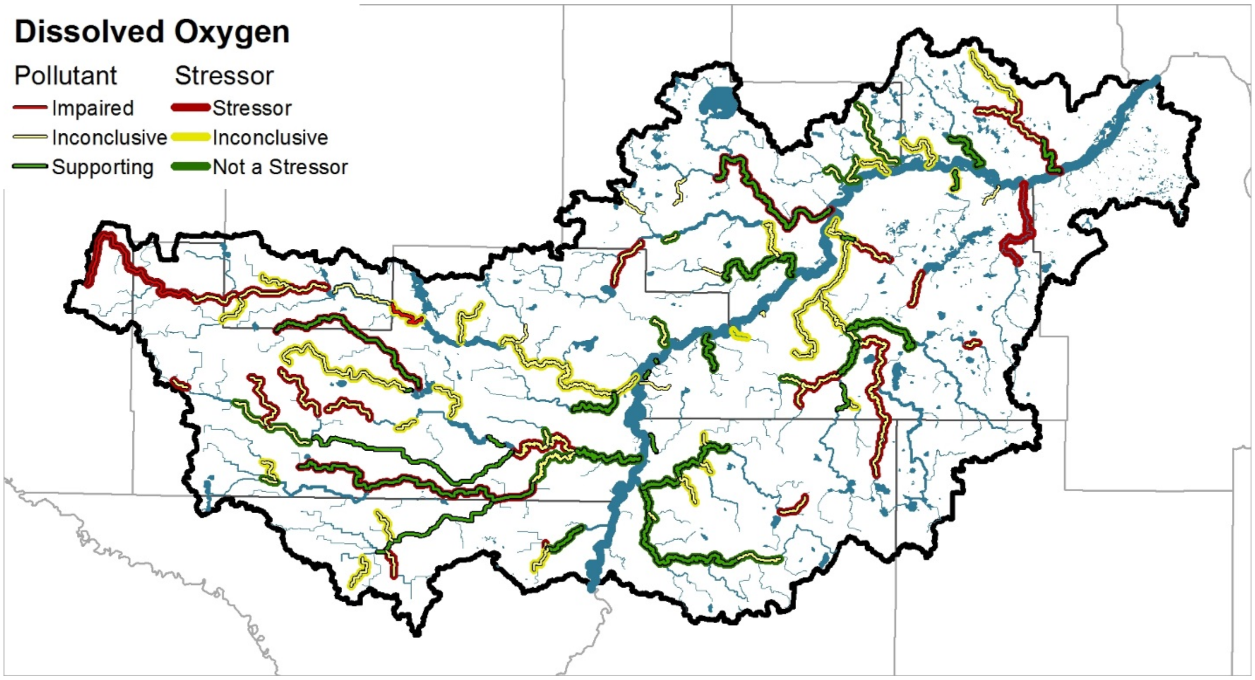


Figure 21 Locations where DO was identified as a stressor or an impairment in the LMRW.

Chloride

Low levels of chloride can be found naturally in the lakes and streams of the LMRW, and are essential for aquatic life. However, high concentrations of chloride is harmful to aquatic life as a result of a disruption in the cellular process called osmosis, which moves molecules, such as water, through cell membranes. Too much chloride in the surrounding water can cause water to leave the cell and also prohibit the transport of needed molecules into the cell. If elevated concentrations of chloride persist in the water, aquatic life become stressed and/or die.

Dissolved chloride also increases the density of water, which can negatively affect the seasonal mixing of lake waters (Novotny et al. 2008). The natural mixing of lakes increases oxygen levels required by aquatic life. Prevention of turnover can result in anoxia in the bottom of lakes and potential death of aquatic biota (Michigan DOT 1993). Changes in mixing can also affect nutrient cycling processes, phytoplankton community composition and productivity, zooplankton community composition and phenology, and fish through trophic cascades.

Winter maintenance of road surfaces currently relies heavily on the use of salt, primarily sodium chloride (NaCl), to prevent ice build-up and remove ice where it has formed. The dissolved chloride moves with the melted snow and ice, largely during warm-up events, and ends up in the water resources. Salt applied in winter for deicing in urban areas is a major source of chloride in the LMRW.

Residential water softener use is also a significant source of chloride. Residential water softeners use chloride to remove hardness, which is typically caused by high levels of calcium and/or magnesium. The use of residential water softeners, which use salt, are common in the LMRW. The chloride from water softeners makes its way to the environment either through discharge to a septic system or by delivery to a municipal WWTP. Chloride is not removed from wastewater using conventional treatment methods. Other less common sources chloride include fertilizer, namely muriate of potash, and animal manure.

Once chloride is in water, the only known technology for its removal is reverse osmosis through massive filtration plants, which is not economically feasible. Chloride will continue to accumulate in the environment over time unless flushed from the system. A study by the University of Minnesota found that about 78% of salt applied in the TCMA for winter maintenance is either transported to groundwater or remains in the local lakes, and wetlands (Stefan et al. 2008).

Chloride was identified as a conclusive stressor in one stream segment and a pollutant in seven other stream segments (Figure 22 and Table 3).

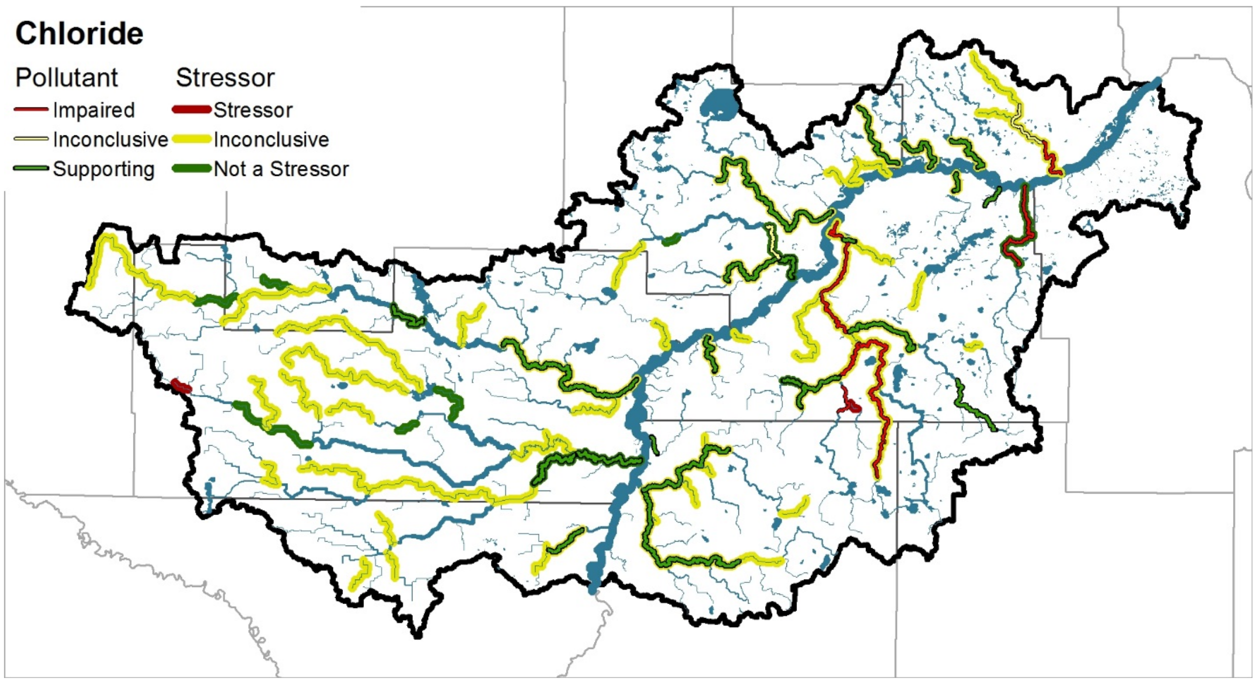


Figure 22 Locations where chloride was identified as a stressor or an impairment in the LMRW.

Table 3: Summary of stressors and probable sources identified in biologically-impaired stream reaches.

Stressor key: stressor; inconclusive; not a stressor **Source key*:** ● = suspected source; ○ = potential source; blank = not a source

HUC-10 Sub-watershed	WD / WMO / County	Stream (AUID)	Impairment type (Fish; Macroinvertebrates)	Dissolved Oxygen			Eutrophication			Nitrate	TSS				Chloride	Habitat					Connectivity				Altered Hydrology		
				Plant Respiration	Lack of flow	Unidentified	Lake influence	Excess Phosphorus	Algal/Plant Shift	Tile Drainage/Land Use	Suspended Algae	Flow Alteration/velocity	Streambank erosion	Channelization	Unidentified	Pasturing/Lack of Riparian	Channel Morphology	Bedded Sediment	Erosion	Habitat diversity	Flow Alteration/Connectivity	Dams/Impoundments	Road Crossings/Perched Culverts	Waterfalls/knickpoint (natural)	Altered Waters/Channelization	Reduced Baseflow	Tile Drainage/Land Use
Minnesota R	Carver WMO	Chaska Creek, US Hwy 212 to Creek Rd (-803)	F, M					○									●	●	●	○	●	●			●	●	
	LMRWD	Unnamed creek (Assumption Creek), Headwaters to Minnesota R (-582)	F	○				○	○																○		
		Unnamed creek (East Creek), Unnamed cr to Minnesota R (-581)	F, M					●	○		○	●	●	●		●	●	●	●	●					●	●	
	NMCWD	Nine Mile Creek, Headwaters to Metro Blvd (-807)	F	○				○	○								●	●	●	●					○	○	
		Nine Mile Creek, Metro Blvd to end of unnamed wetland (-808)	F, M	●	○			●	○							●	●	●		●	●				●	●	●
		Nine Mile Creek, Unnamed wetland to Minnesota R (-809)	F, M	●				●	●							●	○	●	●	●							
		Nine Mile Creek, South Fork, Smetana Lk to Nine Mile Cr (-723)	F, M	●			●	●	●								●	●							●	●	
	PLSLWD	Unnamed creek (County Ditch 13), Unnamed ditch to Spring Lk (-604)	F	●	○			●	●	○						●	●	●	●	●					●	●	●
		Unnamed creek (Prior Lake Outlet Channel), Dean Lk to Blue Lk (-728) †	F, M	●			●	●	●																●	●	
	RPBCWD	Bluff Creek, Headwaters to Rice Lk (-710)	F					●	●			●	●			●	●	●	●	●	●		●		●	●	
		Purgatory Creek, Staring Lk to Minnesota R (-828)	M					○													○	○					
		Riley Creek, Riley Lk to Minnesota R (-511)	F, M	○	○		○	○	○			○	●	○											○	●	
	Scott WMO	Credit River, -93.3526 44.7059 to Minnesota R (-811)	F, M	●				●	●																		
Sand Creek	Le Sueur	Sand Creek, T112 R23W S23, south line to -93.5454 44.5226 (-839)	F	●				●	●			●	●	●		●	●	●	●	●					●		●

HUC-10 Sub-watershed	WD / WMO / County	Stream (AUID)	Impairment type (Fish; Macroinvertebrates)	Dissolved Oxygen			Eutrophication			Nitrate	TSS				Chloride	Habitat					Connectivity				Altered Hydrology		
				Plant Respiration	Lack of flow	Unidentified	Lake influence	Excess Phosphorus	Algal/Plant Shift	Tile Drainage/Land Use	Suspended Algae	Flow Alteration/velocity	Streambank erosion	Channelization	Unidentified	Pasturing/Lack of Riparian	Channel Morphology	Bedded Sediment	Erosion	Habitat diversity	Flow Alteration/Connectivity	Dams/Impoundments	Road Crossings/Perched Culverts	Waterfalls/knickpoint (natural)	Altered Waters/Channelization	Reduced Baseflow	Tile Drainage/Land Use
	Scott WMO	County Ditch 10, CD 3 to Raven Str (-628)	M					●	○	●						●	●	●	○	●					●		○
		Porter Creek, Langford Rd/MN Hwy 13 to Sand Cr (-817)	F, M					●	○		●		●			○		●	●	○					○		○
		Raven Stream, E Br Raven Str to Sand Cr (-716)	F, M					●	●	●	○	○	●			○	○	●	●	○							
		Raven Stream, West Branch, 270th St to E Br Raven Str (-842)	F, M	●				●	●	●						○	●	●	●	●					●	○	●
		Sand Creek, Porter Cr to Minnesota R (-513)	F, M	●				●	●			●	●	○		●	●	●	●	○	●	●			●		
		Sand Creek, Raven Str to Porter Cr (-538)	F					●	○			●	●	○			○	○		○							
		Sand Creek, -93.5454 44.5226 to Raven Str (-840)	F, M	●				●	●			○	●	○		●	●	●	●	●					○		
		Unnamed creek, Headwaters to Sand Cr (-732)	F, M	○				●	●	○			○					●	○	●							○
		Unnamed creek, RR bridge to E Br Raven Str (-822)	F, M	○				●	○	○						○	○	●	●	●					●		●
		Unnamed creek, Unnamed ditch to -93.4251 44.6206 (-849)	F	○	●			●	○	○		○	○	○		○	●	●	●	●					●	●	○
		Picha Creek, Unnamed cr to Unnamed cr (-579)	F, M	●				●	●							●	○	●	●	○	○		●		○	○	
		Picha Creek, Unnamed cr to Sand Cr (-580)	F	○				●	○								○	●	○	●					○	○	
City of Belle Plain-Minn R	Scott WMO	Robert Creek, Unnamed cr to Unnamed cr (at Belle Plaine Sewage Ponds) (-575)	F, M					●	●	○		○	●	○				●	●	●							
		Unnamed creek (Brewery Creek), US Hwy 169 to Minnesota R (-830)	F, M	○				●	○							●	●	●	●	○	○		●		○		
	Sibley	Unnamed creek, Unnamed cr to Minnesota R (-798)	F, M					●	○	○							●	●	●	●	○				○	●	○
Carver Creek	Carver WMO	Carver Creek, MN Hwy 284 to Minnesota R (-806)	F, M	●				●	●		●	●				○		○			●				●		○

HUC-10 Sub-watershed	WD / WMO / County	Stream (AUID)	Impairment type (Fish; Macroinvertebrates)	Dissolved Oxygen			Eutrophication			Nitrate	TSS				Chloride	Habitat					Connectivity				Altered Hydrology		
				Plant Respiration	Lack of flow	Unidentified	Lake influence	Excess Phosphorus	Algal/Plant Shift	Tile Drainage/Land Use	Suspended Algae	Flow Alteration/velocity	Streambank erosion	Channelization	Unidentified	Pasturing/Lack of Riparian	Channel Morphology	Bedded Sediment	Erosion	Habitat diversity	Flow Alteration/Connectivity	Dams/Impoundments	Road Crossings/Perched Culverts	Waterfalls/knickpoint (natural)	Altered Waters/Channelization	Reduced Baseflow	Tile Drainage/Land Use
Bevens Creek	Carver WMO	Bevens Creek, Silver Cr to Minnesota R (-514)	F, M					●	●	○		○	●	○				●	●	○							
		Bevens Creek, -93.8615 44.7265 to -93.8455 44.7327 (-845)	F					●	●			●	●	●		●	●	●	●	●					●		●
		Bevens Creek, -93.7156 44.7438 to Silver Cr (-848)	F, M	○				●	○			○	●	○													
		Silver Creek, -93.769 44.687 to Bevens Cr (-813)	F, M					●	○	●			●	○		○	●	●	●	●							
	Sibley	Bevens Creek, Headwaters (Washington Lk 72-0017-00) to 154th St (-843)	M	●	●			●	●			●	●	●		●	●	●	○	●					●	●	●
Le Sueur Creek	Le Sueur	County Ditch 34, Unnamed ditch to Forest Prairie Cr (-764)	F, M	○	○			○	○																○	●	●
		County Ditch 42, School Lk to Clear Lk outlet (-772)	F, M	○	●			○	○			●	●	●		●	●	●	●	●	●		●		●	●	●
		Forest Prairie Creek, CD 29 to Le Sueur Cr (-725)	F, M					●	○	○												●	●				○
		Judicial Ditch 4, Unnamed ditch to Forest Prairie Cr (-767)	F	○	○			○	○	●		●	○	●		●	●	●	○	●					●		●
		Le Sueur Creek, CD 23 to W Prairie St (-823)	F					●	●	○	●	●	●	●		●	●	●	○	●					●		●
		Le Sueur Creek, W Prairie St to Forest Prairie Cr (-824)	F, M					●	○	●						○	●	●	●	●	○	●	●		●	●	●
		Unnamed creek, CD 56 to Le Sueur Cr (-768)	F, M					○	○	○							○	○			●		●		●		○
		Unnamed ditch, Unnamed ditch to Forest Prairie Cr (-763)	F, M	○	○			●	○	●		○	○	○		●	●	●	●	●	○				○	●	○
	Nicollet	Barney Fry Creek, CD 47A to CD 35 (-602)	F, M					●	○										●						○	○	○
		County Ditch 47A, Unnamed ditch to CD 75 (-792)	F	●	○			●	●	●	○	●	●	●		●	●	●	●	●					●	○	●
		County Ditch 75, Unnamed ditch to CD 47A (-793)	F	●	○			●	●	●	○	●	○	●		●	●	●	●	●	●		●		●	●	○

HUC-10 Sub-watershed	WD / WMO / County	Stream (AUID)	Impairment type (Fish; Macroinvertebrates)	Dissolved Oxygen			Eutrophication			Nitrate	TSS				Chloride	Habitat					Connectivity				Altered Hydrology		
				Plant Respiration	Lack of flow	Unidentified	Lake influence	Excess Phosphorus	Algal/Plant Shift	Tile Drainage/Land Use	Suspended Algae	Flow Alteration/velocity	Streambank erosion	Channelization	Unidentified	Pasturing/Lack of Riparian	Channel Morphology	Bedded Sediment	Erosion	Habitat diversity	Flow Alteration/Connectivity	Dams/Impoundments	Road Crossings/Perched Culverts	Waterfalls/knickpoint (natural)	Altered Waters/Channelization	Reduced Baseflow	Tile Drainage/Land Use
High Island Creek	High Island WD	Buffalo Creek, 276th St /Co Rd 65 to High Island Cr (-832)	F, M					●		○			●				●	●	●	●	○		●		○	●	○
		County Ditch 39, Unnamed ditch to High Island Cr (-683)	M	○	●			○	○	●		●	○	●		●	●	●		●					●	●	●
		High Island Creek, JD 15 to Bakers Lk (-653)	F, M	●				●	●	●	●	●	●	●		●	●	●	●	●					●	●	●
		High Island Creek, -94.0936 44.6181 to Minnesota R (-834)	F, M	●				●	●	●	●	●	●	●			●	●	●								
		High Island Creek, -94.2538 44.6574 to Unnamed cr (-838)	F, M	●				●	●	●		●	●				●	●	●	●					●	●	○
		Judicial Ditch 11, CD 103 to CD 10 (-590)	F	●	○			●	●	●	○	●		●		●	●	●		●					●	●	●
		Judicial Ditch 11, CD 10 to JD 24 (-593)	F, M	○	○			●		●		●	●	●		●	●	●	●	●					●	●	●
		Judicial Ditch 12, Headwaters to High Island Creek (-794)	F	○	●			●		○		●	●	●		●	●	●	●	●					●	●	●
		Judicial Ditch 15, CD 31 to High Island Cr (-682)	F, M	●	○			●	●	●		●	○	●		●	●	●	○	●	●				●	●	●
North Branch Rush R	Sibley	County Ditch 18, Headwaters to CD 40 (-791)	F	○	○			●		●		●	●	●		●	●	●	●	●	●		○		●	●	●
		Rush River, North Branch (CD 55), Titlow Lk to T113 R28W S35, south line (-556)	F, M	○	○			●	●		●	●	●	●		●	●	●	●	●					●	●	●
		Rush River, North Branch (Judicial Ditch 18), Headwaters to Titlow Lk (-555)	F, M	●				●	●	●	●	●	●	●		●	●	●	●	●					○	●	●
Middle Branch Rush R	Sibley	County Ditch 42, Headwaters to T113 R29W S31, south line (-551)	M	●				●	●	●						●	●	●	●	●					●	●	●
		County Ditch 44, Headwaters to M Br Rush R (-786)	F, M	○				●	○	●		●		●		●	●	●		●	●				●	●	●
		County Ditch 49, Unnamed ditch to CD 22 (-677)	F, M	●	○			●	●	●					●	●	●	●	●	●					●	●	●
		County Ditch 50, Co Rd 62 to Rush R (-796)	F, M					●	○	○		○	●	○		○		●	●	○	○				○	●	○

HUC-10 Sub-watershed	WD / WMO / County	Stream (AUID)	Impairment type (Fish; Macroinvertebrates)	Dissolved Oxygen			Eutrophication			Nitrate	TSS				Chloride	Habitat					Connectivity				Altered Hydrology		
				Plant Respiration	Lack of flow	Unidentified	Lake influence	Excess Phosphorus	Algal/Plant Shift	Tile Drainage/Land Use	Suspended Algae	Flow Alteration/velocity	Streambank erosion	Channelization	Unidentified	Pasturing/Lack of Riparian	Channel Morphology	Bedded Sediment	Erosion	Habitat diversity	Flow Alteration/Connectivity	Dams/Impoundments	Road Crossings/Perched Culverts	Waterfalls/knickpoint (natural)	Altered Waters/Channelization	Reduced Baseflow	Tile Drainage/Land Use
		County Ditch 56, Headwaters to Unnamed ditch (-790)	M	○		●		●	○	●		○	○	○		●	●	●	●	●					●	●	●
		Rush River, S Br Rush R to Minnesota R (-521)	F					●	●	○		○	●	○		○	●	●	●	○							
		Rush River, M Br Rush R to S Br Rush R (-548)	F, M			●		●	○	○		○	●	○		○	●	●	●	○							
		Rush River, Middle Branch (CD 23/24), Unnamed ditch to T112 R30W S13, east line (-586)	F, M					●	●	●						●	●	●	●	●					●	●	●
		Unnamed ditch, Unnamed ditch to Unnamed ditch (-788)	M	○	○			○	○	●		●	●	●		●	●	●	●	●					●	●	●
South Branch Rush R	Nicollet	County Ditch 30A, Unnamed ditch to JD 1A (-801)	F, M	●				●	●	●	●	●	○	●		●	●	●	○	●					●	●	●
		County Ditch 32A, CD 32 to Unnamed ditch (-783)	F, M	○	○			○	○	●						●	●	●	●	●					●	●	●
		County Ditch 9, Unnamed ditch to JD 1A (-784)	F	○				○	○	●		●	○	●		●	●	●	○	●					●	●	●
	Sibley	County Ditch 13, Unnamed ditch to JD 1 (-636)	M	●	●			●	●	●		●	●	●		●	●	●	●	●					●	●	●
		Judicial Ditch 1, CD 4A to CD 13 (-785)	M					●	○	●		●	○	●		●	●	●	○	●					●	●	●
		Rush River, South Branch, Unnamed ditch to -94.0478 44.4761 (-825)	F, M	○				●	○	●		●	●	●		●	●	●	●	●					●	○	●
		Rush River, South Branch, -94.0478 44.4761 to Rush R (-826)	F, M					●	○	○		○	●	○		○		○	●						○		

*Additional sources evaluated/considered but not identified for any impairments included: For dissolved oxygen—wetland influence; for eutrophication—wetland influence; for nitrate—wetland/lake influence, wastewater dischargers; for TSS—urbanization, pasture; and for connectivity—beaver dams.

†For this reach (-728) PLSLWD questions eutrophication as a stressor based on their monitoring and observations.

Stressors of biologically-impaired lakes

The report *Lower Minnesota River Watershed Lakes Stressor Identification Report* (DNR 2017) provides the full results for the evaluation of the lakes. A summary of the results for the impaired lakes is provided in Table 4 below. The report notes that *"the rankings for each stressor are independent of each other and represent the relative likelihood that a particular stressor is impacting the fish community in a given lake."* The numbers in parentheses in the table are intended to further distinguish suggested priorities among the rankings, particularly where the ranking descriptors are the same.

It should be further noted that some of the lakes (Waconia, Bryant, and O'Dowd) show excess nutrients as a "moderate (1)" ranking, yet are meeting their nutrient standard for aquatic recreation. This points out that acceptable nutrient levels for aquatic recreation vs. aquatic life needs are not the same. However, there has been no research or study into what the target level of nutrients needs to be for full aquatic life support in these lakes and, therefore, without such a target it is not possible to do an aquatic life-based nutrient TMDL for these lakes.

Table 4: Summary of candidate stressors for lakes with biological impairments to lake fish communities.

		Stressor Likelihood Ranking		
Lake	Lake ID	Excess Nutrients	Non-native Aquatic Species	Riparian Lakeshore Development
Riley	10-0002-00	High (1)	Moderate (3)	Moderate (2)
Lotus	10-0006-00	High (1)	Moderate (3)	Moderate (2)
Bavaria	10-0019-00	Low (3)	Moderate (2)	Moderate (1)
Waconia	10-0059-00	Moderate (1)	Moderate (3)	Moderate (2)
Bryant	27-0067-00	Moderate (1)	Moderate (3)	Moderate (2)
Lower Prior	70-0026-00	Low (3)	High (2)	High (1)
Spring	70-0054-00	High (1)	Low (3)	High (2)
O'Dowd	70-0095-00	Moderate (1)	Low (3)	Low (2)

Pollutant sources

Municipal and Industrial Wastewater

Table 5 and Table 6 list the permitted municipal/industrial wastewater dischargers and MS4s, respectively, that receive wasteload allocations (WLAs) in TMDLs conducted in the LMR TMDL reports (parts I, II, and III only). It should be noted that for TSS and *E. coli,* wastewater facilities operating in compliance with their permits typically discharge at concentrations below these parameters' water quality standards. Thus, they deliver only minimal loading of these pollutants.

Permitted industrial stormwater facilities and sites subject to construction stormwater permits also can contribute pollutant loading.

Table 5: Permitted wastewater dischargers that receive wasteload allocations in LMR TMDL reports Parts I, II and III.

		Impairment type		
Wastewater Facility (NPDES Permit #)	Impairment (AUID)	TP	TSS	*E. coli*
Altona Hutterian Brethren WWTP (MN0067610)	Rush River (521)		✓	
Arlington WWTP (MN0020834)	High Island Creek (834)		✓	
Belle Plaine WWTP (MN0022772)	Robert Creek (575)		✓	✓
Bongards' Creameries Inc (MN0002135)	Unnamed ditch (565)			✓
Cologne WWTP (MN0023108)	Unnamed creek (568)			✓

Wastewater Facility (NPDES Permit #)	Impairment (AUID)	Impairment type		
		TP	TSS	*E. coli*
Dairy Farmers of America Inc–Winthrop (MN0003671)	Rush River (521), Rush River (548)		✓	
Eden Prairie well houses (MNG250084)	Staring Lake	✓		
Gaylord WWTP (MNG580204)	Rush River (521), Rush River (548), Rush River, North Branch (County Ditch 55; 558)		✓	✓
Gibbon WWTP (MNG580020)	Rush River (521)		✓	
Hamburg WWTP (MN0062308)	Bevens Creek (843)	✓		
Jordan WWTP (MN0020869)	Sand Creek (513)	✓	✓	✓
Lafayette WWTP (MN0023876)	Judicial Ditch 1A (509), Rush River (521)		✓	✓
Laketown Community WWTP (MN0054399)	Chaska Creek (804), Gaystock Lake	✓		✓
Le Center WWTP (MN0023931)	Le Sueur Creek (824)			✓
LifeCore Biomedical LLC (MN0060747)	Unnamed creek (East Creek; 581), McKnight Lake	✓	✓	
McLaughlin Gormley King Co (MN00558033)	Unnamed creek (East Creek; 581), Hazeltine Lake	✓	✓	
MG Waldbaum Co (MN0060798)	Rush River (521), Rush River (548), Rush River, North Branch (County Ditch 55; 558)		✓	✓
Montgomery WWTP (MN0024210)	Sand Creek (513), Sand Creek (538), Sand Creek (839), Sand Creek (840)	✓	✓	✓
New Prague Utilities Commission (MNG640117)	Sand Creek (513), Sand Creek (538)	✓	✓	
New Prague WWTP (MN0020150)	Sand Creek (513), Sand Creek (538), Raven Stream (716)	✓	✓	✓
Norwood Young America WWTP (MN0024392)	Unnamed ditch (533), Bevens Creek (848)			✓
Seneca Foods Corp–Arlington (MN0000264)	High Island Creek (834)		✓	
Seneca Foods Corp–Montgomery (MN0001279)	Sand Creek (513), Sand Creek (538), Sand Creek (839), Sand Creek (840)	✓	✓	
Starland Hutterian Brethren Inc (MN0067334)	Rush River (521), Rush River (548), Rush River, Middle Branch (County Ditch 23 and 24; 550)		✓	✓
Winthrop WWTP (MN0051098)	Rush River (521), Rush River (548), Rush River, Middle Branch (County Ditch 23 and 24; 550)		✓	✓

Table 6: Permitted MS4s that receive wasteload allocations in LMR TMDL reports Parts I, II and III.

MS4 Name (Permit #)	Impairment (AUID)	Impairment type				
		Lake P	Stream P	TSS	*E. coli*	Chloride
Bloomington City (MS400005)	Hyland Lake, Penn Lake, Nine Mile Creek (809), Purgatory Creek (828)	✓			✓	✓
Burnsville City (MS400076)	Credit River (811)				✓	✓
Carver City (MS400077)	Unnamed creek (528), Chaska Creek (804), Carver Creek (806)		✓		✓	
Carver County (MS400070)	Unnamed creek (528), Unnamed Creek (East Creek; 581), Chaska Creek (804), Carver Creek (806), Hazeltine Lake, McKnight Lake, Jonathan Lake, Lotus Lake, Lake Lucy, Lake Susan, Riley Lake	✓	✓	✓	✓	
Chanhassen City (MS400079)	Unnamed Creek (East Creek; 581), Hazeltine Lake, McKnight Lake, Silver Lake, Lotus Lake, Staring Lake, Lake Lucy, Lake Susan, Riley Lake, Rice Marsh Lake	✓		✓	✓	
Chaska City (MS400080)	Unnamed creek (528), Unnamed Creek (East Creek; 581), Chaska Creek (804), Hazeltine Lake, McKnight Lake, Jonathan Lake, Lake Grace	✓		✓	✓	
Credit River Township (MS400131)	Credit River (811), Cleary Lake (70-0022-00)	✓			✓	✓
Dakota County (MS400132)	Credit River (811)				✓	✓
Deephaven City (MS400013)	Staring Lake	✓				
Eden Prairie City (MS400015)	Riley Creek (511), Purgatory Creek (828), Lotus Lake, Staring Lake, Riley Lake, Rice Marsh Lake	✓		✓	✓	
Edina City (MS400016)	North Cornelia Lake, South Cornelia Lake, Lake Edina	✓				
Elko New Market City (MS400237)	Sand Creek (513), Porter Creek (815), Porter Creek (817), Lake St. Catherine (70-0029-00)	✓	✓	✓	✓	
Hennepin County (MS400138)	Riley Creek (511), Nine Mile Creek (809), Purgatory Creek (828), Staring Lake, Riley Lake, Hyland Lake, Penn Lake, Wing Lake, Lake Rose, North Cornelia Lake	✓		✓	✓	

MS4 Name (Permit #)	Impairment (AUID)	Impairment type				
		Lake P	Stream P	TSS	*E. coli*	Chloride
Hennepin Technical College (MS400199)	Staring Lake, Purgatory Creek (828)	✓			✓	
Laketown Township (MS400142)	Unnamed ditch (527), Unnamed Creek (East Creek; 581), Unnamed creek (621), Chaska Creek (804), Carver Creek (806), Gaystock Lake	✓	✓	✓	✓	
Lakeville City (MS400099)	Credit River (811)				✓	✓
Louisville Township (MS400144)	Sand Creek (513), Thole Lake (70-0120-01)	✓	✓	✓	✓	
Minnetonka City (MS400035)	Staring Lake, Wing Lake, Lake Rose	✓				
Minnetrista City (MS400106)	Unnamed ditch (527), Unnamed creek (Lake Waconia Inlet; 619), Carver Creek (806)		✓		✓	
MnDOT Metro (MS400170)	Eagle Creek (519), Unnamed Creek (East Creek; 581), Chaska Creek (804), Credit River (811), Nine Mile Creek (809), Purgatory Creek (828), Hazeltine Lake, Jonathan Lake, Lotus Lake, Staring Lake, Lake Susan, Riley Lake, Rice Marsh Lake, Penn Lake, North Cornelia Lake, Lake Edina	✓		✓	✓	✓
Prior Lake City (MS400113)	Sand Creek (513), Eagle Creek (519), Credit River (811), Cleary Lake (70-0022-00), Pike Lake (70-0076)	✓	✓	✓	✓	✓
Prior Lake–Spring Lake Watershed District (MS400189)	Pike Lake (70-0076)	✓				
Richfield City (MS400045)	Penn Lake, North Cornelia Lake	✓				
Savage City (MS400119)	Eagle Creek (519)				✓	
Scott County (MS400154)	Eagle Creek (519), Credit River (811), Cleary Lake (70-0022-00), Pike Lake (70-0076)	✓			✓	✓
Shakopee City (MS400120)	Sand Creek (513), Eagle Creek (519)		✓	✓	✓	
Shorewood City (MS400122)	Silver Lake, Staring Lake	✓				
Spring Lake Township (MS400156)	Credit River (811), Cleary Lake (70-0022-00)	✓			✓	✓
Victoria City (MS400126)	Unnamed Creek (East Creek; 581)	✓		✓	✓	
Waconia City (MS400232)	Unnamed ditch (527), Unnamed creek (621), Carver Creek (806)		✓		✓	

Required reporting by permitted sources allows the MPCA to evaluate permit compliance of facilities and trends in pollution reduction from permitted facilities. Since 2000 significant improvements have been realized in phosphorus loading by WWTF in the LMRW. Upgrades and improvements in WWTF have reduced the phosphorus loading from a high of 138,422 kg per year in 2001 to 50,331 kg in 2018 (Figure 23). The majority of the reductions were realized in improvements from two facilities, Met Council – Blue Lake WWTP and Met Council – Seneca WWTP, but other facilities have also shown reductions. TSS and total nitrogen loading from permitted facilities has remained fairly constant since 2000. Municipal and industrial sources, overall, are minor sources for phosphorus, nitrogen and sediment. These facilities contribute 1% for sediment, 1.6% for nitrogen, and 5.1% for phosphorus of the total loads of the LMRW. While these amounts are minor they may have significant influence in low flow conditions.

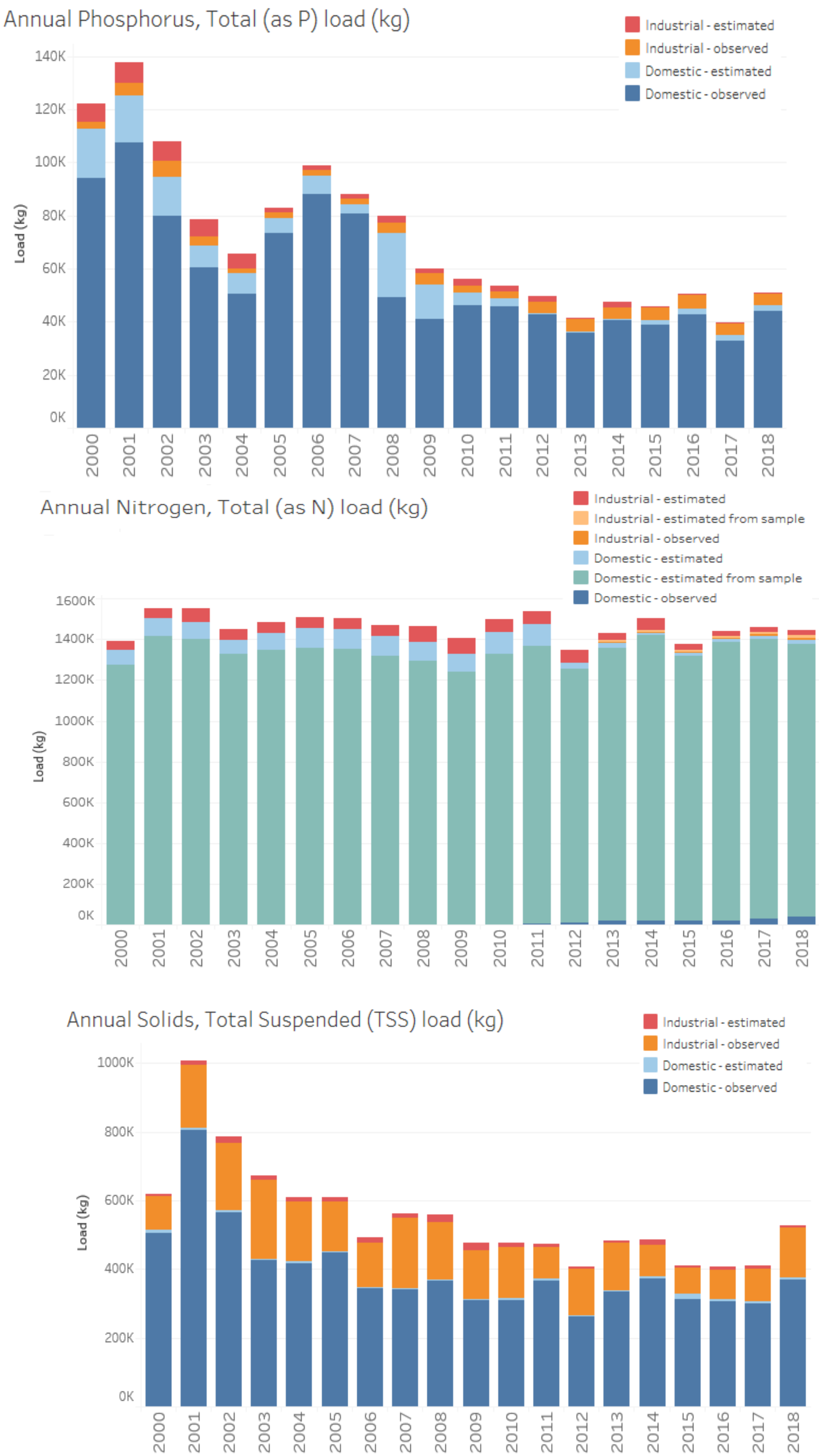


Figure 23 Annual phosphorus, nitrogen and TSS loading to the LMRW from industrial and municipal facilities

Feedlots

Manure contains high concentrations of phosphorus, nitrogen, and bacteria that can run off into lakes and streams when not properly managed. Of the 434 feedlots in the LMRW, there are 36 Concentrated Animal Feeding Operations (CAFOs). Of the 36 CAFOs, 27 are swine facilities, 4 are chicken facilities, 2 are dairy, 2 are cattle and 1 horse facility (Figure 24). The MPCA currently uses the federal definition of a CAFO in its regulation of animal feedlots. In Minnesota, the following types of livestock facilities are issued, and must operate under, a NPDES Permit: a) all federally defined CAFOs, some of which are under 1000 animal units (AUs) in size; and b) all CAFOs and non-CAFOs which have 1000 or more AUs. These feedlots must be designed to totally contain runoff, and manure management planning requirements are more stringent than for smaller feedlots. In accordance with the state of Minnesota's agreement with EPA, CAFOs with state-issued General NPDES Permits must be inspected twice during every five-year permitting cycle and CAFOs with state issued Individual NPDES Permits are inspected annually.

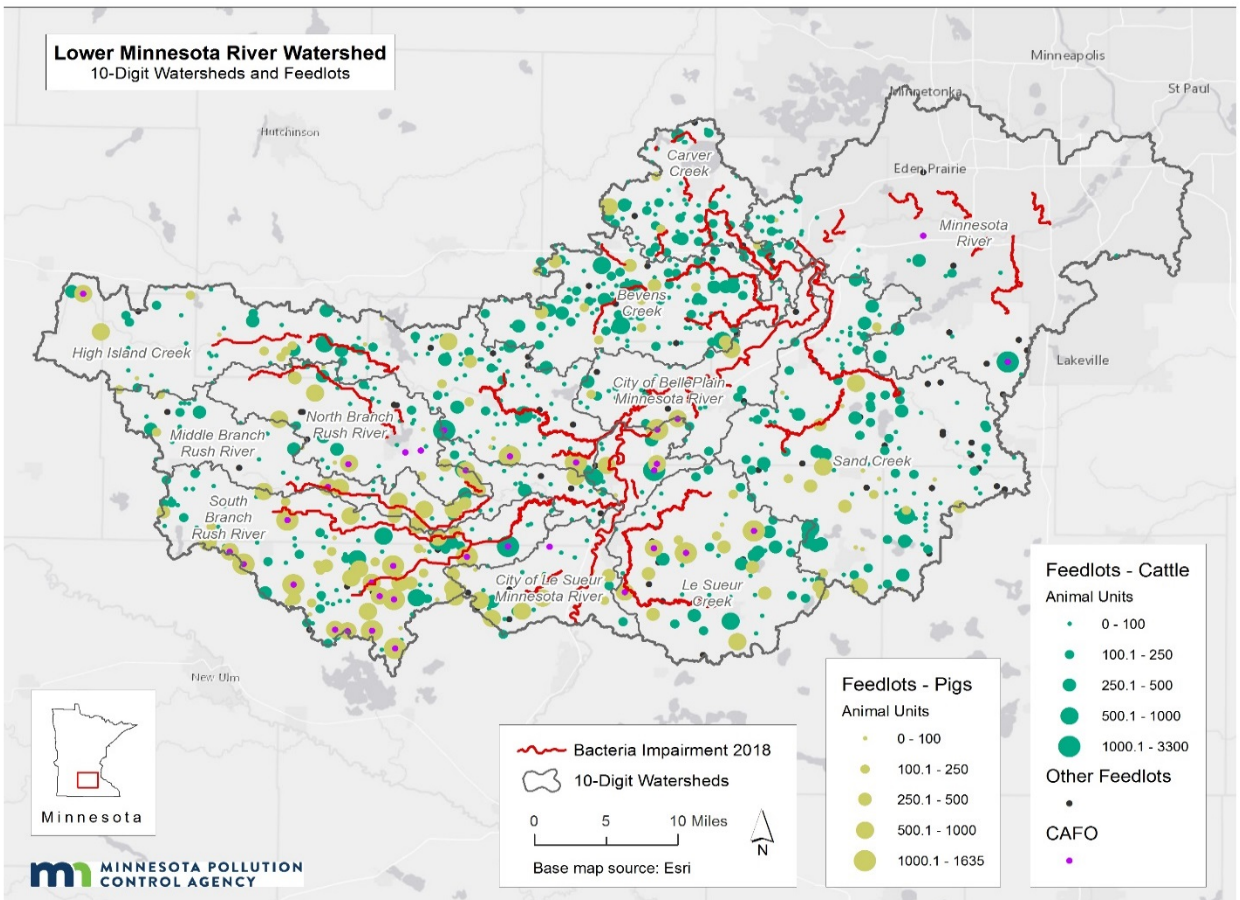


Figure 24 Feedlot locations in the LMRW

While feedlot sites, themselves, are not generally a significant source of pollution in the LMRW, local impacts to water resources in the LMRW could in some cases be significant. Data indicate that there are 57 feedlots located in shoreland (within 1,000 feet of a lake or 300 feet of a river/stream). Of the 57 feedlots in shoreland, 48 have open lots as part of the facility. Feedlots in shoreland with an open lot should be a priority for feedlot inspections, and feedlot fixes if necessary, as they present the highest potential for runoff pollution.

The LMRW has a diverse livestock population. Swine are approximately 42% of the 134,222 AUs in the LMRW. Swine manure is generally applied as liquid manure that is injected or immediately incorporated. Properly injected/incorporated manure presents a lower risk for runoff containing phosphorus and bacteria. Bovine, both dairy and cattle, make up 43% of the AUs. Poultry (13%) and horses (2%) make up the majority of the remaining AUs in the LMRW. Generally, these types of manure are handled as solid manure and additional steps are needed in the application process to ensure the manure is incorporated.

The LMRW has a 108 dairy facilities, of which 93 facilities are less than 300 AU. Many small dairies have limited manure storage, requiring frequent manure application. The LMRW also has four large chicken facilities with limited manure storage that also require frequent manure application. Solid manure left on the surface and not incorporated into the soil prior to a rainfall or a runoff event presents an elevated risk for contaminated runoff. Winter application of manure presents a higher risk for contaminated runoff. Discovery Farms programs of Wisconsin and Minnesota have estimated that late winter, February and March timeframe manure application can increase phosphorus loss in snowmelt by two to four times when compared to early winter applications (Discovery Farms 2019). One study completed by Discovery Farms Wisconsin provides a visual picture of the difference between early and late winter application of manure from two adjacent fields with similar slope and tillage practices (Figure 25). One field (bottom) only had manure applied in November while the other field (top) had manure applied in February.

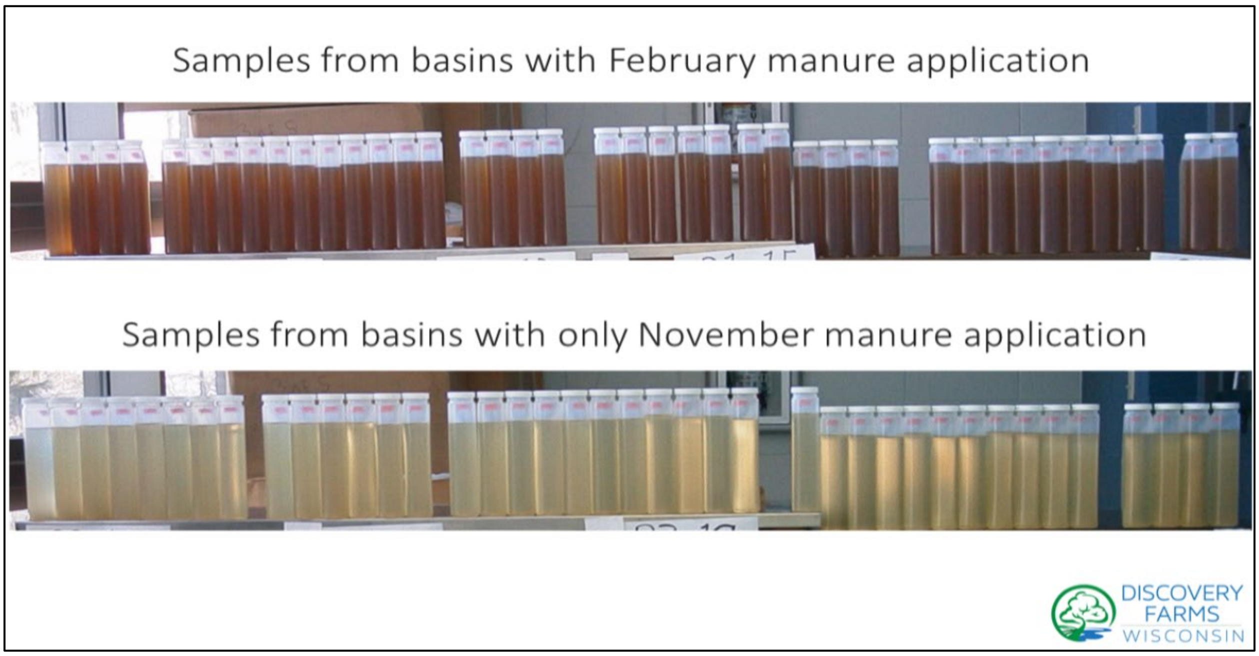


Figure 25 Comparison of runoff when manure is applied in early and late winter (photo from Discovery Farms Wisconsin).

The Minnesota Department of Agriculture (MDA) has recently developed an interactive model to assist livestock producers to evaluate the potential runoff risk for manure applications, based on weather forecasts for temperature and precipitation along with soil moisture content. The model can be customized to specific locations. It is advised that all producers applying manure utilize the model to determine the runoff risk, and use caution when the risk is "medium" and avoid manure application during "high" risk times. For more information and to sign up for runoff risk alerts from the MDA Runoff Risk Advisory Forecast, please see the MDA website.

Septic Systems

Septic systems that are not maintained or failing can contribute excess phosphorus, N, and bacteria. The MPCA collects data yearly from local government units on subsurface sewage treatment systems (SSTS). Estimations are made on the number of: total SSTS systems, the number of compliant systems, number of systems failing to protect ground water (failing) and the number of imminent public health threats (IPHT), which may include straight pipes. Data is reported only to the county level, or to the township level if the township has elected jurisdiction, so data specific to the LMRW is not available. Without site-specific data, it is difficult to provide SSTS data specific to the LMRW. However, using overall county data could indicate potential SSTS compliance percentages within the watershed. Figure 26 provides countywide estimates for SSTS compliance for counties in the LMRW.

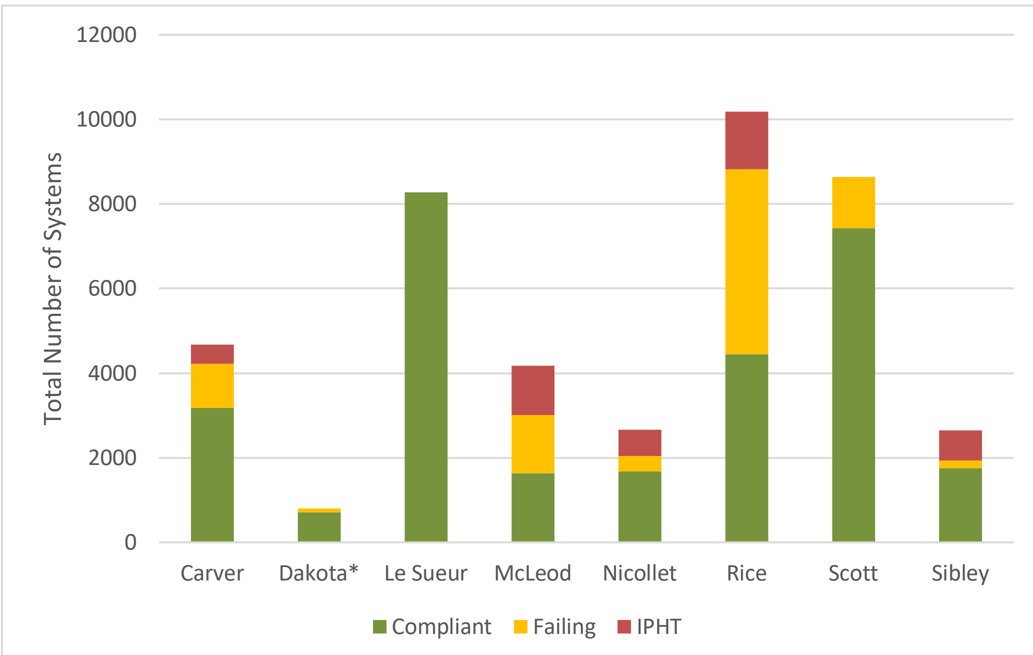


Figure 26 Number of SSTS that are compliant, failing or IPHT by county. Many local government units in Dakota County have jurisdiction over SSTS regulations, therefore a better estimate of systems within the LMRW could be made instead of just providing county wide estimates.

On average, the counties in the LMRW inspect 1.5% to 6.5% of the SSTS yearly within their respective counties. Even though there is potentially a significant number of failing and IPHT systems in the LMRW, they are unlikely to contribute substantial amounts of pollutants and stressors to the total annual loads in the LMRW, when compared to other sources. However, the impacts of failing SSTS on water quality may be pronounced in areas with high concentrations of failing SSTS or at times of low precipitation and/or flow. A watershed-wide SSTS inventory with compliance inspections would help quantify the potential impact SSTS have on the LMRW. Progress on replacing failing and IPHT systems is occurring within the counties of the LMRW. Since 2009, on average 475 systems are replaced or repaired each year within the eight reporting counties (Figure 27).

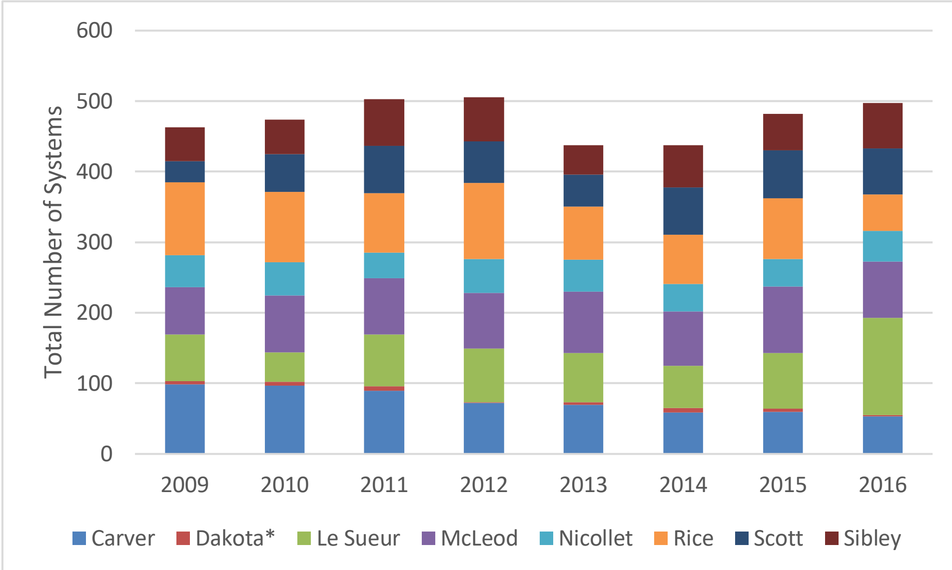


Figure 27 Number of SSTS systems replaced within each county between 2009 and 2016.

Undersewered/Unsewered Communities

Undersewered/Unsewered Community is defined as a cluster of five or more houses or business that are within a half-mile radius that have inadequate wastewater treatment or unknown method of treatment. This may range from a community having failing individual systems to small cities with inadequate collection and treatment infrastructure. Through surveys of counties in 2008 and 2014 and utilizing the 2010 U.S. census information, the MPCA has identified 41 communities, which were considered undersewered/unsewered in the LMRW (Figure 28). The identified communities are at various stages of becoming "sewered" and continued local support is needed to ensure the completion of the projects.

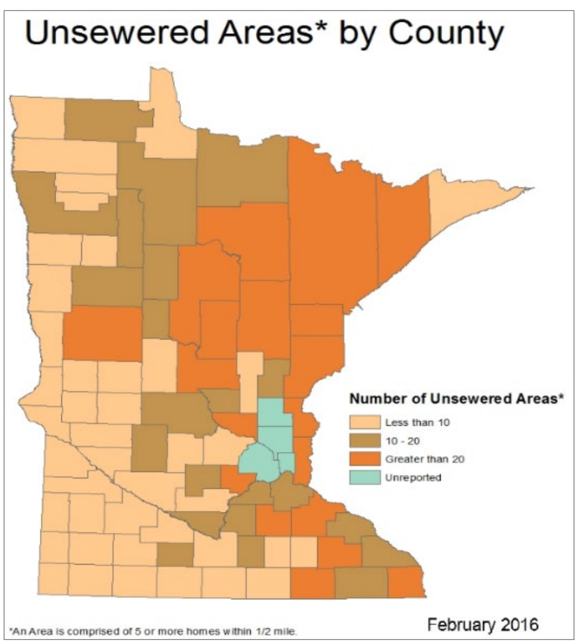


Figure 28 Number of unsewered areas by county.

Total Suspended Solids

Sediment in rivers and streams can be in both a suspended form (pollutant) and/or an embedded form (stressor). The result is a decline in conditions for stream biota, with a degradation of aquatic habitats in both the water column, and the stream channel. Sediment that is suspended in the rivers and streams impacts aquatic life by reducing visibility that reduces feeding, clogging or damaging gills that impairs respiration, and smothering substrate that limits reproduction. Sediment that fills in between larger rocks in the channels is called embedded sediment, where it degrades conditions, such as for spawning, filling in spaces between larger rocks. These coarser sediments also affect the last 15 miles of the main stem where waters are used for recreation and navigation.

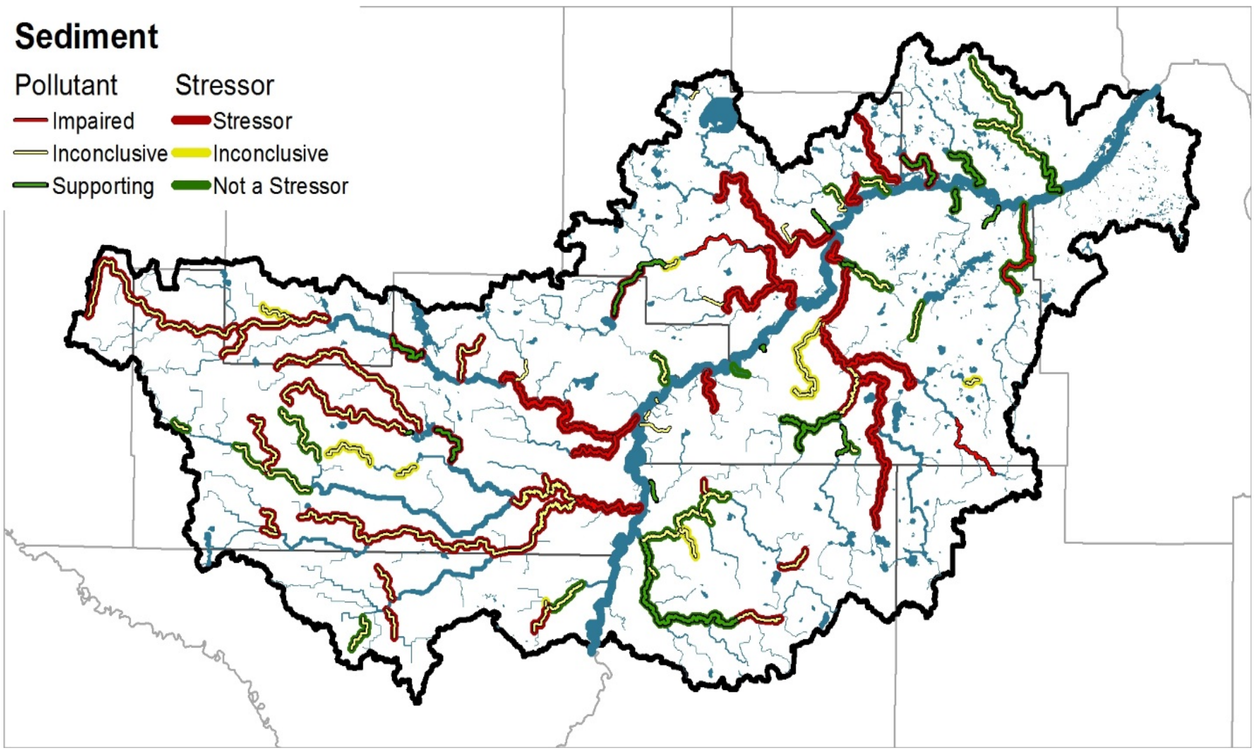


Figure 29 Locations where sediment has been identified as stressor or where streams segments are impaired by TSS.

Table 7 provides a summary of the relative annual TSS loading to the TSS-impaired streams (Figure 29) from both point and nonpoint sources. Riley Creek's estimates are based on observational data and professional judgment. The remaining streams used data from various Minnesota River research studies for near-channel erosion, wastewater data records and [Hydrological Simulation Program – FORTRAN](#) (HSPF [USGS 2014]) modeling for land sources (see LMR TMDL, Part I for further description).

Table 7: Estimated percent annual TSS loading from pollutant sources to impaired reaches and tributary systems.

Stream/Watershed	Impaired Reach (AUID)	Developed (Permitted MS4)	Developed (nonpermitted)	Wastewater	Forest	Cropland	Grassland	Pasture	Wetland	Near-channel erosion
		Percent TSS Load or Relative Magnitude*								
Rush River	521, 548	0%	<1%	<1%	<1%	17%	<1%	<1%	<1%	83%
High Island Creek	588, 653, 832, 834	0%	<1%	<1%	<1%	17%	<1%	<1%	<1%	83%
Unnamed Creek (East Creek)	581	10%	1%	--	<1%	6%	<1%	<1%	<1%	83%
Robert Creek	575	<1%	<1%	0%	<1%	17%	<1%	<1%	<1%	83%
Sand Creek	513, 538, 815, 817, 839, 840	<1%	1%	--	<1%	36%	<1%	<1%	<1%	63%
Riley Creek	511	Low	--	--	V. low	--	--	--	--	V. high

In 2016, the MPCA contracted with Tetra Tech to characterize sediment delivery in the Minnesota River Basin using actual monitoring data paired with computer analysis. Information from the LMRW was utilized in the study. The finding were reported in the memorandum *Minnesota River Basin Sediment Delivery Analysis*. Key findings of the report:

- In the LMRW, when evaluating data from 1995 through 2012, the highest sediment loading months are April through June. Over the course of the study period, these three months accounted for 63.8% of the total sediment loading (Figure 30)

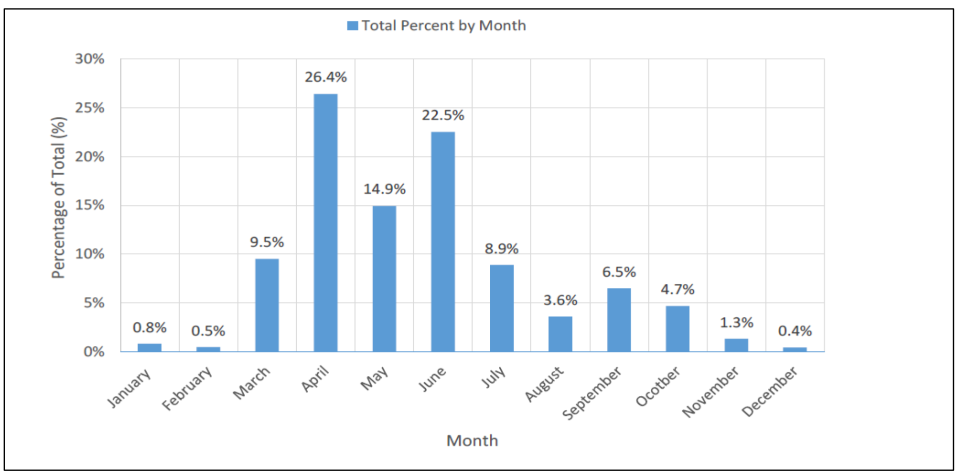


Figure 30 Sediment loading by month in the LMRW

- The sources of sediment change throughout the year, according to the study:
    - *The month of March shows a high index for bluff and stream sources and a low index (little correlation) for upland sources. During March, rivers rebound from winter low-flow conditions, mobilizing sediment from banks and bluff that has been stored in the channel. Snowmelt causes higher flows that scour instream sediment (bed, bank, and bluff) and subsequently the scoured sediment gets transported downstream. Practices such as streambank and bluff stabilization and those that reduce stream power (e.g., vegetative filter strips, water and sediment control basins) can be used to reduce the*

instream sources of sediment by limiting the amount of erosion that a stream can perform on its bed and banks.

  - *April shows an index for bluff and stream that is lower than March, but the bluff and stream indexes are still greater than the upland index. One theory for the March versus April indexes is that April high sediment loads are driven by a combination of snow melt, rain on snow event, and strong spring convective storms, whereas March high sediment loads are driven primarily by snow melt alone*.
  - *The months of May through September show a high index for upland, with high indexes for bluff and stream in April, May, and June. Therefore, late spring convective storms produce sediment from both upland and instream sources, whereas late summer and early fall events produce sediment primarily from land-based sources. Land with recent mechanical disturbance and/or bare soil is more susceptible to raindrop impact and particle detachment, and is therefore more likely to contribute to the sediment load exported from each HUC8. Practices such as cover crops and no-till or low-till farming should be considered to reduce the land susceptibility to erosion. Practices identified such as streambank and bluff stabilization, vegetative filter strips, and water and sediment control basins should also be considered to reduce sediment from convective storms in the Spring, Summer, and Fall.*
  - *Those months with a high sediment load outside the March to June time period resulting from upland erosion were typically due to long duration or very intense precipitation events that produced large amounts of overland flow.*

- The study determined: *Tile drains with surface inlets can be direct sources of sediment load. Tile drains also likely exacerbate sediment erosion from stream banks due to higher volumes of water drained from both snowmelt and convective storms. Tile drains provide a pathway for water to efficiently be removed from the landscape. Without tile drains snowmelt and/or convective storm water would be held in root zone storage for a longer period of time (weeks to months), as compared to when tile drains are present.*
- The study concluded: *The multiple sources of sediment and relationships to precipitation intensity are variable enough that no one management practice alone is likely to mitigate high sediment loads; instead, a suite of management practices that address the different sources and pathways will likely be needed.*

Near-channel erosion (e.g., streambank, bluff and ravine erosion) is the dominant loading source for TSS in the LMRW. Tributaries in the LMRW are naturally prone to high sediment loads. Around 13,400 years ago the glacial River Warren carved the wide Minnesota River Valley, lowering the existing river valley by roughly 200 feet (DNR 2017). This deepening of the river valley resulted in the tributaries of the Lower Minnesota River cutting through the landscape to adjust to the new gradient, creating knickpoints. A knickpoint is created where there is sharp change in the slope of a river or channel often resulting in channel erosion. Continued erosion of the stream channel causes knickpoints to migrate further upstream in an attempt to match the much lower elevation of the Minnesota River. While this process is natural in origin, the current rate of human-induced near-channel erosion is much greater than historic natural rates, and are nearly four times greater than estimated accumulation rates in 1900 (MPCA 2015). Altered hydrology (described in the previous section) is the main driver for this increase.

In the development of the An Integrated Sediment Budget for the Le Sueur River Basin Report (2011), Gran et al studied several watersheds in southern Minnesota including the Rush River and High Island Creek. By comparing upstream and downstream monitoring stations, the report determined: "*The comparison of upstream/downstream gauges clearly indicates that much of the loading occurs as the rivers move through the incised portions of the watershed… Increases in TSS yield are generally much larger than the corresponding increase in drainage area, indicating that disproportionately large amounts of sediment are supplied in the incised reaches between each pair of gauges."* Figure 31 shows the significant increase in TSS yield between the two gauges. In the Rush River, it was estimated that 90.3% of the sediment yield is picked up in the knick zone and 94.5% in High Island Creek.

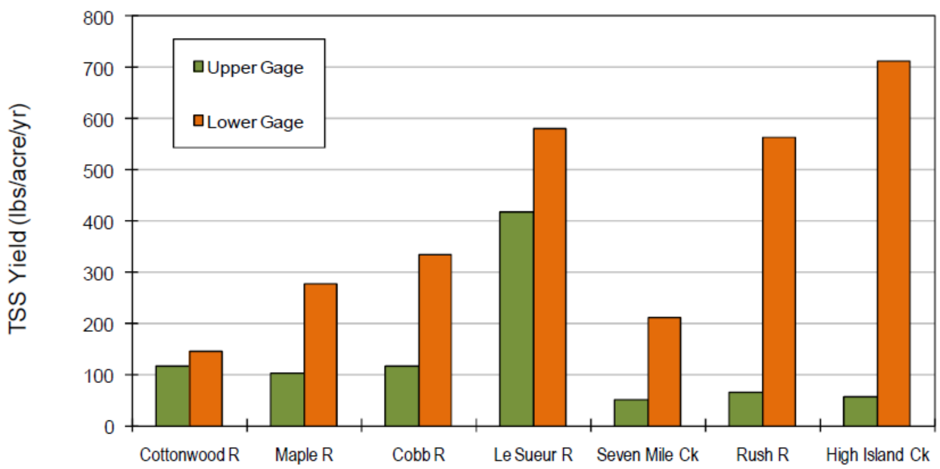


Figure 31 Comparison of TSS yields, above and below knickpoints in streams in Southern Minnesota. Rush River and High Island Creek showing some the largest differences between the two sampling points.

The Watershed Pollutant Load Monitoring Network (WPLMN) is also able to detect this increase in the knickpoint sediment loading on High Island Creek. The WPLMN has two monitoring stations located near Arlington and near Henderson which are approximately nine miles apart. From the years 2013 through 2016, the average annual load of TSS at Arlington was 5.9 million pounds. During the same time period the average load of TSS near Henderson was 78.4 million pounds, more than a 10 times increase. Figure 32 compares the daily loading of these two stations during the month of June in 2013.

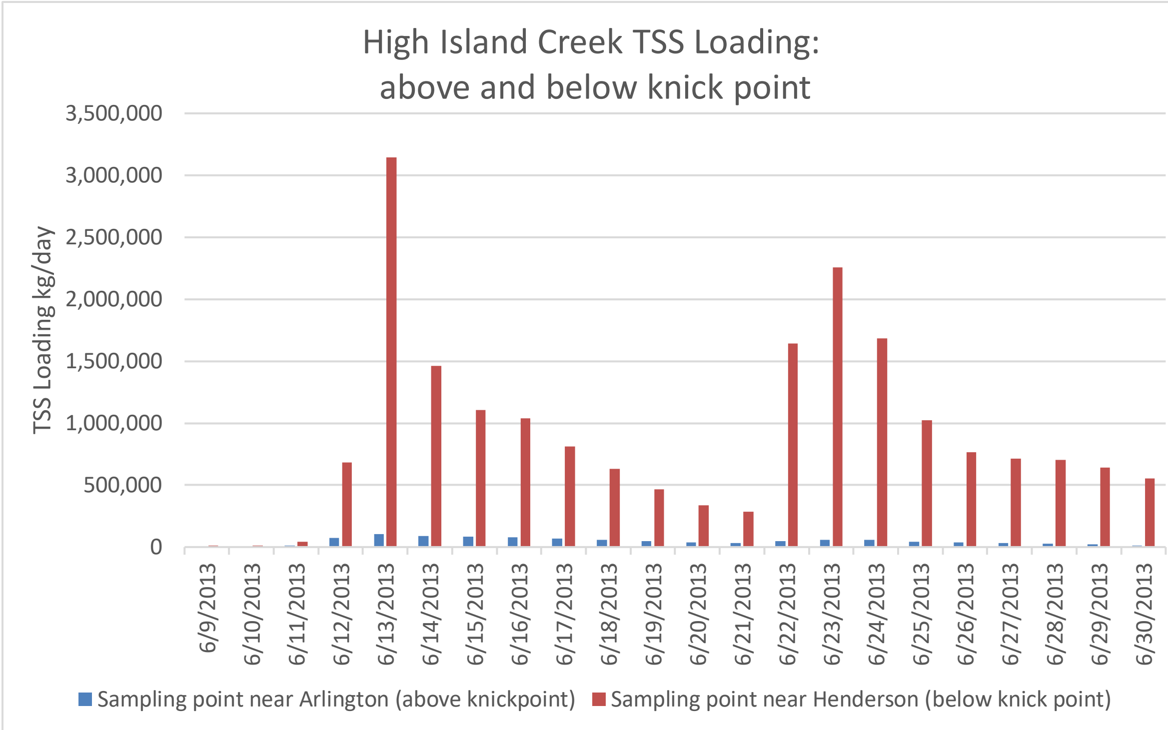


Figure 32 TSS loading on High Island Creek above the knickpoint near Arlington and below near Henderson. Significant increase in TSS loading in seen between the two sampling locations even though they are only separated by nine miles.

While near channel sources are the major contributor of sediment in the LMRW, cropland is the second leading source of sediment. The DNR administrative Region 4 evaluated sediment sources within the region's area (McLeod, Sibley, Nicollet, Le Sueur, and Rice Counties) for the report [Minnesota River, Shakopee Watershed Characterization Report] (2017) and determined that "*On the flat areas of the watershed, wind erosion is a common sediment contributor to drainage ditches and local streams… Lack of residue during winter and spring months has led to soil erosion from wind that typically gets transported into drainage ditches and other water pathways.*" The LMRW is prone to moderate wind erosion and areas in the watershed may erode at three to five tons per year based on NRCS analysis (NRCS 2000) (Figure 33).

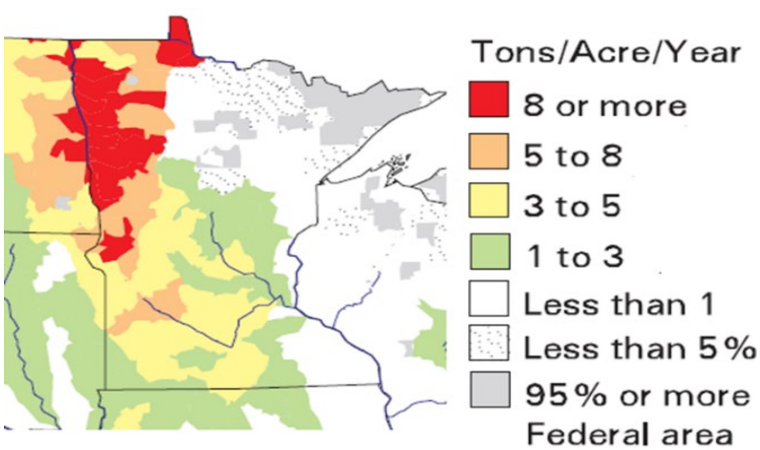


Figure 33 Estimated wind erosion in Minnesota (NRCS)

NRCS soil survey information can be utilized to determine the Wind Erodibility Index and Wind Erodiblity Group, which indicate the natural susceptibility of soil to wind erosion in cultivated areas. Figure 34 shows the Wind Erodibility Group for the LMRW. Soils assigned Group 1 are the most susceptible to wind erosion, and those assigned to Group 8 are the least susceptible. Many areas of the western side of the watershed, along with areas adjacent to the mainstem of the river are moderately susceptible to wind erosion (Figure 34).

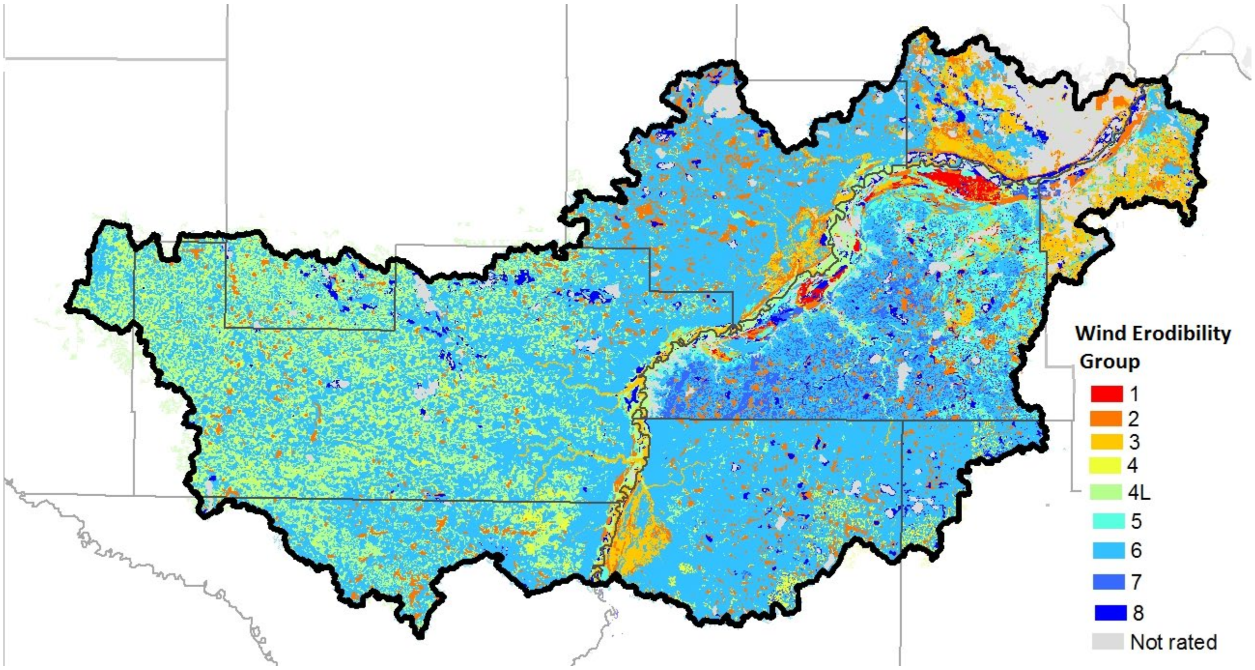


Figure 34 Wind Erodibility Index for the LMRW. Many areas in the western half and along the Minnesota River mainstem are moderately susceptible to wind erosion.

Soil erodibility is also related to the integrated effects of rainfall, runoff and infiltration on soil loss. Commonly called the soil erodibility factor (K), which represents the effect of soil properties and soil profile characteristics on soil loss, K takes into account soil texture, structure, permeability, and organic matter content in determining its value. K was developed by the NRCS for use in estimating soil losses with the Universal Soil Loss Equation (USLE). Values of K range from 0.02 (lowest erodibility) to 0.69 (highest erodibility). In general, the higher the K value, the greater the susceptibility of the soil to rill and sheet erosion by rainfall. Figure 35 provides a condensed scale of K showing low, medium and high soil erodibility in the LMRW. The majority of the watershed is considered to have a moderate level of soil erodibility with pockets of high erodibility.

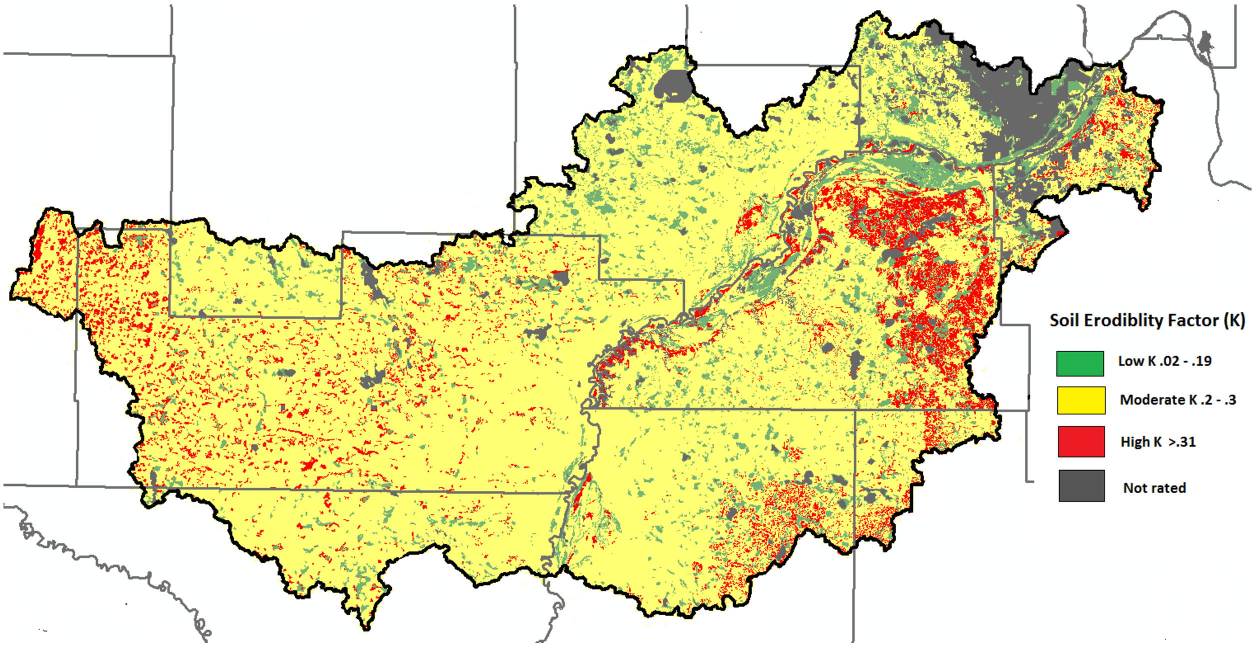


Figure 35 Soil Erodibility Factor K for the LMRW. The majority of the watershed is considered to have a moderate level of soil erodibility with pockets of high erodibility.

One of the biggest factors in upland soil erosion is tillage of agricultural land. Understanding the amount and type of tillage occurring is essential in developing strategies to address erosion. Tillage Transect Surveys (TTS) are a method to estimate the tillage practices of farmland. TTS were conducted in Minnesota counties from around 1989 to the mid-2000s and associated with funding from various sources. In 2007, the Minnesota Board of Water and Soil Resources (BWSR) coordinated with the Water Resources Center at Minnesota State University to compile previous TTS data (1989 through 2007) into one location at the Minnesota TTS Data Center. Although the TTS is reported by county, it does provide a good indication of tillage practices that are occurring within the LMRW. From 1989 to 2007 the overall

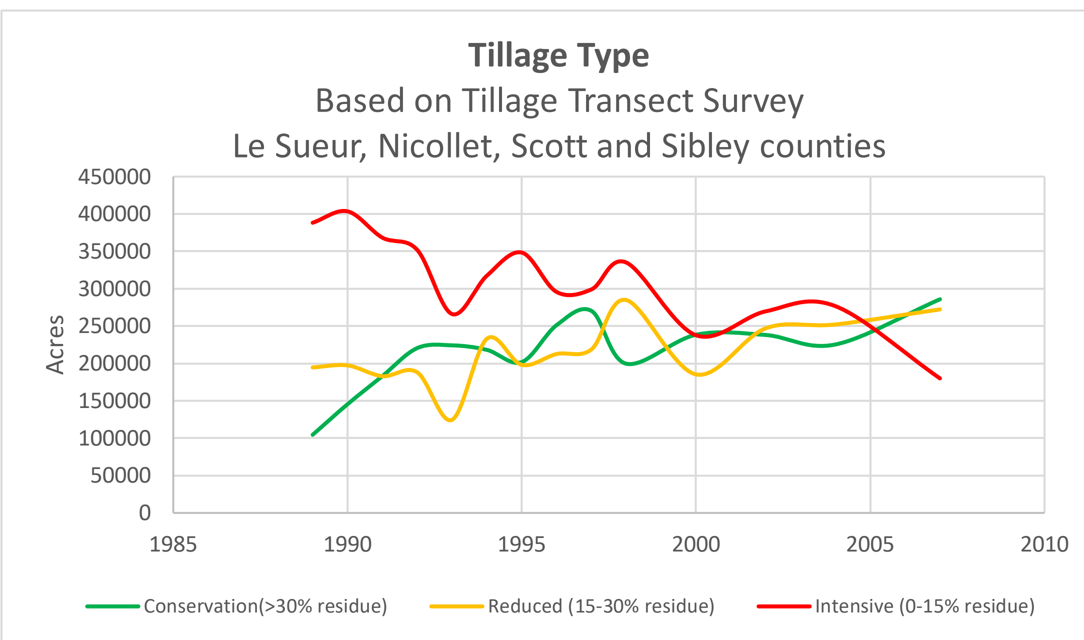


Figure 36 Tillage type for Le Sueur, Nicollet, Scott and Sibley counties from 1989 through 2007).

trend is less intensive tillage and more reduced or conservation tillage (Figure 36). Conservation tillage is defined as a system that leaves enough crop residue on the soil surface after planting to provide 30% soil cover, the amount needed to reduce erosion below tolerance levels.

More recently, BWSR has developed a process to systematically and unbiasedly collect tillage data utilizing remote sensing methods. Satellite imagery from Landsat 8 (an American satellite) and Sentinel 2 (European satellite) was calibrated using ground truth data for crop residue cover and cover crops. A simple regression model was used to calibrate and validate satellite surface reflectance data for crop residue cover. Pixel resolution ranges from 2 to 30 meters, depending on the satellite. Percent residue was then averaged for all land uses to an entire HUC-12 level. Individual field data is not available with this process.

Because the percent residue is averaged for all land uses, and not just cropped fields, comparisons to pervious TTSs residue cover is extremely limited. For example, previously if an area was considered to have 30% residue cover this was considered conservation tillage (limited or no till as described); whereas with the current process a 30% residue would indicate a significant amount of tillage had occurred within the area.

2017 was the first year this process was used in the LMRW. Figure 37 depicts the data that was collected May 6, 2017, through May 13, 2017. While Figure 37 would indicate there is an excessive amount of tillage (any tillage not considered conservation tillage or no till) occurring in the LMRW, the reader is cautioned in making judgements on only one year of information. There are a number of variables that impact a farmer's decision on tillage, so it is important to look at long-term trends when evaluating overall tillage methods in an area.

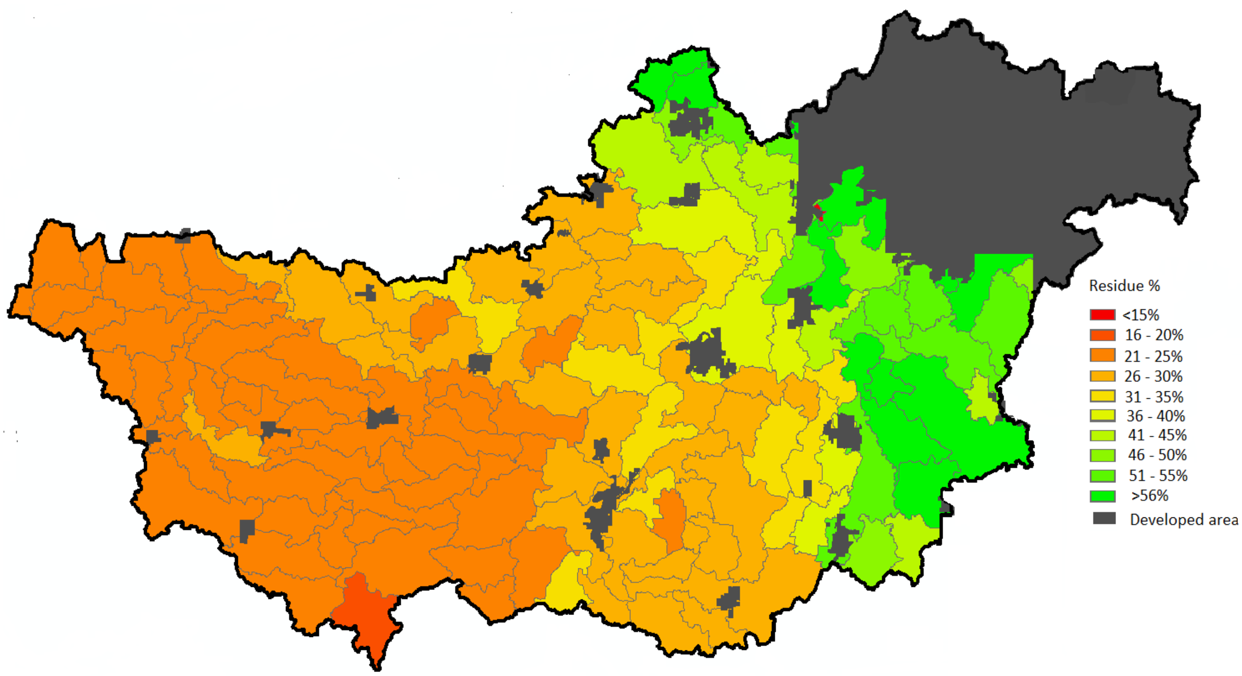


Figure 37 Percent residue coverage in the LMRW based on BWSR analysis for May 2017.

The Sediment Reduction Strategy for the Minnesota River Basin and South Metro Mississippi River (MPCA 2015) provides guideance on strategies to reduce sediment in the LMRW and the Minnesota

River. The Sediment Reduction Strategy indicated that to meet sediment reductions goals within the Minnesota River Basin:

- A high level of change across the landscape is needed. Promotion of soil health across the basin is needed that:
    - Keeps the soil covered as much as possible;
    - Disturbs the soil as little as possible;
    - Keeps plants growing throughout the year (especially early spring and fall) on agricultural land; and
    - Diversifies crop rotation and includes cover crops.
- Only install direct near-channel protection near infrastructure, as practices are typically quite expensive and only address small problem areas relative to the magnitude of all near-channel sources.
- Coordinate implementation with the Minnesota Nutrient Reduction Strategy (NRS), as many practices reduce both sediment and nutrients.
- Ensure Point Sources (WWTF, MS4 and Industrial and Construction Stormwater) have appropriate waste load allocations assigned and are in compliance with their respective permits.
- Increase water storage on the landscape. Reduce two-year annual peak flow by 25% by 2030, and decrease the number of days the two-year peak flow is exceeded by 25%. Key practices include:
    - Increase in perennial vegetation and other soil health practices;
    - Controlled drainage on land with less than 1% slope; and
    - Temporarily store upland waters during the first 24 to 48 hours after a runoff event.

Lastly, the Sediment Reduction Strategy concludes: *Implementation of upland BMPs without addressing hydrology (flow reduction) will not meet sediment reductions goals.* A revision to the Sediment Reduction Strategy is in progress and will be released in 2020.

Figure 38 depicts HSPF-derived TSS loading by subwatershed from upland areas and can be used in targeting upland practices.

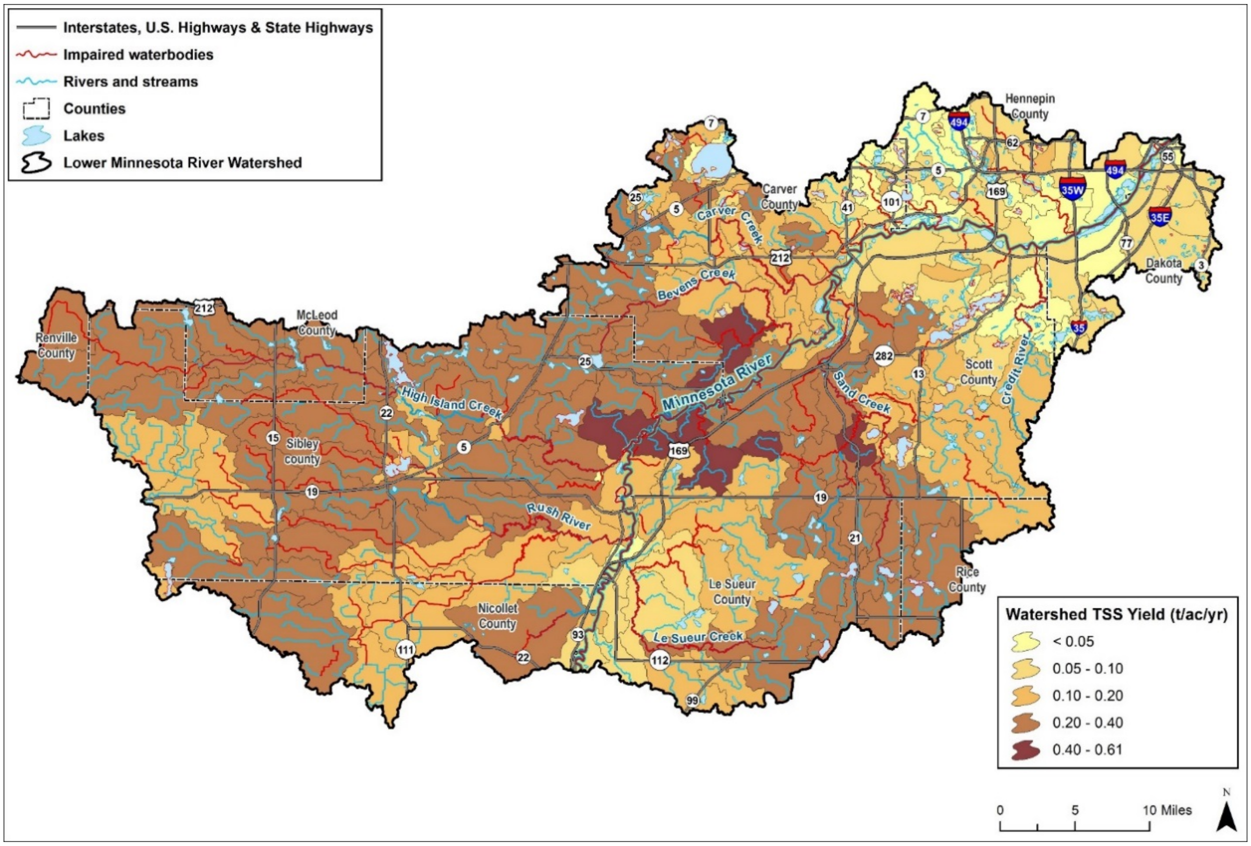


Figure 38 Modeled HSPF outputs indicating subwatershed TSS yields (developed by Tetra Tech)

E. coli

Use of watershed models for estimating relative contributions of *E. coli* sources delivered to streams is difficult and generally has high uncertainty. Thus, a simpler weight of evidence approach was used to determine the likely primary sources of *E. coli*, with a focus on the sources that can be effectively reduced with management practices. Table 8 is adapted from the completed TMDL reports for the project and focuses on sources to target for implementation. (Note: Local wildlife communities were identified by Scott County staff as potentially contributing to *E. coli* impairment in Sand Creek (-513), Porter Creek (-817), and Eagle Creek (-519) impairments.) To illustrate the potential connection to livestock sources for *E. coli* impairments in the rural portions of the LMRW, Figure 24 shows feedlots and bacteria impairments. Whether a feedlot is a contributor or not depends on various factors, e.g., proximity to the waterbody; manure handling and storage methods; and rate, timing and method of application of manure. Failing septic systems and urban stormwater, where present, are likewise high priority sources for targeting.

Table 8: Summary of *E. coli* sources for implementation targeting in impaired watersheds.

Stream / Watershed	Reach Name	AUID	Source (● = *E. coli* source that is a higher priority for targeting; ○ = *E. coli* source that is a lower priority for targeting; – = Not a priority *E. coli* source)			
			Livestock	Developed Area Stormwater Runoff, Permitted and Nonpermitted (Including Wildlife and Pets)	SSTS (IPHT)*	Permitted Wastewater
Minnesota R	Chaska Creek	804	●	● Chaska	●	○ Laketown Community WWTP
	Eagle Creek	519	–	● Savage, Shakopee	○	–
	Unnamed creek	528	–	● Carver	●	–
	Unnamed creek (East Creek)	581	–	● Chaska	●	–
	Nine Mile Creek	809	–	● Bloomington	–	–
	Purgatory Creek	828	–	● Bloomington, Eden Prairie	–	–
	Riley Creek	511	–	● Eden Prairie	–	–
	Credit River	811	●	● Burnsville, Savage	○	–
Sand Creek	County Ditch 10	628	●	–	○	–
	Raven Stream, West Branch	842	●	–	○	–
	Raven Stream	716	●	○ New Prague	●	○ New Prague WWTP
	Porter Creek	817	●	–	○	–
	Sand Creek	513	●	● Jordan	○	○ Jordan WWTP Montgomery WWTP New Prague WWTP
City of Belle Plain-Minn R	Big Possum Creek	749	●	–	○	–
	Robert Creek	575	○	–	○	○ Belle Plaine WWTP
	Unnamed creek	746	–	–	○	–
	Unnamed creek	753	–	–	○	–
	Unnamed creek	756	●	–	○	–
	Unnamed creek (Brewery Creek)	830	●	● Belle Plaine	○	–
Carver / Bevens Creek	Unnamed creek	526	●	–	●	–
	Unnamed creek	568	●	● Cologne	●	○ Cologne WWTP
	Unnamed creek	618	●	–	●	–
	Unnamed creek	621	–	● Laketown Township, Waconia	●	–
	Unnamed creek (Goose Lake Inlet)	907	○	–	●	–

Stream / Watershed	Reach Name	AUID	Source (● = *E. coli* source that is a higher priority for targeting; ○ = *E. coli* source that is a lower priority for targeting; – = Not a priority *E. coli* source)			
			Livestock	Developed Area Stormwater Runoff, Permitted and Nonpermitted (Including Wildlife and Pets)	SSTS (IPHT)*	Permitted Wastewater
	Unnamed creek (Lake Waconia Inlet)	619	●	–	●	–
	Unnamed ditch	527	○	● Waconia	●	–
	Unnamed ditch	533	○	● Norwood Young America	●	○ Norwood Young America WWTP
	Unnamed ditch	565	●	–	●	○ Bongards' Creameries
	Judicial Ditch 22	629	●	–	●	–
City of Le Sueur-Minn R / Le Sueur Ck	Barney Fry Creek	602	●	–	●	–
	Le Sueur Creek	824	●	○ Le Center	●	○ Le Center WWTP
	Forest Prairie Creek	725	●	–	●	–
	Unnamed creek	761	●	–	●	–
High Island / Rush	Rush River, North Branch (Judicial Ditch 18)	555	●	–	●	–
	Unnamed Ditch	713	○	–	●	–
	County Ditch 18	714	–	–	●	–
	Rush River, North Branch (County Ditch 55)	558	●	○ Gaylord	●	○ Gaylord WWTP MG Waldbaum Co
	Rush River, Middle Branch (County Ditch 23 and 24)	550	●	○ Winthrop	●	○ Starland Hutterian Brethren Inc Winthrop WWTP
	Judicial Ditch 1A	509	●	–	●	○ Lafayette WWTP

* subsurface sewage treatment systems considered to be an imminent public health threat

Phosphorus

Table 9 provides a summary of the relative annual TP loading to the river eutrophication-impaired streams from both point and nonpoint sources. The estimates are based on wastewater data records and HSPF modeling for land sources (see LMR TMDL, Part I for further description). Locations of impaired streams are depicted in Figure 39.

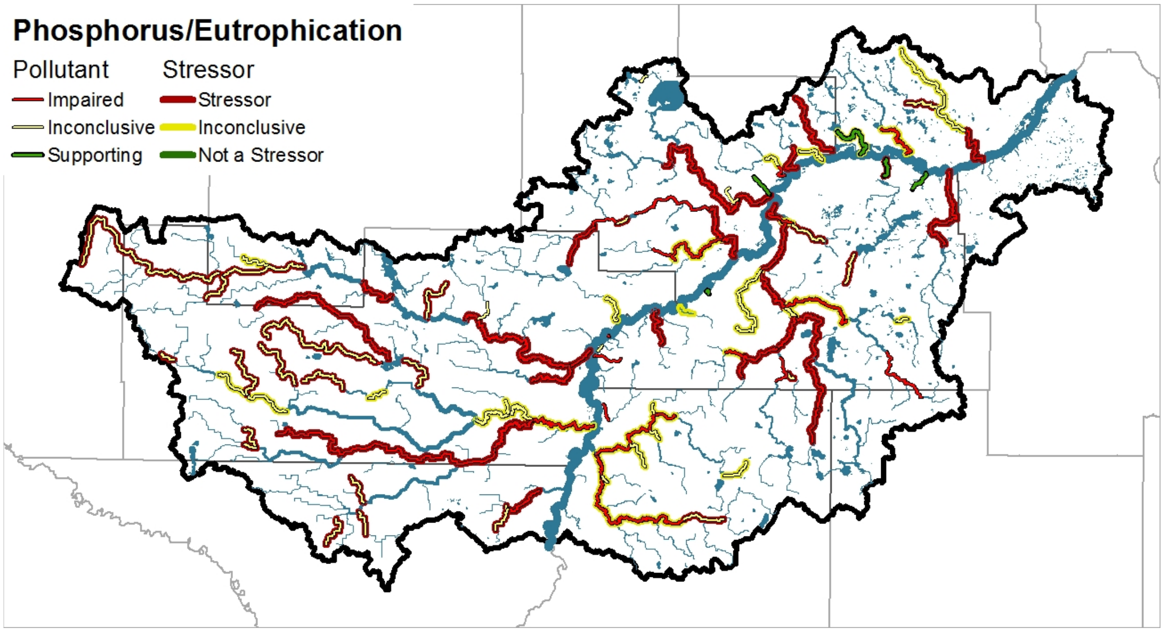


Figure 39 Locations where phosphorus has been identified as stressor or where streams segments are impaired by eutrophication.

Stream/Watershed	Impaired Reach (AUID)	Developed (Permitted	Developed (nonpermitted	Wastewater	Natural	Agriculture	Septic systems	Near-channel erosion	Upstream lakes
		Percent TP Load							
Bevens Creek	843	0%	2%	2%	<1%	43%	1%	12%	40%
Carver Creek	806	1%	1%	0%	<1%	12%	1%	4%	81%
Sand Creek	839	0%	3%	2%	<1%	16%	1%	6%	72%
	840	0%	2%	0%	<1%	18%	2%	6%	72%
	513	<1%	4%	2%	<1%	40%	3%	12%	39%

Table 9: Estimated percent annual TP loading from pollutant sources to impaired reaches and tributary systems.

It is important to note that a summary of annual TP loads such as this is more representative of sources that contribute during high flow events (e.g., field runoff). However, eutrophication is more likely occurring during lower flows when phosphorus has greater residence time in the streams. The table shows that upstream eutrophic lakes, which generally contribute during the full range of flows, are a major source. Agriculture is also a dominant source. An additional source that is difficult to quantify, and thus was not able to be represented in this analysis is wetlands (natural and altered). These wetlands are numerous in these watersheds and with alternating wetting/drying cycles can release significant amounts of TP over a range of flows. Wastewater, where present, appears to be a small contributor in terms of annual contribution, but separate analysis (LMR TMDL, Part I and *Procedures for implementing river eutrophication standards in NPDES wastewater permits in Minnesota* (MPCA 2015)) indicate that wastewater can be a sizeable source at lower flows.

Table 10 provides a summary of the relative annual TP loading to impaired lakes. Estimation methodology and categorization varied by TMDL report and each report provides further characterization and description of the sources. One important note, particularly for the LMR TMDL, Part I lakes is that the source estimation tool used did not simulate phosphorus loading (or attenuation) from wetlands, which, as described for phosphorus-impaired streams, can be significant, particularly from altered wetlands.

Some conclusions to be drawn from the results in Table 10 include:

- Internal loading is a significant source. It contributes a higher percentage of the existing load than watershed runoff sources in nearly two-thirds of the lakes studied. The source of the internal load could be anoxic sediment release, carp or other rough fish and/or curly-leaf pondweed senescence.
- Runoff sources reflect what type of watershed the lake resides in—urban versus rural/agricultural.

Table 10: Phosphorus source assessment (percent) for impaired lakes.

Subwatershed	Lake name	Lake name	Cropland / pasture	Forest / shrub / rural residential	Developed*	Wastewater	Near-channel erosion	Groundwater	Feedlots	Septic systems	Internal load	Atmospheric deposition	Upstream lakes
				Percent TP Load (Blank = not applicable or not quantified)									
	From LMR TMDL, Part I												
MN R - PLSLWD	Fish	70-0069-00	16%	6%	0%				49%	16%	**	12%	
	Pike	70-0076-00	5%	2%	8%				11%		56%	<0.5%	18%
MN R - Scott WMO	Cleary	70-0022-00	27%	14%	4%				21%		32%	3%	
	Thole	70-0120-01	3%	3%						9%	74%	4%	8%
Sand Ck - Le Sueur	Pepin	40-0028-00	23%	<0.5%	2%				5%	<0.5%	69%	1%	
	Sanborn	40-0027-00	46%	1%	3%				<0.5%	<0.5%	46%	4%	
Sand Ck - Rice	Cody	66-0061-00	20%	<0.5%	4%				10%	<0.5%	46%	1%	19%
	Hatch	66-0063-00	7%	<0.5%	1%				3%	<0.5%	88%	2%	
	Phelps	66-0062-00	4%	<0.5%	<0.5%				3%	<0.5%	43%	1%	49%
Sand Ck - Scott WMO	Cynthia	70-0052-00	2%	1%	<0.5%				<0.5%	<0.5%	84%	<0.5%	13%
	Pleasant	70-0098-00	13%	2%					7%	4%	63%	11%	
	St. Catherine	70-0029-00	23%	2%	<0.5%				8%	<0.5%	66%	1%	
Carver Ck - Carver WMO	Rutz	10-0080-00	35%	2%					8%	1%	49%	4%	
Le Sueur Ck - Le Sueur	Clear	40-0079-00	13%	<0.5%	1%				3%	<0.5%	82%	1%	
	Greenleaf	40-0020-00	28%	<0.5%	3%				19%	1%	41%	7%	
High Island Ck - High Island WD	High Island	72-0050-01	15%	<0.5%	2%				<0.5%	<0.5%	82%	2%	
	Silver	72-0013-00	21%	<0.5%	1%				1%	<0.5%	73%	2%	
N Br Rush R - Sibley	Titlow	72-0042-00	38%	<0.5%	3%				28%		30%	1%	

Subwatershed	Lake name	Lake name	Cropland / pasture	Forest / shrub / rural residential	Developed*	Wastewater	Near-channel erosion	Groundwater	Feedlots	Septic systems	Internal load	Atmospheric deposition	Upstream lakes
			Percent TP Load (Blank = not applicable or not quantified)										
S Br Rush R - Sibley	Clear	72-0089-00	24%	<0.5%	3%				8%	<0.5%	58%	6%	
	From LMR TMDL, Part II												
MN R - NMCWD	Cornelia (N.)	27-0028-01			63%						36%	1%	
	Cornelia (S.)	27-0028-02			6%						49%	1%	44%
	Edina	27-0029-00			45%						10%	1%	44%
	Penn	27-0004-00			83%						16%	1%	
	Rose	27-0092-00			37%						25%	3%	35%
	Wing	27-0091-00			20%			1%			53%	2%	24%
MN R - RPBCWD	Hyland	27-0048-00			15%						80%	5%	
	Lotus	10-0006-00			27%		1%	1%			64%	8%	
	Rice Marsh	10-0001-00			43%						33%	4%	20%
	Riley	10-0002-00			31%						40%	4%	25%
	Silver	27-0136-00			51%		9%	2%			26%	12%	
	Staring	27-0078-00			42%	<0.5%	4%				39%	3%	12%
	Susan	10-0013-00			22%		32%	3%			39%	3%	2%
	From LMR TMDL, Part III†												
MN R – Carver WMO	Gaystock	10-0031	64%		2%	1%			10%	<0.5%	21%	1%	2%
	Grace	10-0218	<0.5%		4%							<0.5%	96%
	Hazeltine	10-0014	6%		8%	2%				<0.5%	82%	2%	
	Jonathan	10-0217	5%		5%						3%	<0.5%	88%
	McKnight	10-0216	21%		10%	<0.5%					29%	<0.5%	39%
Bevens Ck – Carver WMO	Maria	10-0058	19%		<0.5%				8%	1%	67%	6%	

* "Developed" land for Part I lakes includes both stormwater-permitted and nonpermitted areas; for Part II and III lakes percentages reflected only permitted areas.

** Internal load was not quantified with lake model used, but monitoring data indicates sediment release of phosphorus

† The combined "Crop/pasture" and "Forest/shrub" includes any other land uses that are not stormwater-permitted.

Internal loading is a significant source of phosphorus for many lake in the LMRW. Internal loading is complex and not always well understood because of its changing nature. State agencies drafted the document "Minnesota State Government Review of Internal Phosphorus Load Control" to help local partners understand internal loading and potential controls. Key information of this draft document include:

- *There is no "one size fits all" formula that can be used to predict internal phosphorus load reductions achieved from application of control methods. Internal phosphorus loads depend on a multitude of factors including the physical, chemical and/or biological attributes of a particular lake, on the size and shape of the lake relative to its watershed, as well as the geographical location and associated land-use of the lake's watershed.*
- *There are currently no specific thresholds that outline how external phosphorus load and internal phosphorus load reduction efforts should be balanced or timed for Minnesota lakes… if external load is a major source of phosphorus, the effectiveness and longevity of internal reductions could be compromised.*
- *Phosphorus reduction treatments can have unintended consequences, ranging from thin winter ice to increased "nuisance" vegetation to changing fish community composition.*

- *Practices employed to reduce internal loading should only be considered in the context of a comprehensive lake management plan. Ideally, lake management plans reflect the agreed upon goals of diverse stakeholders. The methods for protecting and/or restoring a lake and its watershed, which could include internal phosphorus controls, are derived from those goals. A holistic approach to lake management that incorporates watershed and in-lake practices is more likely to lead to long-term success and sustainability*

This document is still in draft form and is subject to change but is included in appendix 3. This document is intended to be used for informational purposes to inform local policy makers of the current knowledge of known practices to address internal loading. It is not intended to be an endorsement of any type of internal loading controls as many factors come into play when determining if internal loading control is appropriate.

In 2014, the state of Minnesota completed the Minnesota NRS in response to the 2008 Gulf of Mexico Hypoxia Action Plan. The NRS provides the information and collective objectives needed to address watershed nutrient goals downstream of the HUC-8 watersheds. Minnesota has assumed a nutrient reduction goal that is proportional to the load reductions needed in the Gulf of Mexico drainage area as a whole, as a percentage of baseline loads. In the future, it is possible that states could be allocated a nutrient load to meet the Gulf of Mexico goals. In the meantime, Minnesota will strive to reduce nutrient loads by applying an equitable “fair-share” approach using a proportional reduction of the baseline load (NRS 2014).

The phosphorus reduction goal identified in the NRS calls for a 45% reduction from the 1980 through 1996 conditions for watersheds that drain to the Mississippi River. Because of previous phosphorus reduction achieved across the state, the current goal calls for a 12% reduction from current conditions. In the LMRW, according to modeling done for the NRS, baseline loading for the LMRW is 746,044 pounds per year and a reduction of 89,507 pounds of phosphorus is needed to achieve the downstream goals that were outlined. The NRS acknowledges that local water quality goals may require additional reductions than those outlined by the NRS, and this is the case for the LMRW.

Figure 40 depicts HSPF-derived TP loading by subwatershed from upland areas (does not include near-channel sources). It should be noted that HSPF does not simulate the output of TP from altered wetlands, such as channelized riparian wetlands that exist in many parts of the watershed. These landscape features may produce significant phosphorus due to periodic wetting and drying, and hydraulic connection to the streams.

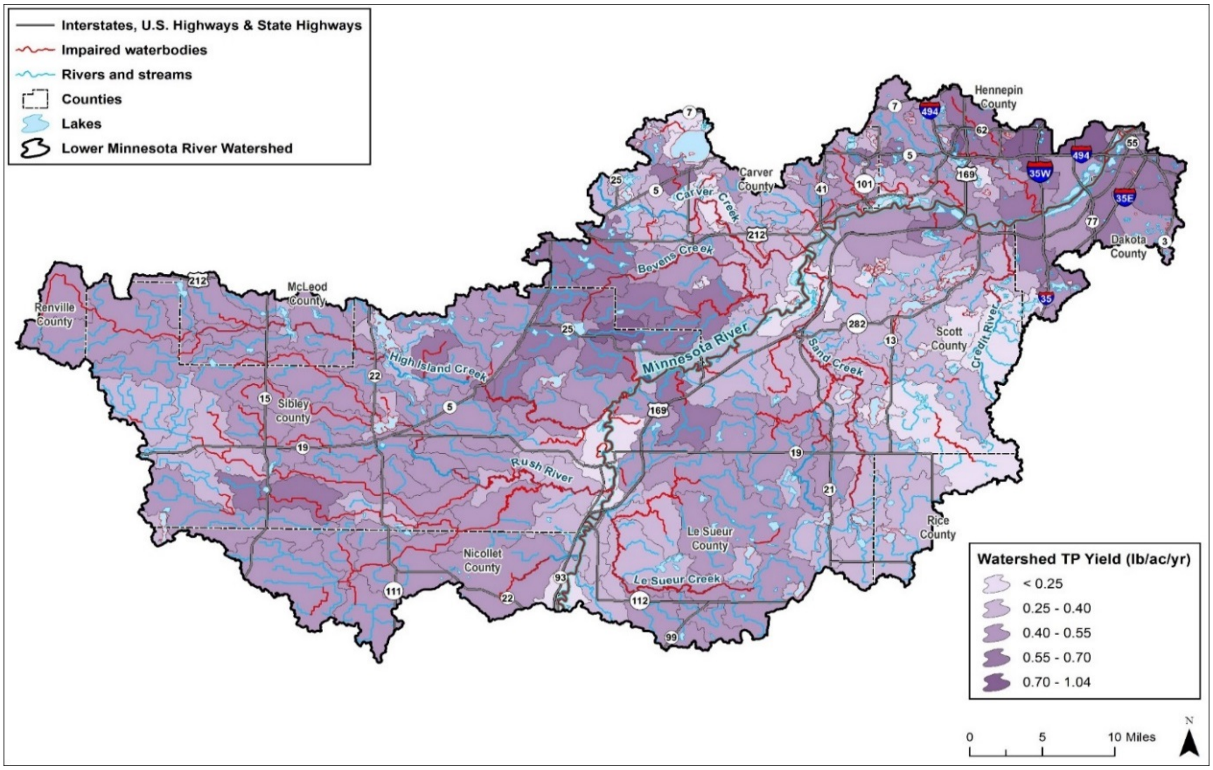


Figure 40 Modeled HSPF outputs indicating subwatershed TP yields (developed by Tetra Tech).

Nitrogen

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

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

In 2013, the MPCA, in collaboration with the University of Minnesota and U.S. Geological Survey, released the report Nitrogen in Minnesota Surface Waters: conditions, trends, sources and reductions This report allows a better understanding of N conditions in Minnesota's surface waters, along with the sources, pathways, trends and potential ways to reduce N in Minnesota's waters. This report identified the sources and amount of N entering Minnesota surface waters for each of the 10 major basins from point and nonpoint sources during low (dry), average and high (wet) flow conditions. Figure 41 represent findings of the report related to pathways in the Minnesota River Basin (which includes the LMRW) during average flow years. Cropland drainage and cropland groundwater are the dominant pathways of N in the Minnesota River Basin and when combined contribute 85% of N in the basin in an average flow year.

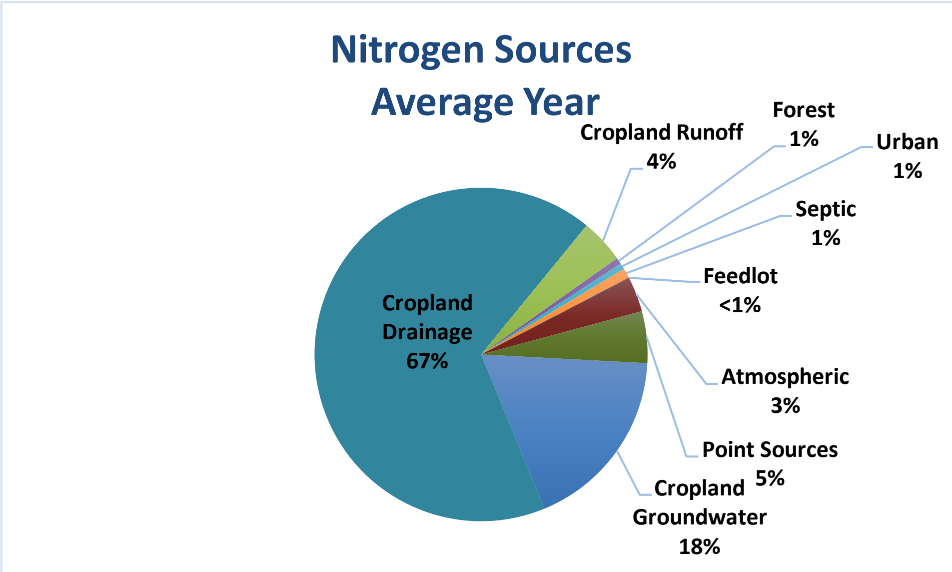


Figure 41 Nitrogen source assessment for the Minnesota River Basin based on an average flow year. Cropland drainage is the main source (pathway) for nitrogen.

In the Nitrogen report, the LMRW was identified as the highest loading watershed for Total Nitrogen (TN) to the Mississippi River in Minnesota, when comparing loads at Keokuk, Iowa (Figure 42). The LMRW estimated loading was 19,956,095 pounds per year of TN which is 7.3% of the total Minnesota TN load to the Mississippi River. While the LMRW contributed the highest amount of TN, when comparing on a per acre basis was 10th overall at 15.9 pounds per acre (the highest was the Cedar River Watershed at 24.6 pounds).

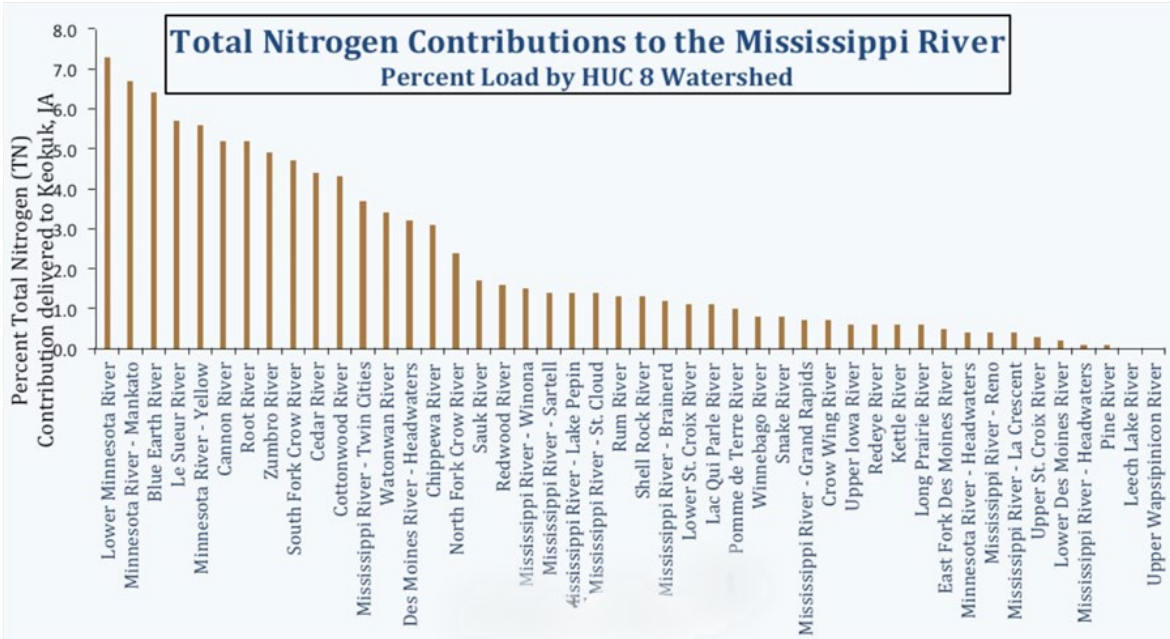


Figure 42 Minnesota HUC 8 Watershed total nitrogen contributions to the Mississippi River. The LMRW is the highest loading watershed in Minnesota for nitrogen to the Mississippi River.

N from cropland groundwater, drainage and runoff comes from a variety of sources (Figure 43). The MPCA (2013) determined that statewide, commercial fertilizer represents the largest source of N that is added to soil. Manure, legumes, and atmospheric deposition are also significant sources; and when added together provide similar N amounts as the fertilizer additions. SOM mineralization is not a N source in itself, but rather a process that mobilizes large quantities of N from the soil bank. While mineralization is an ongoing natural phenomenon, the increase in tile drainage has resulted in an increased transport of this N to surface waters. Septic systems, lawn fertilizers and municipal sludge add comparatively small amounts of N to soils statewide (less than 1% of added N).

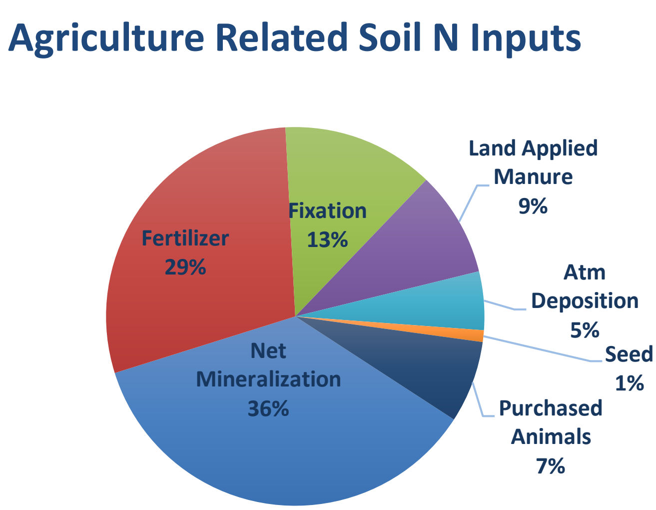


Figure 43 Nitrogen inputs to agricultural soils (statewide).

The MDA has partnered with the National Agricultural Statistics Service (NASS) to survey Minnesota corn growers to assess the status of nitrogen use and best management practices (BMPs) awareness on corn acres throughout Minnesota. The most recent survey was conducted in early 2015 to assess the nitrogen use on corn grown in 2014. The survey evaluated nitrogen use from commercial sources and manure. In 2017 the MDA released two companion documents: Commercial Nitrogen and Manure Fertilizer Selection and Management Practices Associated with Minnesota 2014 Corn Crop and Commercial Nitrogen and Manure Fertilizer Application on Minnesota 2014 Corn Crop Compared to the University of Minnesota Nitrogen Guidelines detailing the findings of the survey. The results were aggregated to either the county level or the MDA defined BMP region. Carver, Le Sueur, McLeod, Nicollet, Rice, Scott, and Sibley were associated with the South Central BMP region, encompasses 18 counties in south central Minnesota. Dakota County was included in the Southeastern BMP region and Hennepin County was included in the Irrigated and non-irrigated sandy soils BMP region. The number of respondents to the survey and number of corn acres operated by the respondents in the South Central BMP region are shown in Table 11.

Table 11 Number of respondents to nitrogen use survey in the LMRW

County	Manure Applied (main nitrogen source)		Acres Where Nitrogen Was Applied (all sources)	
	Number of Respondents	Total Corn Acres (in survey)	Number of Respondents	Total Corn Acres (in survey)
Carver	15	722	26	2,461
Le Sueur	13	615	27	4,554
McLeod	13	662	32	8,149
Nicollet	13	2,397	33	12,547
Rice	15	1,332	33	8,123
Scott	9	697	18	3,353
Sibley	16	891	39	8,625
Total South Central	**236**	**28,372**	**580**	**171,613**

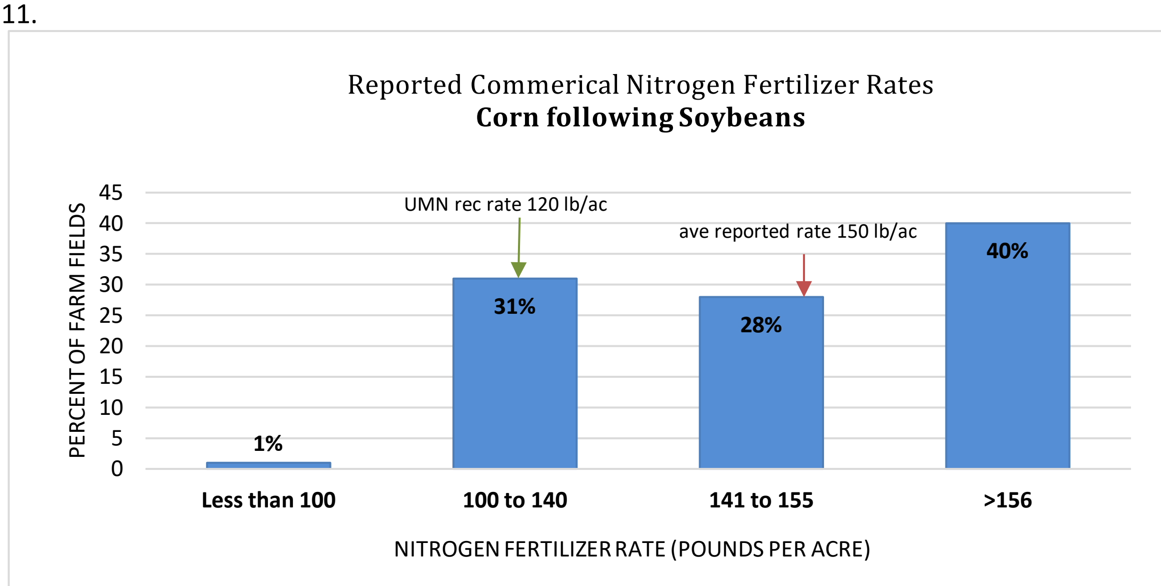


Figure 44 Reported nitrogen rates for corn following soybeans based on nitrogen use survey responses in south central Minnesota for crop year 2014.

Figure 44 and Figure 45 provide the results of the MDA nitrogen use survey of corn growers in South Central Minnesota for the 2014 growing season. While this survey was not specific to the LMRW it does provide some indication of nitrogen use in the region. Seventy-nine percent of farm fields, that were part of the survey, received nitrogen at or below the UMN-Extension nitrogen recommendations when utilizing commercial fertilzer for corn following corn. However, when corn follows soybeans this number drops to just 32% of the fields at or below the UMN-Extension nitrogen recommendations when utilizing commerical fertilzer. Similar results were noted when manure is the main nitrogen source. It should be noted that since this survey was conducted, the UMN-Extension has increased the nitrogen recommendation based on its own research (https://extension.umn.edu/crop-specific-needs/fertilizing-corn-minnesota).

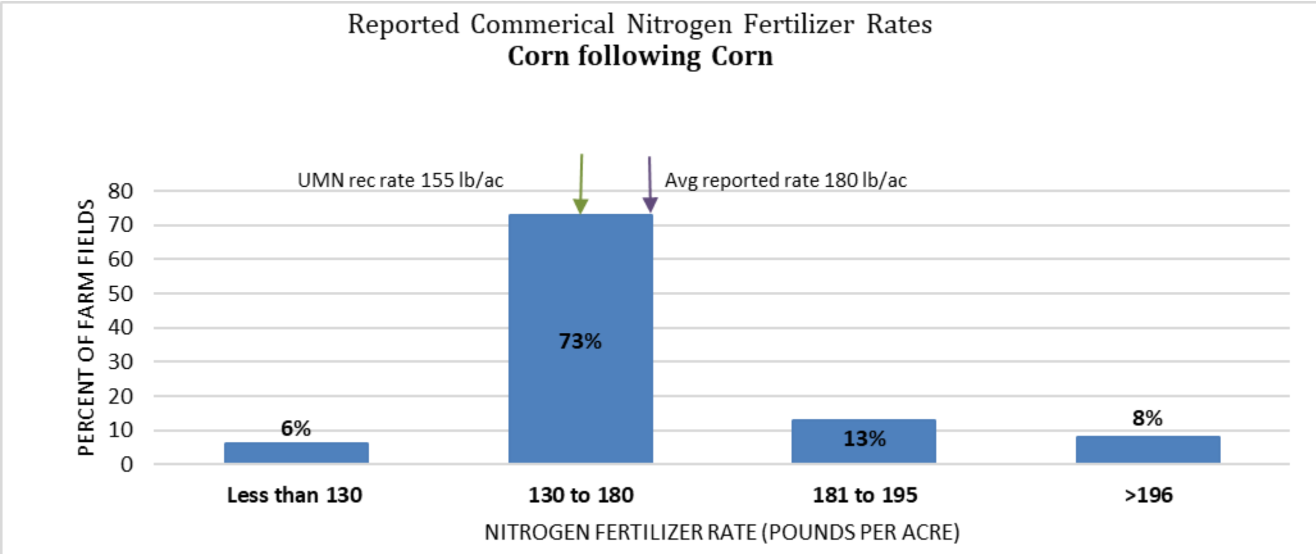


Figure 45 Reported nitrogen rates for corn following corn based on nitrogen use survey responses in south central Minnesota for crop year 2014. Good overall compliance with University of Minnesota nitrogen recommendations when corn follows corn crop rotation.

The MDA has tested private wells within LMRW for nitrates through the Township Testing Program. Nitrate data is collected from private wells in sensitive areas where groundwater is prone to contamination. Seven townships within the LMRW (only a very small portion of Kasota Township in Le Sueur County is within the LMRW) were selected for the program (Figure 46Figure 46 MDA Nitrate

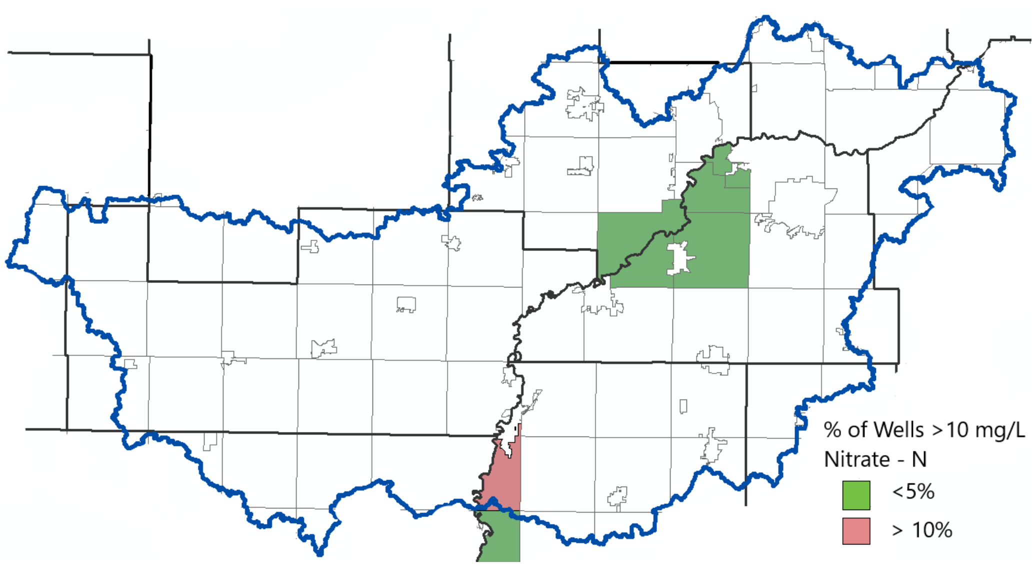


Figure 46 MDA Nitrate Township Testing Program locations in the LMRW.

Township Testing Program locations in the LMRW.). A total of 896 wells were tested for nitrates and 22 initially tested above the safe drinking water standard of 10 mg/L (Table 12).

Table 12 Nitrate Township Testing Program results

Township	Number of Wells Tested	Min	Max	Mean	Median	Percent of Wells >10 mg/L
		Nitrate-N mg/L or PPM				
Carver County						
San Francisco	160	<0.03	12	0.83	<0.03	2.5%
Le Sueur County						
Kasota	234	<0.03	24.5	0.9	<0.03	2.1%
Ottawa	14	<0.03	16	8.7	9.08	42.9%
Scott County						
Jackson	81	<0.03	16.5	1.57	0.49	3.7%
Louisville	157	<0.03	13.3	1.93	0.39	2.5%
Sand Creek	187	<0.03	5.3	0.09	<0.03	0.0%
St. Lawrence	63	<0.03	8.6	0.49	<0.03	0.0%

Figure 47 identifies areas within the LMRW where Nitrogen contributes to fish and macroinvertebrate impairments. Nitrogen as a stressor was identified in 40 stream reaches, ruled out in 26, and was inconclusive in six streams. Nitrogen was not found as a pollutant in any stream reach, and was found inconclusive in 58 stream reaches and ruled out as a pollutant in 30 reaches.

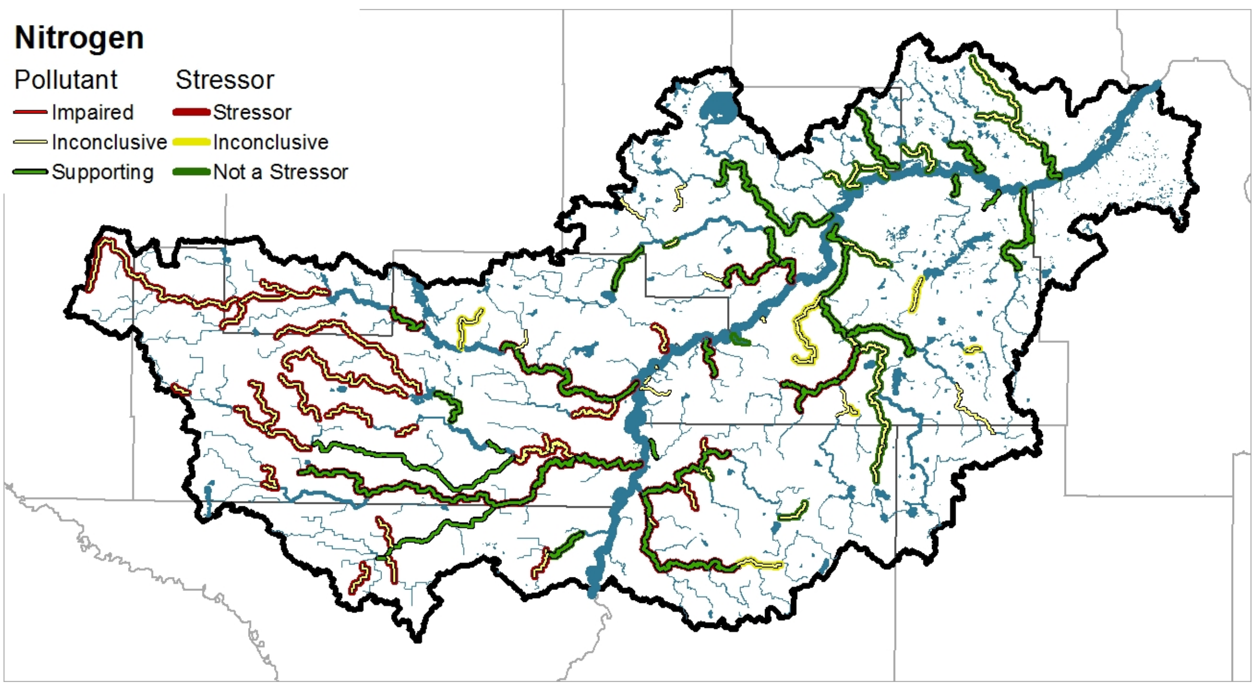


Figure 47 Locations where nitrogen has been identified as stressor in stream reaches in the LMRW.

The N reduction goal identified in the NRS call for a 45% reduction from the 1980 through 1996 conditions. However, the NRS recognizes the difficulty in achieving the 45% reduction and sets a milestone reduction of 20% by 2025. The NRS indicates, "*While progress can be made with existing BMPs for nitrogen reduction, achieving nitrogen goals for the Mississippi River will also require research and development of new BMPs and adjustment to some current BMPs to make them more widely* *applicable. As a result, a longer timeframe is proposed for nitrogen reduction implementation. In addition, nitrate standards for aquatic life that are currently being considered will require several years for approval and implementation. For nitrogen in the Mississippi River Major Basin, a milestone reduction of 20 percent is established with a target date of 2025. Future milestones for nitrogen reduction will be established based on progress toward the milestone, along with adaptations that integrate new knowledge and needs for continued improvement. The timeframe for achieving the provisional goal is likely between 2035 and 2045 and will be refined after the success of future BMP research is evaluated, and as the Gulf of Mexico Hypoxia Task Force further considers timeframes for reaching goals. For now, a projected target date for achieving the NRS provisional goal of 45 percent reduction is 2040."* The NRS estimates the reductions needed in the LMRW to achieve the 20% reduction would equate to 4,078,100 pounds of N. To achieve the 45% goal, a reduction of 9,175,900 pounds of N is required.

Watershed-wide HSPF-Estimated Sources

Monitoring for pollutants and stressors is generally extensive with the watershed approach, 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 HSPF, represent complex natural phenomena with numeric estimates and equations of natural features and processes. HSPF model data provide a reasonable estimate of pollutant concentrations across watersheds and can be used for TMDL calculations, prioritizing and targeting, and other efforts. However, these data are not used for impairment assessments since monitoring data are required for those assessments.

HSPF incorporates data including: stream pollutant monitoring, land use, weather, soil type, etc. to estimate flow, sediment, and nutrient conditions within the watershed. *Building a Picture of a Watershed* (MPCA 2014) explains the model's uses and development. Information on the HSPF development, calibration, and validation in the *Model Resegmentation and Extension for Minnesota River Watershed Model* (RESPEC 2014), and "*Minnesota River Basin HSPF Model Hydrology Recalibration*" (Tetra Tech 2015), and "*Minnesota River Basin HSPF Model Sediment Recalibration"* (Tetra Tech 2016).

A modeled numeric estimate of the LMRWs phosphorus, nitrogen, and sediment sources are presented in Figure 48. Agricultural land uses and drainage were estimated to be the largest source of phosphorus and nitrogen.

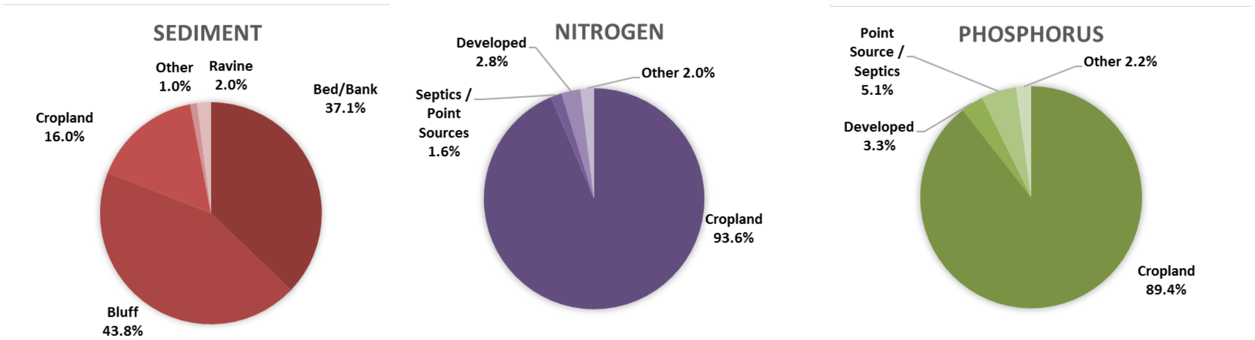


Figure 48 Source assessment based on HSPF modeling.

2.4 TMDL summary

TMDLs have been completed for all of the TSS, river eutrophication, chloride and *E. coli* stream impairments in Table 1 and all of the lake eutrophication impairments in Table 2. This is a total of 98 listings. The calculation of 'overall estimated pollutant loading reduction needed to meet water quality standards' was a primary part of the TMDLs and is provided in Table 12 through Table 15 of Section 3.4 (where data were sufficient to make this estimate). There are a few notable conclusions that can be made regarding needed reductions, which include:

- The overall load reduction percentages needed is similar for the four main TMDL types of this project (those noted above, excluding chloride), each with a median overall percent load reduction of about 70% for the waterbodies studied.
- There appears to be limited geographic differences in overall percent load reduction within any one TMDL type, with the exception of lake phosphorus. Specifically, the lakes of the LMR TMDL Part II report (the urban lakes of Riley Purgatory Bluff Creek WD and Nine Mile Creek WD) have a median overall load reduction of 40%, whereas the remaining lakes, which are largely in the rural portions of the watershed, have a median overall load reduction of 82%. The lower reduction needs of the Part II urban lakes may in part be due to the extent of actions that have already occurred.
- The relatively high overall percent load reduction needed for many of the waterbodies of this watershed represents a significant challenge. As such, restoration of waters will be a long-term undertaking requiring prioritization of efforts (e.g., which waterbodies to focus on first) and require a substantial outlay of financial resources.

2.5 Protection considerations

Because of the relatively high proportion of impaired to unimpaired waters and because of the large number of impairments in this watershed, much of the project focus was on evaluating and restoring impaired waters. However, protecting unimpaired waters from worsening and/or becoming impaired is no less important. A limited number of lakes in this watershed have previously had protection studies developed with MPCA funding, but local efforts (studies, plans, etc.) for protection are generally the norm.

Table 1 and Table 2 include waters that are currently meeting standards. Table 2 further highlights (with an asterisk) 13 lakes that are “close to” the eutrophication standards (i.e., for lakes in the NCHF ecoregion within ±10% of the standard; for lakes in the WCBP ecoregion within ±15% of the standard). Such lakes may be of a higher priority for attention, and perhaps more so are the subset of those that also have a declining water clarity trend.

Other waters that may warrant greater priority for protection are those with either high quality or of special significance/resource value. Specifically, the bluffs of the Minnesota River valley give rise to many springs including Boiling Springs in Savage, a sacred site to the Mdewakanton Sioux Tribe, and Fredrick-Miller Spring, an artesian well in Eden Prairie. Also, Assumption Creek, Eagle Creek and Black Dog Creek are coldwater systems that are designated trout streams. In addition, calcareous fens, including Savage and Seminary Fen, are unique features within the bluffs of the lower Minnesota River valley. Calcareous fens are one of the rarest natural wetland communities and are protected under Minn. Stat. 103G.223. They are very dependent on a constant supply of groundwater, highly susceptible to disturbance, and support numerous rare plant species.

3. Prioritizing and implementing restoration and protection

The Clean Water Legacy Act (CWLA) requires that WRAPS reports summarize priority areas for targeting actions to improve water quality, and identify point sources and nonpoint sources of pollution with sufficient specificity to prioritize and geographically locate watershed restoration and protection actions. In addition, the CWLA requires including an implementation table of strategies and sample actions that are capable of cumulatively achieving needed pollution load reductions for point and nonpoint sources.

To better understand what strategies are needed to accomplish water quality goals in the LMRW a review of work already completed should be considered. Since 2004, 3,376 BMPs have been installed in the watershed at a cost of $47,999,000 (Figure 49).

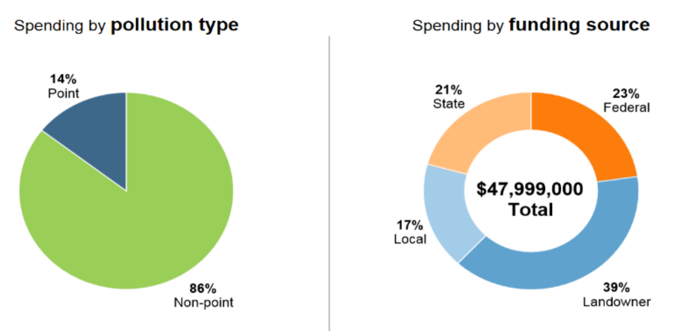


Figure 49 Expenditures for practices to address water quality issues in the LMRW

This number could be significantly higher, as these are only the BMPs documented through governmental agencies. An unknown number of BMPs have been installed by local landowners without government assistance. Some notable BMP accomplished: 73,913 acres of nutrient management; 58,664 of reduced tillage; 229,360 feet of stream bank, bluff and ravine stabilization and 57 urban stormwater runoff controls. Established BMP specifics can be found at the MPCA's [Healthier Watersheds](#) website. BMP locations are tracked to the HUC – 12 level (Figure 50).

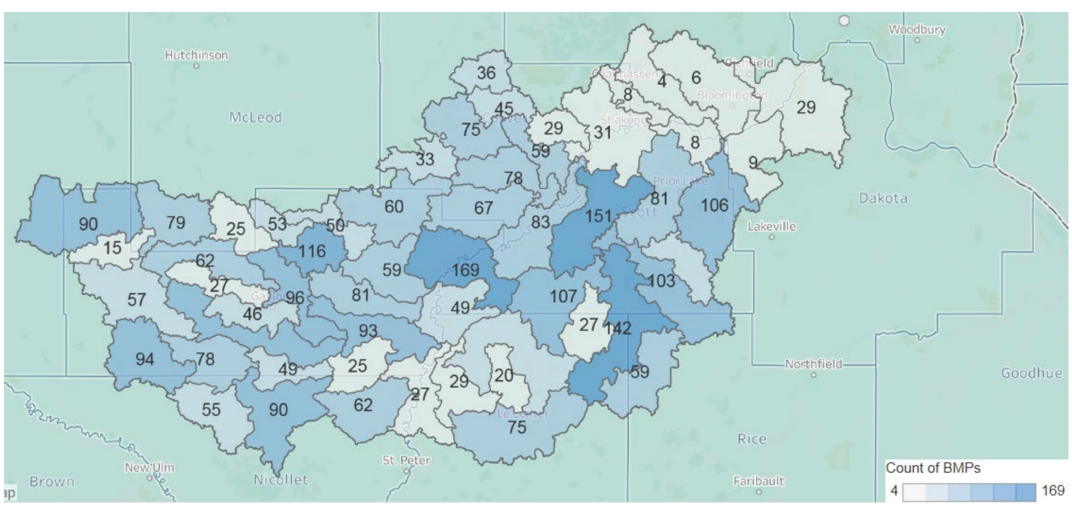


Figure 50 BMP locations within LMRW since 2004.

Of the 26 million acres of farm land statewide (MDA 2015), 476,433 acres operated by 720 producers have been certified in the [Agricultural Water Quality Certification Program](#) (MDA 2018). In the LMRW, 8 producers have certified 1,329 acres in the program.

Compliance with the State of Minnesota's 2015 Buffer Law within the LMRW, ranges from 70% to 100% (Figure 51).

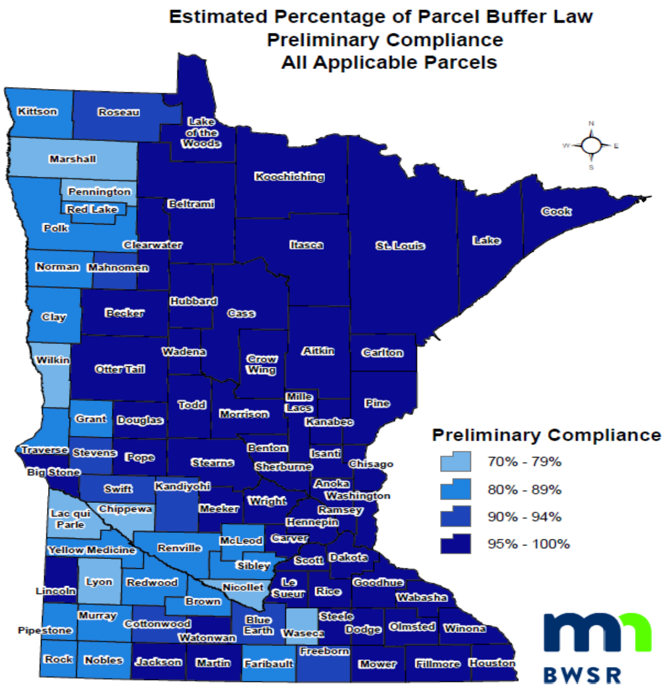


Figure 51 Estimated buffer compliance January 2019

The implementation strategies, including associated scales of adoption and timelines, provided in this section are the result of watershed modeling efforts and professional judgment based on what is known at this time and, thus, should be considered approximate. Strategies and priorities identified in this WRAPS are intended to inform local planning efforts. Furthermore, many strategies are predicated on needed funding being secured (see Table 13 for a partial list of state and federal implementation funding sources). As such, the proposed actions outlined are subject to adaptive management—an iterative approach of implementation, evaluation and course correction.

Table 13: Partial list of state and federal implementation funding sources.

Sponsor or Information Source	Funding Programs Description
MPCA	Section 319 Grants: Federal grant funding from the EPA as part of the Clean Water Act, Section 319. Grants awarded by MPCA to local governmental units (LGUs) and other groups are to address NPS pollution through implementation projects in small subwatersheds. Clean Water Partnership Loans: The state funded Clean Water Partnership Program awards loans to LGUs and other groups for work on projects that address NPS pollution. Clean Water State Revolving Fund (SRF) Loans: The SRF provides loans for both point source (wastewater and stormwater) and NPS water pollution control projects.
Board of Water and Soil Resources (BWSR)	Clean Water Fund Competitive Grants: These grants are to restore, protect, and enhance water quality. Eligible activities must be consistent with a comprehensive watershed management plan, county comprehensive local water management plan, SWCDs comprehensive plan, metropolitan local water plan or metropolitan groundwater plan that has been State approved and locally adopted or an approved TMDL, WRAPS document, surface water intake plan, or well head protection plan. Targeted Watershed Demonstration Program: This program awards grants to LGUs organized for the management of water in a watershed or subwatershed where multiyear plans that will result in a significant reduction in water pollution in a selected subwatershed are in place.

Sponsor or Information Source	Funding Programs Description
	The Erosion Control and Water Management Program, commonly known as the State Cost-Share Program*: This program provides funds to SWCDs to share the cost of systems or practices for erosion control, sedimentation control, or water quality improvements that are designed to protect and improve soil and water resources. Through this program, land occupiers can request financial and technical assistance from their local District for the implementation of conservation practices.* Other BWSR grant programs are available as well.
Minnesota Department of Agriculture (MDA)	AgBMP Loan Program: This program encourages implementation of BMPs that prevent or reduce pollution problems, such as runoff from feedlots, erosion from farm fields and shoreline, and noncompliant septic systems and wells. MDA provides a wide array of other information from their agency as well as other state and federal agencies on conservation programs addressing agriculture and other land uses. In addition, Clean Water Research Projects are available for funding.
Minnesota DNR	DNR grants are available for a variety of programs relating to land preservation, wildlife and habitat, native prairie, forestry and wetlands.
USDA-Natural Resource Conservation Service (NRCS)	Environmental Quality Incentives Program (EQIP): EQIP is a voluntary program to implement conservation practices, or activities, such as conservation planning, that address natural resource concerns for agricultural producers. Conservation Reserve Program – Continuous Signup (CCRP): The CCRP is a USDA Farm Service Agency-funded voluntary program designed to help farmers restore and protect environmentally sensitive land—particularly wetlands, wildlife habitat and water quality buffers. Conservation Stewardship Program (CSP): CSP is a voluntary program to improve resource conditions such as soil quality, water quality, water quantity, air quality, habitat quality, and energy. Other NRCS funding opportunities are available as well.

3.1 Targeting of geographic areas

Many of the local watershed partners in the LMRW have produced various analyses of the landscape to provide priority or critical areas for implementation. These include fine-scale pollutant load models for urban areas and some rural areas as well. Other work includes detailed field surveys of near-channel erosion sources (e.g., streambank, bluff and ravine) have been conducted by local partners in the Riley Creek and Sand Creek watersheds and are used for prioritizing that pollutant source. Besides HFPF, other watershed wide analyses include:

Environmental Benefits Index

Figure 52 depicts the Environmental Benefits Index (EBI) for the watershed (specifically, those areas within the 100th to 85th percentile in scores). Developed by BWSR and the University of Minnesota, this is a finer-scale analysis than is provided by HSPF and identifies lands that have high potential for runoff and soil erosion impacts to surface waters, due to relatively large catchment areas, steep slopes, highly erodible soils and close proximity to surface waters. The high biological habitat scores for these lands also suggest that they are, in some cases, high value areas for conservation, and in other cases, areas with good recovery potential. Use of this analysis should include a follow-up step of field reconnaissance to evaluate actual conditions.

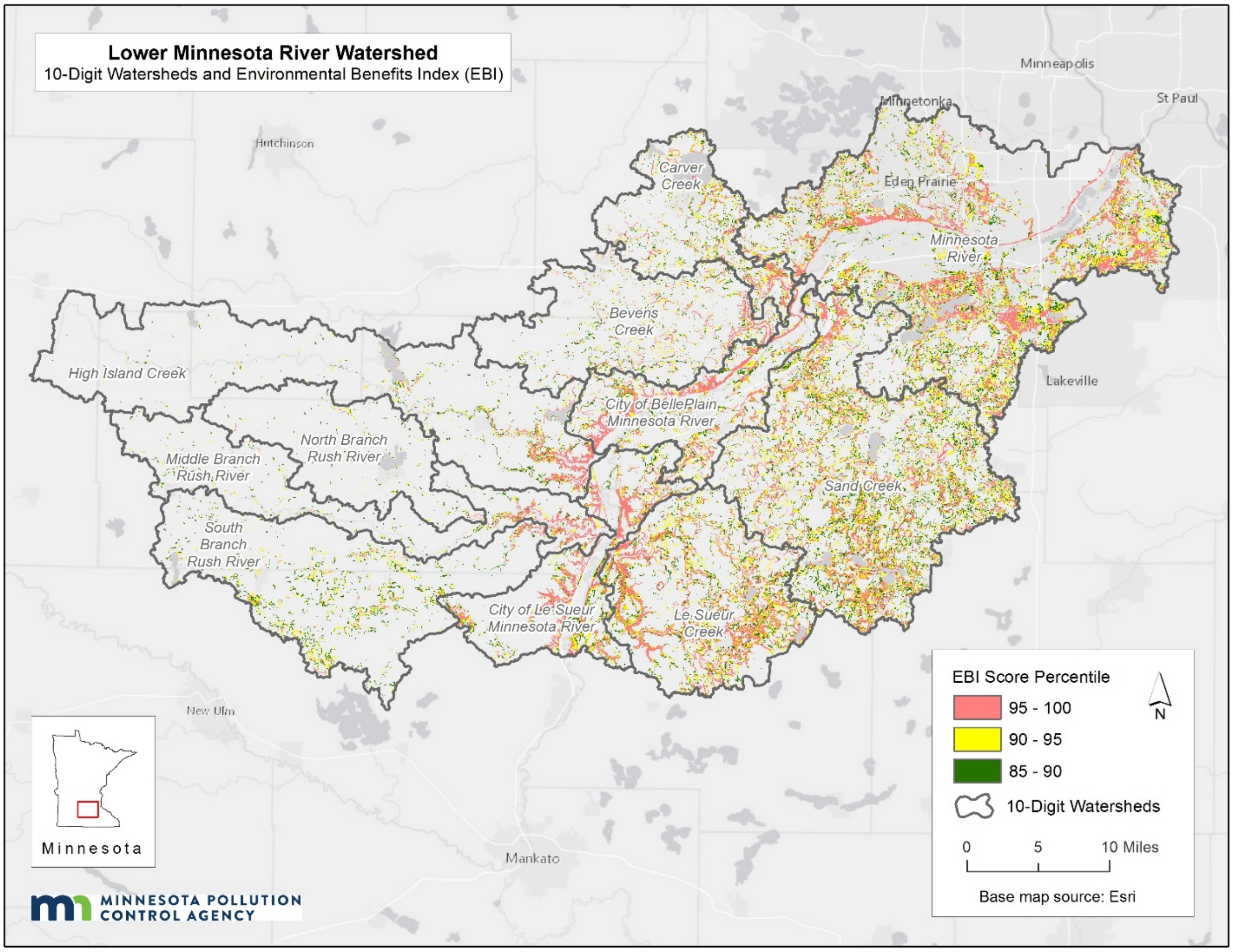


Figure 52 Environmental Benefits Index (EBI) analysis.

Lakes of Phosphorus Sensitivity Significance.

A phosphorus sensitivity significance index was formulated to prioritize lakes as they relate to Minnesota's objective of focusing on high quality, unimpaired lakes at greatest risk of becoming impaired. Phosphorus sensitivity was estimated for each lake by predicting how much water clarity would be reduced with additional phosphorus loading to the lake. The phosphorus sensitivity significance index, which is a function of phosphorus sensitivity, lake size, lake total phosphorus (TP) concentration, proximity to MPCA's phosphorus impairment thresholds, and watershed disturbance, was used to determine the lake's Priority Class. In the LMRW, there are thirteen lakes in the "highest" category indicating they are unimpaired lakes with the highest sensitivity to additional phosphorus. These lakes are identified in Figure 53, which shows the locations of all the lakes with a high, higher and highest rating in the LMRW.

Lakes of Phosphorus Sensitivity Significance (highest rating)				
Lake	County	Acres	Mean TP (mg/L)	Mean Secchi (meters)
Lucy	Carver	87.53	61.65	1.15
Bavaria	Carver	166.46	33.05	1.94
Waconia	Carver	3080.36	40.48	1.73
Brickyard Clayhole	Carver	16.64	19.06	4.2
Wood Park	Dakota	14.23	49	1.35
Orchard	Dakota	237.93	31.74	2.14
Lac Lavon	Dakota	65.89	16.49	3.89
Bush	Hennepin	170.97	18.74	2.93
Shady Oak	Hennepin	90.61	30	2.71
Glen	Hennepin	60.1	28.79	3.08
Lower Prior	Scott	956.16	33.68	2.35
McMahon	Scott	162.26	74.28	1.03
O'Dowd	Scott	300.52	51.53	1.22

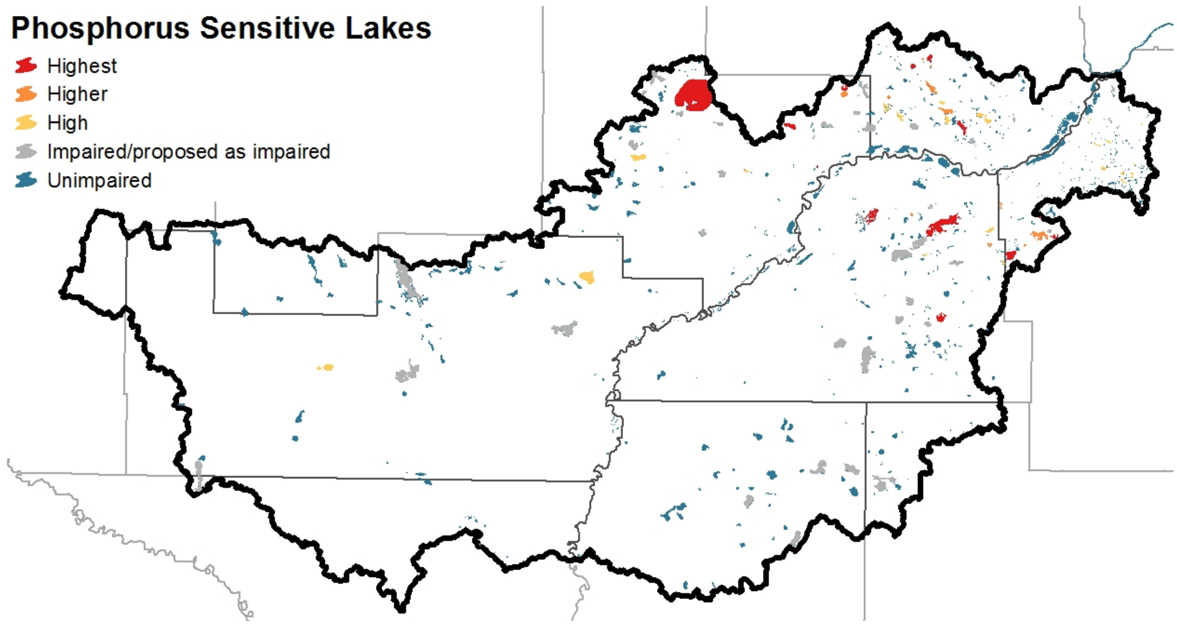


Figure 53 Lakes of Phosphorus Sensitivity Significance

Restorable wetlands

[Restorable wetlands]() are shown in Figure 54. This GIS layer was created by identifying areas of ponding and USDA-NRCS Soil Survey Geographic Database (SSURGO) soils with a soil drainage class of poorly drained or very poorly drained. Wetland restoration improves wildlife habitat, reduces phosphorus and nitrogen levels in surface and ground water, moderates stream flow and reduces flood risk potential. Wetlands do have the potential to become nutrient sinks/sources; however, the storage and other mulitple benefits (habitat, nutrient use, denitrification, etc.) mean that they are an important land use/practice. Restoration techniques that maintain moist soil in wetlands should be used as a means to minimize phosphorus release from wetland soils (Aldous et al. 2005). Reducing contributing watershed phosphorus inputs to wetlands helps reduce the potential for wetlands to become phosphorus sources. A holistic approach to waterbody management that incorporates watershed and within waterbody practices is more likely to lead to long-term success and sustainability.

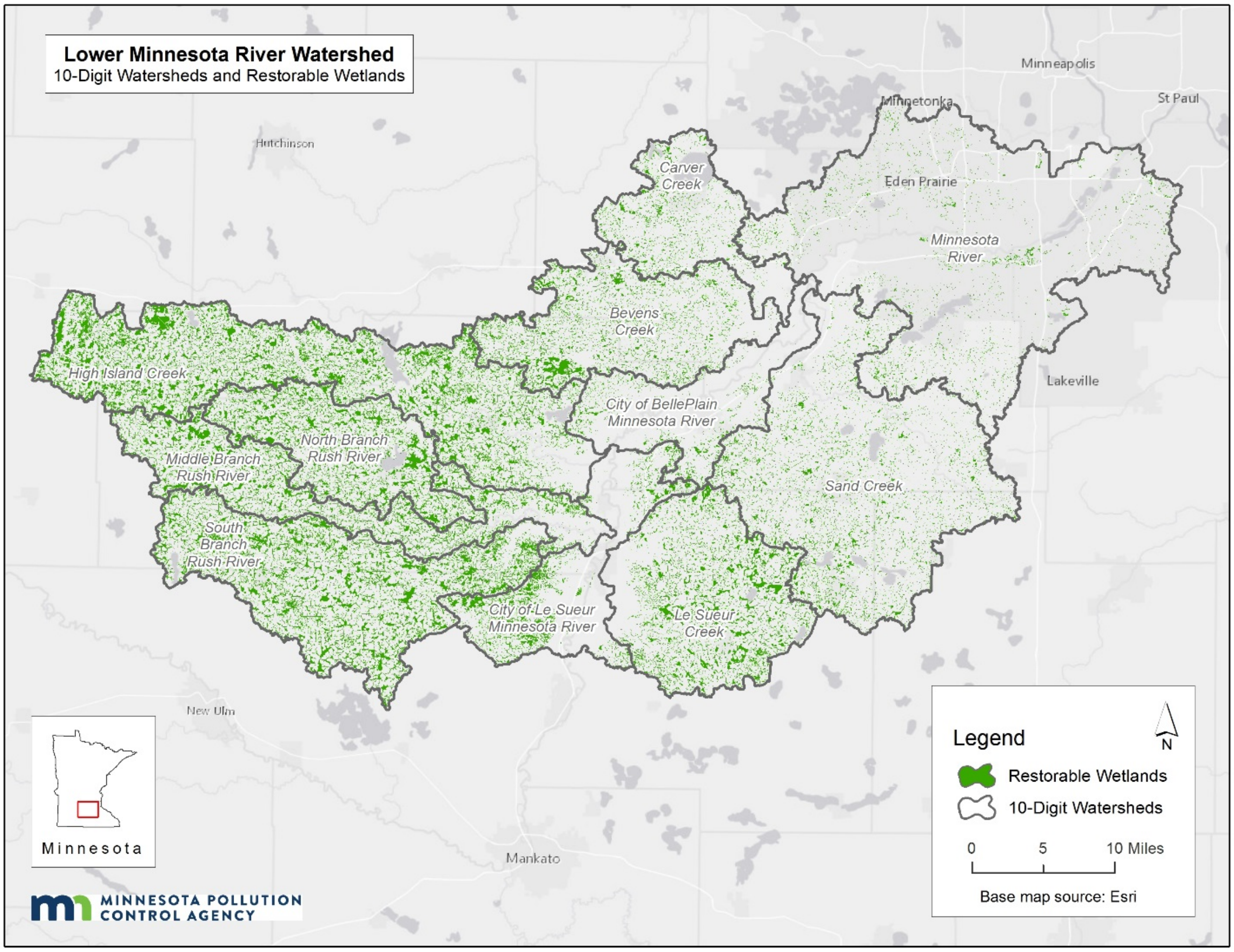


Figure 54 Restorable wetland analysis

Prioritizing Locations

Prioritizing is the process of selecting priority areas or issues based on justified water quality, environmental, or other concerns. Priority areas can be further refined by considering additional information: other water quality, environmental, or conservation practice effectiveness models or concerns; ordinances and rules; areas to create habitat corridors; areas of high public interest/value; and many more that can be selected to meet local needs.

Several priority areas were identified using the feedback from participants from the western side of the LMRW. Impaired lakes (Pepin, Sanborn, Clear, Greenleaf, High Island, Silver, Cody, Phelps, Spring, Upper Prior, Lower Prior, and Waconia) were identified as priority lakes within the LMRW. Impaired streams for priority work include South Branch of Rush River, Roger's Creek, Barney Fry Creek, Le Sueur Creek, Forest Prairie and Unnamed creeks (07020012-761 and 07020012-798). The metro area trout streams (Black Dog Creek, Eagle Creek, and Assumption Creek) were identified as protection waterbodies (Figure 55). These waterbodies provide both ecological and recreational value to local residents and are of high social importance. Areas with rare and natural plant and animal communities should be protected and enhanced. Rebuilding habitat utilized by rare and threatened species will help restore their populations while also helping improve watershed health and stream stability. A priority to protect drinking and groundwater sources especially in Ottawa, Sharon and Tyrone townships in Le Sueur County were also mentioned by the work group.

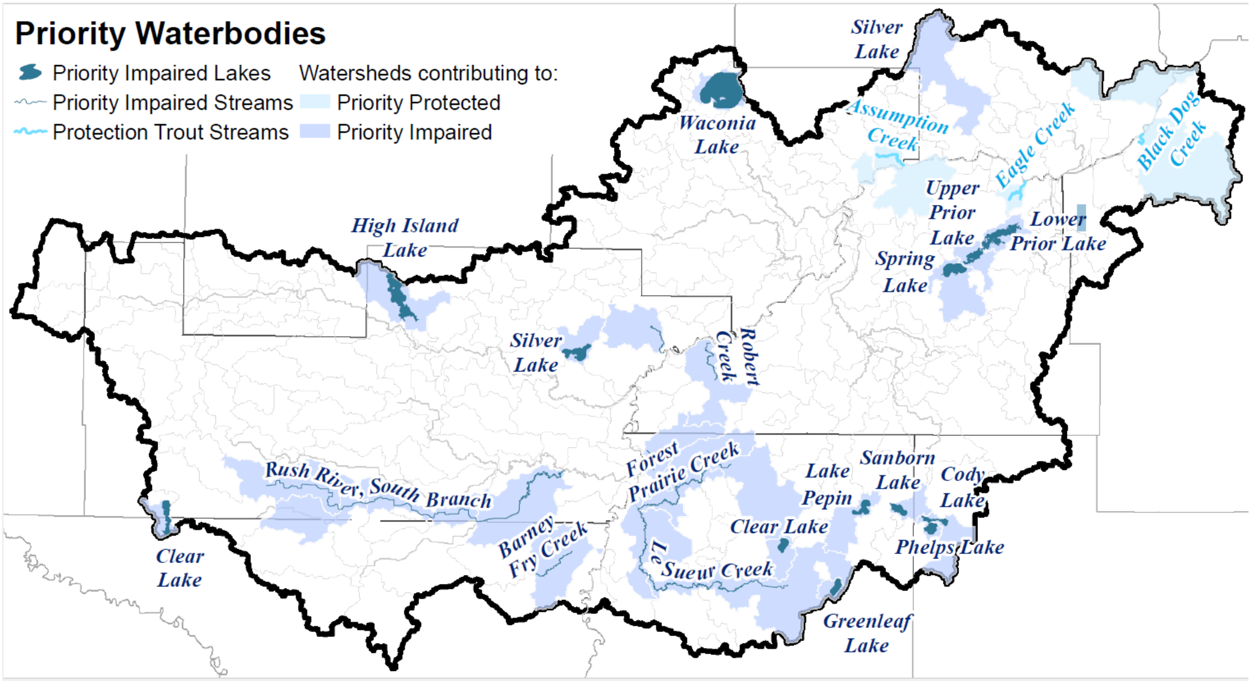


Figure 55 locally identified priority waterbodies in the LMRW.

Other priorities include focusing on "high impact/ mitigating" areas with the ability to mitigate pollutants and stressors when ideally managed or a disproportionately high negative impact when poorly managed. This would include reducing ditch and/or channel cleanouts when the channel has achieved a stable form with a floodplain. This naturally occurring process reduces sediment loading from bed and bank erosion, creates aquatic habitat and allows for water and sediment to be stored on the floodplain, and increases nutrient uptake. Two-stage channels often form in wider ditches, as a smaller channel forms within deposited sediment. These ditches function as narrow floodplains along the sides of the main channel and improve vegetative cover, resulting in decreased erosion potential and maintenance needs. For ditch improvement projects, collaboration is needed with drainage authorities, engineers, landowners, SWCDs, county and agency staff, and stakeholders to determine if it is possible to incorporate water storage as a part of the improvement process.

Restoring healthy channels and riparian areas of streams and ditches throughout the watershed offers critical habitat, improves water quality, and has the ability to buffer impacts of other stressors. Previously channelized streams in prioritized headwater reaches can be re-meandered to restore stable conditions, increase stream length, floodplain accessibility, improve habitat and decrease sediment. Reconnecting incised streams to their floodplains improves ecological and hydrological functions, including increased resiliency in the system and reducing downstream flooding impacts. Collaborative assessment, targeting, and planning is necessary on a subwatershed scale to strategically plan before engaging in stream restoration. Streambank stabilization practices should only be used in appropriate locations (for example threatened infrastructure) due to the natural hydrologic regime being so heavily altered in the LMRW resulting in unstable incised channels.

Since elevations drastically drop as water flows from relatively flat agricultural lands into the steeper Minnesota River valley, streams and ravines are naturally more erosive in these actively incising areas. Coupled with the change in relief and land use and hydrology changes, there have been numerous identified heavily eroding ravines. Ravines provide a unique set of challenges, but vegetative and structural practices can be incorporated on a site by site basis. An emphasis should be placed on increasing water storage to reduce flows in ravines.

These priority areas can be utilized as zones to focus restoration or protection strategies during the next 10 years.

3.2 Civic engagement

A key part of making progress in protecting and restoring waters is meaningful civic engagement and other forms of public participation. The goals of these efforts include raising awareness of land and water resources, shaping/informing local plans and projects, collecting data, and motivating/encouraging landowners to implement actions.

Accomplishments and ongoing efforts

In the eastern portion of the watershed local partners employ a range of efforts to engage and involve the public. These efforts include:

- Citizen advisory committees
- A farmer-led council
- Water quality improvement volunteer opportunities
- Volunteer water quality monitoring
- Outreach events: watershed tours, “Thank you” picnics for landowners participating in conservation efforts
- Other education/outreach: press releases, newsletters, website information, one-on-one contact

In the western portion of the watershed (Sibley, Le Sueur, Nicollet, McLeod, Renville, and Rice counties) civic engagement and public participation was a major focus during the LMRW project. This public participation work occurred from 2014 through the summer of 2018. The MPCA worked with county and SWCD staff in the watershed, consultants, citizens, and other state agency staff to work on two projects to promote civic engagement collaboratively in the area. Projects were tailored to local partner interest and capacity.

The Lower Minnesota Watershed civic engagement projects were the *Lower Minnesota Watershed WRAPS Civic Engagement North* and *Lower Minnesota Watershed WRAPS Civic Engagement South*.

The following contains a brief summary and results of each project as well as opportunities and constraints to water quality improvements that were identified as part of these individual projects. Complete final reports and attachments are found in the *Lower Minnesota River Watershed Approach Civic Engagement Project Summary* (MPCA 2018).

Lower Minnesota Watershed WRAPS Civic Engagement North and South

The purpose of these projects was to identify community/landowner opportunities, obstacles, and opinions on land management and water quality in the rural portions of the LMRW. Ultimately, this work helped identify land management options for the purposes of surface water quality restoration and protection within the western portion of the LMRW. Sibley and Le Sueur Counties sponsored the North and South projects respectively. Subcontracts were developed with other counties and SWCDs, University of Minnesota Department of Forestry staff, and Queenan Productions staff to develop project strategies based on their specialized expertise and knowledge of local community goals and interests. Preliminary meetings with local partners determined that basic level public participation (education, outreach, survey input and interviews) was appropriate for this project. Public participation included BMP and water quality focused education and outreach events specific to the watershed, a mail survey, interviews and other short surveys focused on BMP implementation. Contract participants also gathered, compiled, and analyzed information from the interactions (surveys, interviews and outreach events). The project also encouraged team building of different LGUs to develop WRAPS strategies for the rural portions of the LMRW.

Opportunities and Constraints

Based on the efforts of the “North” and “South” projects summarized above, opportunities and constraints for water quality improvements were identified. The list below reflects some of the future opportunities, influences on decision making and recognized accomplishments participants noted.

- There is some interest in water retention projects
- Landowners putting land into CCRP because of financial incentives
- Feel a good job has been done addressing some point source pollution areas
- Social influences drive conservation decision making
- Stewardship ethic and perceived benefits to land and community drive practice adoption
- Multiple factors can constrain conservation action
- Tillage changes could be easier to adopt (mulch, ridge, strip till) – possibly cheaper than cover crops
- Discussing conservation practice options could be beneficial during land management contract talks
- Owner/operators easier to target for cover crops
- Increased interest in soil health, CRP, cover crops
- Vegetative strips around ravines – less erosion
- Majority of landowners understand that water resources are important
- Need for more education and outreach for landowners on a variety of topics related to watersheds and conservation practices

- Work should be done to develop tools for farmers to estimate their fields' impact/results of practice adoption
- The list below reflects some of the constraints and conflicts identified by participants.
- Different incentives would make implementing practices more appealing
- Government shouldn't be competing with producers
- Issues with phosphorus in cities/towns not being treated
- Lack of personal and social norms for civic action is a major constraint to community engagement in water protection
- Cover crop programs are too restrictive
- Financial reasons
- Lack of equipment to implement and install BMPs
- Technical assistance not available in the area
- Community leadership is lacking regarding water quality issues
- Many landowners have already implemented BMPs

Public notice for comments

Throughout all phases of this project multiple meetings were held with stakeholders to discuss and seek input. In addition, the MPCA provided opportunities to stakeholders to review and comment on the draft reports. As a final step, an opportunity for public comment on the draft WRAPS report was provided via a public notice in the *State Register* from July 22, 2019 through September 20, 2019. As a result, there were 12 comment letters received and responded to.

3.3 Restoration and protection strategies

This section provides sets of strategies estimated to achieve water quality targets for the subject waterbodies of this project. The strategies are provided in Tables 14 through Table 17, which are organized geographically: Table 14 – western subwatersheds (High Island Creek, Rush River, City of Le Sueur HUC-10 and Le Sueur Creek), Table 15 – Carver County WMO and Lower Minnesota River WD waterbodies in Carver County, Table 16 – Nine Mile Creek WD and Riley-Purgatory-Bluff Creek WD and Table 17 – Scott County and Le Sueur/Rice County portions of Sand Creek.

Where possible the strategies were derived through quantitative methods; however, in other cases, only more qualitative characterization of actions was feasible. The chief goal of providing this information is to inform local planning. Specifically, by providing an overall set of actions needed to meet the goals (over some period of years or decades), local planners can focus on a subset of actions to take on for their shorter-term (e.g., 10-year) planning cycle. This provides a means to gauge a plan's ability to make progress over time.

One of the primary tools used to estimate reductions for sediment (TSS) and phosphorus for impairments in the agricultural parts of the watershed is HSPF-Scenario Application Manager or SAM.

(Note: SAM can also be used for nitrate-nitrogen. This is discussed further below in this section.) SAM is a graphical interface with the HSPF model developed for the project. Among its functions is user selection of BMPs (primarily agricultural) at specified levels of implementation to determine resulting pollutant load reductions and water quality improvements. Within the database that SAM draws upon are the acres 'suitable', or available, for implementation of a given BMP (based on data provided by NRCS for each HUC-12 indicating acres that had previously been implemented from 2004 through 2015). (For further information on SAM see references in Section 5.)

A key consideration for strategies for waterbodies in this watershed is recognizing established needs for larger downstream waterbodies. Currently, TSS load reductions are called for in the Minnesota River, the Mississippi River and Lake Pepin (per the *South Metro Mississippi River TSS TMDL* (MPCA 2015) and accompanying *Sediment Reduction Strategy* (MPCA 2015)). Phosphorus reductions are needed in the Minnesota River per both the *Lower Minnesota River Dissolved Oxygen TMDL* (MPCA 2004) and the *Lake Pepin Watershed Phosphorus TMDLs* (in draft). Also, there are statewide or basin goals for nitrate for the Gulf of Mexico hypoxia problem (per the *Minnesota Nutrient Reduction Strategy* (MPCA 2014). Other considerations for BMP selection for a scenario included: load reduction-effectiveness, cost-effectiveness, state law requirements, and landowner willingness. (Also, the BMP must be among those BMPs currently in the SAM platform. Notable BMPs that SAM cannot simulate but that can be very effective include channel restoration of rivers and streams, and restoration of altered wetlands).

With these factors in mind, a SAM scenario was derived as shown below for use in all agricultural areas. The strategy tables provide detail of load reductions for the individual BMPs associated with this scenario for waterbodies with either TSS or TP impairments.

BMP	Adoption Rate (% of suitable acres)	Rationale for selection in scenario
Nutrient management (fertilizer, soil, manure)	100%	This is a profitable practice and essentially translates to using the University of MN's recommendations for TP and N for commercial fertilizer and manure, including right rate, timing, placement and source. Also, proper manure application practices reduce *E. coli* loading.
Riparian buffers (50 ft)	100%	Required by state law. Good compliance has occurred for several of the areas in this watershed, so remaining suitable acres may be inaccurate.
Conservation tillage (>30% residue cover) on lands > 2% slope	100%	This is a relatively well-accepted practice that has many benefits (TP, TSS reduction; improved soil health), but some challenges for some soil types (thus, 100% is an aggressive goal).
Alternative intakes (perforated riser pipe)	100%	Very low-cost solution; other alternate practices (e.g., rock inlets) can be used as well. Reduces TP and sediment.
Cover crops with corn and soybeans	75%	This practice and rate is an essential part of the Sediment Reduction Strategy for Minnesota River and South Metro Mississippi River. 75% is an aggressive goal; more demonstration/assessment is needed on the landscape in order to achieve this. Multiple benefits: TP, TSS, N reductions; improved hydrology and soil health.
Perennial crops for harvest	20%	This practice and rate is an essential part of the Sediment Reduction Strategy. 20% is an aggressive goal and is contingent on continued research for profitable perennial crops. Multiple benefits: TP, TSS, N reductions; improved hydrology and soil health. (Conversion of cropland to rural residential—a trend in areas close to the metro area—may yield similar reductions.)

BMP	Adoption Rate (% of suitable acres)	Rationale for selection in scenario
Water and sediment control basins (WASCOBs)	25%	This is a relatively well-accepted and effective practice. (The 25% selected has no special significance—it was set to represent a reasonably high-level of adoption. Other equivalent practices (e.g., grassed waterways) could be substituted.)

Some further explanation and comments on the above approach:

- The scenario above was limited to the seven practices above largely for simplicity and to minimize the length of the strategy tables. Therefore, other practices with similar effectiveness should certainly remain in the mix for ongoing work. In addition, practices that are important and needed, but are not in the SAM platform, are included in the strategy table where appropriate (though load reductions are not quantified).
- This scenario is intended to be aggressive since the majority of the impairments require high reductions. For many of the impairments; however, the outlined actions alone may not predict enough reduction to reach the water quality targets. This may be because: 1) additional BMPs added to the strategy tables are not quantifiable by SAM and so do not add to the sum total, 2) the degree of land alteration and/or water resource degradation may be extensive and not fully restorable with the selected actions, 3) limits of the tool and underlying data and model (i.e., amount/quality of data available, calibration of the HSPF model, and accuracy/knowledge of BMP effectiveness and other variables entered into SAM), or 4) a combination of the above. As such, ongoing evaluation of efforts and “adaptive management” will be essential.

Some additional factors and comments regarding the contents and construction of the strategy tables include the following:

- There is a layer of complexity added by the fact that geographically many of the impairments are “nested”, i.e., one impaired waterbody flows into another impaired waterbody, which flows into another impaired waterbody, etc. This means that the effort for a given waterbody depends on what occurs for upstream waterbodies. This nesting is noted in the strategy tables for TSS and TP impairments with references to reductions needed in upstream waterbodies. For upstream lakes, the reduction in TP at the outflow was calculated using BATHTUB and takes into account settling of a portion of the TP that occurs in the lake.
- Strategies for *E. coli* reductions were done in a qualitative fashion due to the general lack of quantitative information on BMP performance with this parameter. Strategy types are limited to feedlots, septic systems and urban stormwater. (Although land-applied manure may be a source needing reduction, this was not specifically called out for any of the *E. coli* impairments because it is already captured in the watershed wide SAM scenario within the nutrient management BMP.)
- Strategies for many of the biota impairments likewise were done in a qualitative fashion because: 1) TMDLs were often not associated with these impairments (i.e., no specific pollutant load reduction is currently available) and 2) the nonpollutant stressors of biota impairments (e.g., degraded habitat) are not amenable to quantification. It is also important to note that strategies listed for biota impairments were kept limited since any one impairment would take a

significant level of evaluation and review. For many biota impairments, a reference to the strategies for TSS and/or TP is made because those strategies should make significant progress towards both the pollutant and nonpollutant stressors.

- Strategies for lake TP impairments often include a mix of load reductions estimated by the SAM scenario strategies (for agricultural sources) and load reductions called for by the TMDL (e.g., internal load reduction or MS4 reduction to meet a wasteload allocation).

Although not included in the strategy tables, a nitrate-nitrogen reduction scenario was conducted using SAM at the watershed wide level. Specifically, the seven BMPs and adoption rates in the scenario above were run for the LMRW and showed a reduction to the Minnesota River of 9.6 million pounds/year of nitrogen from the estimated 20.1 million pounds/year presently delivered from this watershed. This represents a 48% reduction in loading. The Minnesota NRS calls for a 20% reduction in nitrogen loading by 2025 and a 45% reduction by 2040. (These reductions levels use a baseline of 1980 through 1996 conditions, so a direct comparison to the SAM scenario done here cannot be made).

In addition to the nitrogen reduction scenario above, watershed wide reduction scenarios were also run for both TSS and TP using SAM. The TP scenario showed a reduction of approximately 238,000 pounds/year or 28% from baseline conditions; the TSS scenario showed a reduction of approximately 29,000 tons/year or 12% from baseline conditions.

3.4 Interim targets and timeframes

Among the required elements of WRAPS are timelines for achieving water quality targets and interim milestones within 10 years of strategy adoption. It is the intent of the implementing organizations in this watershed to make steady progress in terms of pollutant reduction. However, as noted previously, needed load reductions are generally high—the impaired conditions were a long time in the making. Accordingly, as a very general guideline or goal, it is assumed that 1% to 2% of the overall needed reduction will occur per year on average. This means that a waterbody needing an overall 10% reduction will be achieved in 5 to 10 years and one with an overall reduction of 50% will take 25 to 50 years.

Again, this is a general guideline and approximation. Factors that may mean slower progress include limits in funding or landowner acceptance, challenging fixes (e.g., unstable bluffs and ravines, invasive species) and unfavorable climatic factors. Conversely, there may be faster progress for some impaired waters, especially where high-impact fixes are slated to occur or where the watershed is subject to focused efforts.

Table 14: Strategies and actions proposed for the Lower Minnesota River Watershed.

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
All	All	All	--	--	--	SAM Scenario: combination of seven strategies for agricultural areas (see description of scenario in text); addresses downstream needs in Minnesota River, Lake Pepin and Gulf of Mexico hypoxia; other equivalent BMPs can be substituted.					The relevant SAM scenario actions are shown for specific TP or TSS TMDL waterbodies below with load reductions quantified.
						Wetland restoration: where feasible; reduces TP, N; improves hydrology and wildlife habitat. This helps both local and downstream waters.					
						NPDES and general permit compliance: wastewater facilities, CAFOs, MS4s, construction sites, industrial stormwater sites					
						Reduce salt used on roads, parking lots and sidewalks (*see TCMA Chloride Management Plan (2016)*)					
High Island Creek WD	High Island Ck (-653)		Sediment /TSS	210 mg/L (90th percentile); 6556 tons/yr (per HSPF)	69% reduction; 4524 tons/yr	Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	8,328	Acres Treated	180	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	6,918	Acres	82	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	40,092	Acres draining to	899	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	37,059	Acres	659	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	1,967	Acres draining to	42	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	11,027	Acres	254	
						Stream banks, bluffs and ravines protected/restored	Streambanks/shoreline - stabilized or restored [580]	--	--	TBD	
									Total tons reduced	2,116	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
			Biota pollutant stressors: TSS, TP, N	FIBI = 10.5 - 20.0; MIBI = 10.7	FIBI = 35; MIBI = 22	*See applicable SAM scenario strategies from downstream TSS impairments (-653, -834) + nutrient management strategy from watershedwide scenario*					Low DO also ID'ed as stressor, but causation not fully evaluated.
			Biota nonpollutant stressors: habitat, altered hydrology								
	JD 11 (-590, -593), JD 15 (-682)		Biota pollutant stressors: TSS, TP, N	-590: FIBI = 0 - 17.4; -593: FIBI = 0, MIBI = 6.1; -682: FIBI = 0, MIBI = 10.1	-590: FIBI = 15; -593: FIBI = 35, MIBI = 22; -682: FIBI = 15, MIBI = 22						Low DO also ID'ed as stressor for -590 and -593, but causation not fully evaluated.
			Biota nonpollutant stressors: habitat, altered hydrology								
	CD 39 (-683)		Biota pollutant stressors: N	MIBI = 17.4	MIBI = 22						
			Biota nonpollutant stressors: habitat, altered hydrology								
	High Island Ck (-838)		Biota pollutant stressors: TSS, TP, N	FIBI = 13.9 - 24.1; MIBI = 13.0	FIBI = 50; MIBI = 37						
			Biota nonpollutant stressors: habitat, altered hydrology								
	JD 12 (-794)		Biota pollutant stressors: TSS, TP	FIBI = 26.7	FIBI = 33						

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	Waterbody (ID)	Location and Upstream Influence Counties	Pollutant/ Stressor	Current WQ Conditions (conc. / load / biota scores)	Final WQ Goal (% / load to reduce / biota score target)	Strategy Type	BMP	Amount	Unit	Est'd reduction (TSS = tons/yr; TP = lbs/yr)	Notes
			Biota nonpollutant stressors: habitat, altered hydrology								
	High Island Ck (-834)		Sediment /TSS	247 mg/L (90th percentile); 15,834 tons/yr (per HSPF)	74% reduction; 11,717 tons/yr	Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	8,343	Acres Treated	288	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	7,905	Acres	145	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	19,298	Acres draining to	607	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	33,743	Acres	909	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	2,038	Acres draining to	67	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	9,744	Acres	340	
						Stream banks, bluffs and ravines protected/restored	Streambanks/shoreline - stabilized or restored [580]	--	--	TBD	
									Total tons reduced	2,356	
			Biota pollutant stressors: TSS, TP, N	FIBI = 23.7 - 52.1; MIBI = 19.4 - 61.2	FIBI = 50; MIBI = 37	*See applicable SAM scenario strategies + nutrient management strategy from watershedwide scenario*					
			Biota nonpollutant stressors: habitat								
	High Island Ditch 2 (-588)		Sediment /TSS	Limited TSS data; 732 tons/yr (per HSPF)	Not calculated	Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	1,175	Acres Treated	52	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	545	Acres	13	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	2,949	Acres draining to	125	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	4,836	Acres	169	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	193	Acres draining to	8	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	1,438	Acres	65	
						Stream banks, bluffs and ravines protected/restored	Streambanks/shoreline - stabilized or restored [580]	--	--	TBD	
									Total tons reduced	432	
	Buffalo Ck (-832)		Sediment /TSS	375 mg/L (90th percentile); 934 tons/yr (per HSPF)	83% reduction; 775 tons/yr	Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	2,551	Acres Treated	52	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	1,648	Acres	17	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	9,844	Acres draining to	178	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	10,212	Acres	152	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	535	Acres draining to	10	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	2,852	Acres	55	
						Stream banks, bluffs and ravines protected/restored	Streambanks/shoreline - stabilized or restored [580]	--	--	TBD	
									Total tons reduced	464	
			Biota pollutant stressors: TSS, TP, N	FIBI = 39.7 - 54.1; MIBI = 22.7 - 32.9	FIBI = 55; MIBI = 37	*See applicable SAM scenario strategies + nutrient management strategy from watershedwide scenario*					
			Biota nonpollutant stressors: habitat, connectivity, altered hydrology			Habitat & stream connectivity management	Culvert replacement	TBD	--	TBD	
			Phosphorus			Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	5,111	Acres	132	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
	High Island Lk (main basin) (72-0050-01)			0.311 mg/L; 31,019 lbs/yr	85% reduction; 26,222 lbs/yr	Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	557	Acres Treated	276	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	709	Acres	127	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	1,538	Acres draining to	440	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	3,364	Acres	527	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	178	Acres draining to	82	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	1,022	Acres	469	
						Septic system improvements	Septic System Improvement [126M]	3 (est.)	Systems	4	
						In-lake management	TBD	--	--	24,031	
									Total lbs reduced	26,088	
	Silver (72-0013-00)		Phosphorus	0.249 mg/L; 10,824 lbs/yr	89% reduction; 9694 lbs/yr	Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	3,761	Acres	76	
						Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	797	Acres Treated	244	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	805	Acres	112	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	2,055	Acres draining to	480	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	2,746	Acres	334	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	201	Acres draining to	72	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	757	Acres	269	
						Septic system improvements	Septic System Improvement [126M]	3 (est.)	Systems	4	
						In-lake management	TBD	--	--	7,864	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
									Total lbs reduced	9,455	
North Branch Rush River	CD 18 (-791)		Biota pollutant stressors: TSS, TP, N	FIBI = 13.7	FIBI = 33	*See applicable strategies listed for TP for downstream Lk Titlow*					
			Biota nonpollutant stressors: habitat, connectivity, altered hydrology								
	CD 18 (-714)		Bacteria /E. coli	Geomean = 1100 orgs/100 mL	89% reduction	Septic system improvements	Septic System Improvement [126M]	High	--	TBD	
	Rush R, N Br (JD 18) (-555)		Biota pollutant stressors: TSS, TP, N	FIBI = 7.7 - 20.3; MIBI = 14.1	FIBI = 33 - 35; MIBI = 22	*See applicable strategies listed for TP for downstream Lk Titlow*					Low DO also ID'ed as stressor, but causation not fully evaluated.
			Biota nonpollutant stressors: habitat, altered hydrology								
			Bacteria /E. coli	Geomean = 1256 orgs/100 mL	90% reduction	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	High	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	High	--	TBD	
	Unnamed ditch (-713)		Bacteria /E. coli	Geomean = 1180 orgs/100 mL	89% reduction	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	Low	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	High	--	TBD	
	Titlow Lk (72-0042-00)		Phosphorus	0.272 mg/L; 29,306 lbs/yr	82% reduction; 24,049 lbs/yr	Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	29,814	Acres	563	
						Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	5,147	Acres Treated	1,436	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	4,378	Acres	564	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	23,577	Acres draining to	5,007	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	20,057	Acres	2,252	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	1,149	Acres draining to	381	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	6,002	Acres	1,975	
						Stream banks, bluffs and ravines protected/restored	Streambanks/shoreline - stabilized or restored [580]	--	--	TBD	
						Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	--	--	TBD	
						In-lake management	TBD	--	--	8,313	
									Total lbs. reduced	20,491	
	Rush R, N Br (CD 55) (-556)		Biota pollutant stressors: TSS, TP	FIBI = 6.5 - 21.0; MIBI = 19	FIBI = 35; MIBI = 22	*See applicable strategies listed for TSS for downstream -548 (on Middle Br Rush R) + nutrient management strategy from watershedwide scenario*					
			Biota nonpollutant stressors: habitat, altered hydrology								
	Rush R, N Br (CD 55) (-558)		Bacteria /E. coli	Geomean = 1509 orgs/100 mL	17% reduction	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	High	--	TBD	
						Urban Stormwater Runoff Control	Stormwater practices to meet TMDL & permit conditions	Low	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	High	--	TBD	
Middle Branch Rush River	CD 49 (-677)		Biota pollutant stressors: TP, N, Cl	FIBI = 0; MIBI = 15.9	FIBI = 15; MIBI = 22	*See applicable strategies listed for TSS for downstream -548 + nutrient management strategy from watershedwide scenario*					Low DO also ID'ed as stressor, but causation not fully evaluated. Chloride source not identified.
			Biota nonpollutant stressors: habitat, altered hydrology								

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
	CD 44 (-786)		Biota pollutant stressors: TSS, TP, N	FIBI = 8.9; MIBI = 9.9	FIBI = 33; MIBI = 22						Low DO also ID'ed as stressor, but causation not fully evaluated.
			Biota nonpollutant stressors: habitat, connectivity, altered hydrology								
	Rush R, M Br (CD 23 & 24) (-586)		Biota pollutant stressors: N	FIBI = 23.1; MIBI = 15.2	FIBI = 35; MIBI = 24						
			Biota nonpollutant stressors: habitat, altered hydrology								
	CD 42 (-551), CD 56 (-790)		Biota pollutant stressors: TP, N	-551: MIBI = 9.7; -790: MIBI = 11.2	-551: MIBI = 24; -790: MIBI = 22						Low DO also ID'ed as stressor, but causation not fully evaluated.
			Biota nonpollutant stressors: habitat, altered hydrology								
	Unnamed ditch (-788)		Biota pollutant stressors: N	MIBI = 21.9	MIBI = 22						
			Biota nonpollutant stressors: habitat, altered hydrology								
	Rush R, M Br (CD 23 & 24) (-550)		Bacteria /E. coli	Geomean = 795 orgs/100 mL	21% reduction	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	High	--	TBD	
						Urban Stormwater Runoff Control	Stormwater practices to meet TMDL & permit conditions	Low	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	High	--	TBD	
	Rush R (-548)		Sediment /TSS	Limited TSS data; 7634	Not calculated	Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	21,148	Acres Treated	353	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	Waterbody (ID)	Location and Upstream Influence Counties	Pollutant/ Stressor	Current WQ Conditions (conc. / load / biota scores)	Final WQ Goal (% / load to reduce / biota score target)	Strategy Type	BMP	Amount	Unit	Est'd reduction (TSS = tons/yr; TP = lbs/yr)	Notes
				tons/yr (per HSPF)		Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	18,575	Acres	153	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	82,975	Acres draining to	1,283	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	78,111	Acres	1,009	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	5,150	Acres draining to	77	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	22,549	Acres	380	
						Stream banks, bluffs and ravines protected/restored	Streambanks/shoreline - stabilized or restored [580]	--	--	TBD	
									Total tons reduced	3,255	
			Biota pollutant stressors: TSS, N	FIBI = 37.0 - 40.5; MIBI = 18.1 - 27.1	FIBI = 50; MIBI = 37	*See applicable strategies listed for TSS + nutrient management strategy from watershedwide scenario*					Low DO also ID'ed as stressor, but causation not fully evaluated.
			Biota nonpollutant stressors: habitat								
	CD 50 (-796)		Biota pollutant stressors: TSS, N	FIBI = 50.4; MIBI = 27.2	FIBI = 55; MIBI = 37	*See applicable strategies listed for TSS for downstream -548 + nutrient management strategy from watershedwide scenario*					
			Biota nonpollutant stressors: habitat, connectivitiy, altered hydrology								
	Rush R (-521)		Sediment /TSS	580 mg/L (90th percentile); 13,059 tons/yr (per HSPF)	89% reduction; 11,623 tons/yr	Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	20,427	Acres Treated	408	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	22,982	Acres	287	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	72,930	Acres draining to	1,418	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	77,587	Acres	1,314	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	6,272	Acres draining to	140	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	21,984	Acres	485	
						Stream banks, bluffs and ravines protected/restored	Streambanks/shoreline - stabilized or restored [580]	--	--	TBD	
									Total tons reduced	4,052	
			Biota pollutant stressors: TSS, N	FIBI = 37.6 - 40.9	FIBI = 49	*See applicable strategies listed for TSS + nutrient management strategy from watershedwide scenario*					
			Biota nonpollutant stressors: habitat								
South Branch Rush River	CD 32A (-783)		Biota pollutant stressors: TP, N	FIBI = 7.2; MIBI = 14.5	FIBI = 15; MIBI = 22	*See applicable strategies listed for TSS for downstream -521 + nutrient management strategy from watershedwide scenario*					
			Biota nonpollutant stressors: habitat, altered hydrology								
	Rush R, S Br (-825), CD 9 (-784), CD 13 (-636), CD 30A (-801), JD 1 (-785)		Biota pollutant stressors: TSS, TP, N	-825: FIBI = 17.6 - 30.1, MIBI = 20.5 - 23.4; -784: FIBI = 30.6; -636: MIBI = 13.3; -801: FIBI = 8.9, MIBI = 12.4; -785: MIBI = 16.1	-825: FIBI = 35, MIBI = 24; -784: FIBI = 33; -636: MIBI = 22; -801: FIBI = 15, MIBI = 22; -785: MIBI = 22						Low DO also ID'ed as stressor for -828 and -801, but causation not fully evaluated.
			Biota nonpollutant stressors: habitat, altered hydrology								
	JD 1A (-509)		Bacteria /E. coli			Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	High	--	TBD	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
				Geomean = 1844 orgs/100 mL	32% reduction	Septic system improvements	Septic System Improvement [126M]	High	--	TBD	
	Rush R, S Br (-826)		Biota pollutant stressors: TSS, TP, N	FIBI = 29.8; MIBI = 27.5	FIBI = 50; MIBI = 37	*See applicable strategies listed for TSS for downstream -521 + nutrient management strategy from watershedwide scenario*					
City of Le Sueur - MN R HUC10	CD 75 (-793)		Biota pollutant stressors: TSS, TP, N	FIBI = 17	FIBI = 33	*See watershedwide SAM scenario strategies*					
			Biota nonpollutant stressors: habitat, connectivity, altered hydrology			Habitat & stream connectivity management	Culvert replacement	--	--	TBD	
	CD 47A (-792)		Biota pollutant stressors: TP, N	FIBI = 15.3	FIBI = 33	*See watershedwide SAM scenario strategies*					Low DO also ID'ed as stressor, but causation not fully evaluated.
			Biota nonpollutant stressors: habitat, altered hydrology								
	Barney Fry Ck (-602)		Biota pollutant stressors: TP	FIBI = 33.0 - 44.8; MIBI = 14.7	FIBI = 55; MIBI = 37						
			Biota nonpollutant stressors: altered hydrology								
			Bacteria /E. coli	Geomean = 500 orgs/100 mL	75% reduction	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	High	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	High	--	TBD	
	Unnamed Ck (-761)		Bacteria /E. coli	Geomean = 448 orgs/100 mL	72% reduction	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	High	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	High	--	TBD	
			Phosphorus			Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	558	Acres	21	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
Le Sueur Creek	Greenleaf Lk (40-0020-00)			0.112 mg/L; 1713 lbs/yr	66% reduction; 1125 lbs/yr	Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	130	Acres Treated	74	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	207	Acres	56	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	169	Acres draining to	75	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	400	Acres	94	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	56	Acres draining to	39	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	114	Acres	79	
						Septic system improvements	Septic System Improvement [126M]	2 (est.)	Systems	2	
						In-lake management	TBD	--	--	530	
									Total lbs reduced	970	
	Clear Lk (40-0079-00)		Phosphorus	0.334 mg/L; 15,884 lbs/yr	96% reduction; 15,243 lbs/yr	Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	1,837	Acres	64	
						Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	365	Acres Treated	193	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	823	Acres	200	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	422	Acres draining to	170	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	1,318	Acres	279	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	206	Acres draining to	129	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	368	Acres	228	
						Septic system improvements	Septic System Improvement [126M]	3 (est.)	Systems	3	
						In-lake management	TBD	--	--	12,882	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
									Total lbs reduced	14,148	
	Le Sueur Ck (-823)		Biota pollutant stressors: TSS, TP	FIBI = 5.6	FIBI = 15	*See watershedwide SAM scenario strategies*					
			Biota nonpollutant stressors: habitat								
	Le Sueur Ck (-824)		Biota pollutant stressors: N	FIBI = 26.9 - 41.0; MIBI = 17.8 - 40.4	FIBI = 50; MIBI = 37						
			Biota nonpollutant stressors: habitat, connectivity, altered hydrology			Habitat & stream connectivity management	Culvert replacement	--	--	TBD	
			Bacteria /E. coli	Geomean = 301 orgs/100 mL	58% reduction	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	High	--	TBD	
						Urban Stormwater Runoff Control	Stormwater practices to meet TMDL & permit conditions	Low	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	High	--	TBD	
	Unnamed Ck (-768)		Biota pollutant stressors: N	FIBI = 48.0 - 54.2; MIBI = 34.1	FIBI = 55; MIBI = 37	*See watershedwide SAM scenario strategies*					
			Biota nonpollutant stressors: connectivity, altered hydrology			Habitat & stream connectivity management	Culvert replacement	--	--	TBD	
	CD 42 (-772)		Biota pollutant stressors: TSS	FIBI = 0; MIBI = 29.9	FIBI = 33; MIBI = 30	*See watershedwide SAM scenario strategies*					Low DO also ID'ed as stressor, but causation not fully evaluated.
			Biota nonpollutant stressors: habitat, connectivity, altered hydrology			Habitat & stream connectivity management	Culvert replacement	--	--	TBD	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	Waterbody (ID)	Location and Upstream Influence Counties	Pollutant/ Stressor	Current WQ Conditions (conc. / load / biota scores)	Final WQ Goal (% / load to reduce / biota score target)	Strategy Type	BMP	Amount	Unit	Est'd reduction (TSS = tons/yr; TP = lbs/yr)	Notes
	JD 4 (-767)		Biota pollutant stressors: TSS, N	FIBI = 0	FIBI = 33	*See watershedwide SAM scenario strategies*					
			Biota nonpollutant stressors: habitat								
	CD 34 (-764)		Biota pollutant stressors: Stressor ID inconclusive	FIBI = 0; MIBI = 20.3	FIBI = 55; MIBI = 37						
	Unnamed Ditch (-763)		Biota pollutant stressors: N	FIBI = 0; MIBI = 27.7	FIBI = 55; MIBI = 43						
			Biota nonpollutant stressors: habitat								
	Forest Prairie Ck (-725)		Biota pollutant stressors: N	FIBI = 9.2 - 48.7; MIBI = 12.1 - 22.1	FIBI = 50; MIBI = 37						
			Biota nonpollutant stressors: habitat, connectivity, altered hydrology			Habitat & stream connectivity management	Culvert replacement	--	--	TBD	
Bevens Creek	Lk Maria (10-0058-00)		Phosphorus	0.188 mg/L; 1020 lbs/yr	85% reduction; 869 lbs/yr	Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	108	Acres	2	
						Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	23	Acres Treated	7	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	61	Acres	8	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	0	Acres draining to	0	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	73	Acres	9	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	15	Acres draining to	5	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	23	Acres	8	
						Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	--	--	50	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
						Septic system improvements	Septic System Improvement [126M]	4 (est.)	Systems	3	
						In-lake management	TBD	--	--	680	
									Total lbs reduced	773	
	Unnamed ditch(-335)		Bacteria /E. coli	Geomean = 2420 orgs/100 mL	48% reduction	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	Low	--	TBD	
						Urban Stormwater Runoff Control	Stormwater practices to meet TMDL & permit conditions	High	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	High	--	TBD	
	Bevens Ck (-843)		Phosphorus	0.388 mg/L; 18,630 lbs/yr (per HSPF)	61% reduction; 11,364 lbs/yr	Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	18,500	Acres	501	
						Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	3,603	Acres Treated	1,598	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	3,279	Acres	614	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	8,586	Acres draining to	2,568	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	13,089	Acres	2,132	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	950	Acres draining to	459	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	3,804	Acres	1,816	
						Stream banks, bluffs and ravines protected/restored	Streambanks/shoreline - stabilized or restored [580]	--	--	TBD	
						Wastewater Point Source Management	Wastewater phos. reductions to meet TMDL & permit conditions	--	--	(Not calculated)	
									Total lbs Reduced	9,688	
			Biota pollutant stressors: TSS, TP	MIBI = 18.4	MIBI = 30	*See applicable strategies listed for TP; also, Carver and Bevens Creek: Turbidity TMDL Implementation Plan (2013)*					Low DO also ID'ed as stressor, but causation not fully evaluated.

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
			Biota nonpollutant stressors: habitat, altered hydrology								
	Bevens Ck (-845)		Biota pollutant stressors: TP	FIBI = 21.0	FIBI = 35	*See watershedwide SAM scenario strategies; also, Bevens Creek Turbidity TMDL Implementation Plan (2013)*					
			Biota nonpollutant stressors: habitat, altered hydrology								
	Bevens Ck (-848)		Biota pollutant stressors: TSS, TP	FIBI = 37.9 - 47.0; MIBI = 30	FIBI = 50; MIBI = 30						
	Bevens Ck (-514)		Biota pollutant stressors: TSS, TP, N	FIBI = 47.4; MIBI = 26.1	FIBI = 50; MIBI = 37						
	JD 22 (-629)		Bacteria /E. coli	Geomean = 1245 orgs/100 mL	90% reduction	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	High	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	High	--	TBD	
	Silver Ck (-813)		Biota pollutant stressors: TSS, N	FIBI = 21.2 - 33.6; MIBI = 21.5 - 27.3	FIBI = 50 - 55; MIBI = 37 - 43	*See watershedwide SAM scenario strategies; also, Bevens Creek Turbidity TMDL Implementation Plan (2013)*					
			Biota nonpollutant stressors: habitat								
Carver Creek			Phosphorus			Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	166	Acres	4	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
	Rutz Lk (10-0080-00)			0.179 mg/L; 573 lbs/yr	81% reduction; 464 lbs/yr	Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	13	Acres	1	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	128	Acres	6	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	4	Acres draining to	0.3	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	111	Acres	5	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	32	Acres draining to	5	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	38	Acres	4	
						Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	--	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	3 (est.)	Systems	4	
						In-lake management	TBD	--	--	268	
									Total lbs Reduced	297	
	Lk Waconia (10-0059)		Biota pollutant stressors: TP	FIBI = 12.8	FIBI = 45	TBD					Evaluation of needed TP reduction for aquatic life not conducted
			Biota nonpollutant stressors: nonnative aquatic species, lakeshore development			In-lake management	Aquatic invasive species evaluation/management TBD	--	--	--	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	Waterbody (ID)	Location and Upstream Influence Counties	Pollutant/ Stressor	Current WQ Conditions (conc. / load / biota scores)	Final WQ Goal (% / load to reduce / biota score target)	Strategy Type	BMP	Amount	Unit	Est'd reduction (TSS = tons/yr; TP = lbs/yr)	Notes
						Riparian lakeshore restoration	Restore/enhance riparian lakeshore habitat complexity, including reestablishment of trees, shrubs, and natural ground cover	--	--	--	
	Unnamed Ck (-907)		Bacteria /E. coli	Geomean = 704 orgs/100 mL	82% reduction	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	Low	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	High	--	TBD	
	Unnamed Ck (-618)		Bacteria /E. coli	Geomean = 274 orgs/100 mL	54% reduction	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	High	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	High	--	TBD	
	Unnamed Ck (-619)		Bacteria /E. coli	Limited data	Not calculated	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	High	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	High	--	TBD	
	Unnamed ditch (-527)		Bacteria /E. coli	Geomean = 296 orgs/100 mL	57% reduction	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	Low	--	TBD	
						Urban Stormwater Runoff Control	Stormwater practices to meet TMDL & permit conditions	High	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	High	--	TBD	
	Unnamed ditch (-565)		Bacteria /E. coli	Est conc = 2005 orgs/100 mL (based on limited data)	Not calculated	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	High	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	High	--	TBD	
	Unnamed Ck (-621)		Bacteria /E. coli	Geomean = 151 orgs/100 mL	17% reduction	Urban Stormwater Runoff Control	Stormwater practices to meet TMDL & permit conditions	High	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	High	--	TBD	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
	Unnamed Ck (-568)		Bacteria /E. coli	Geomean = 158 orgs/100 mL	20% reduction	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	High	--	TBD	
						Urban Stormwater Runoff Control	Stormwater practices to meet TMDL & permit conditions	High	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	High	--	TBD	
	Unnamed Ck (-526)		Bacteria /E. coli	Geomean = 1246 orgs/100 mL	90% reduction	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	High	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	High	--	TBD	
	Carver Ck (-806)		Phosphorus	0.373 mg/L; 10,227 lbs/yr (per HSPF)	60% reduction; 6,136 lbs/yr	*Stream impairment addressed through meeting Miller Lake TP TMDL--see Carver Creek lakes Excess Nutrients TMDL and Implementation Plan (2010); also, see Carver Creek Turbidity TMDL and Implementation Plan (2013)*					Low DO also ID'ed as stressor, but causation not fully evaluated.
			Biota pollutant stressors: TSS, TP	FIBI = 22.9 - 30.9; MIBI = 25.1	FIBI = 50; MIBI = 37						
			Biota nonpollutant stressors: habitat, connectivity								
Carver WMO and Lower Minnesota River WD (Carver Co. portions) in Minnesota River HUC-10	Gaystock Lk (10-0031-00)		Phosphorus	0.320 mg/L; 3132 lbs/yr	88% reduction; 2768 lbs/yr	Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	216	Acres	5	
						Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	63	Acres	18	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	159	Acres	23	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	0	Acres draining to	0	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	149	Acres	19	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	Waterbody (ID)	Location and Upstream Influence Counties	Pollutant/ Stressor	Current WQ Conditions (conc. / load / biota scores)	Final WQ Goal (% / load to reduce / biota score target)	Strategy Type	BMP	Amount	Unit	Est'd reduction (TSS = tons/yr; TP = lbs/yr)	Notes
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	42	Acres draining to	16	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	47	Acres	19	
						Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	--	--	43	
						Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	--	--	262	
						Septic system improvements	Septic System Improvement [126M]	2 (est.)	Systems	1	
						In-lake management	TBD	--	--	671	
						Upstream lake reduction	*Reduction in unassessed Aue Lk*	--	--	41	
									Total lbs Reduced	1,117	
	Hazeltine Lk (10-0014-00)		Phosphorus	0.296 mg/L; 2996 lbs/yr	91% reduction; 2720 lbs/yr	Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	28	Acres	1	
						Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	5	Acres	2	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	18	Acres	3	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	0	Acres draining to	0.0	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	15	Acres	2	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	4	Acres draining to	2	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	6	Acres	2	
						Wastewater Point Source Management	Wastewater phos. reductions to meet TMDL & permit conditions	--	--	37	
						Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	TBD	--	129	
						Septic system improvements	Septic System Improvement [126M]	1 (est.)	Systems	1	
						In-lake management	TBD	--	--	2,457	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
									Total lbs Reduced	2,635	
	Jonathan Lk (10-0217-00)		Phosphorus	0.202 mg/L; 1883 lbs/yr	72% reduction; 1328 lbs/yr	*See watershedwide SAM scenario strategies for agricultural areas*				47	SAM scenario could not be calculated because this watershed was not individually separated in the HSPF model.
						Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	TBD	--	44	
						In-lake management	TBD	--	--	46	
						Upstream lake reduction	*See McKnight Lk*	--	--	1,190	
									Total lbs Reduced	1,327	
	McKnight Lk (10-0216-00)		Phosphorus	0.231 mg/L; 2107 lbs/yr	77% reduction; 1625 lbs/yr	*See watershedwide SAM scenario strategies for agricultural areas*				275	SAM scenario could not be calculated because this watershed was not individually separated in the HSPF model. Bavaria reduction is for noncompliant septic systems only.
						Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	TBD	--	137	
						In-lake management	TBD	--	--	615	
						Upstream lake reduction	*Reductions in Bavaria and unassessed Big Woods lakes*	--	--	627	
									Total lbs Reduced	1,654	
	Lk Grace (10-0218-00)		Phosphorus	0.118 mg/L; 1617 lbs/yr	67% reduction; 1090 lbs/yr	Upstream lake reduction: Jonathan			Total lbs reduced	1,090	
	Bavaria Lk (10-0019-00)		Biota nonpollutant stressors: nonnative aquatic species, lakeshore development	FIBI = 14.8	FIBI = 45	In-lake management	Aquatic invasive species evaluation/management TBD	--	--	--	
						Riparian lakeshore restoration	Restore/enhance riparian lakeshore habitat complexity, including reestablishment of trees, shrubs, and natural ground cover	--	--	--	
	Unnamed Ck (-528)		Bacteria /E. coli	Geomean = 170 orgs/100 mL	26% reduction	Urban Stormwater Runoff Control	Stormwater practices to meet TMDL & permit conditions	High	--	TBD	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
						Septic system improvements	Septic System Improvement [126M]	High	--	TBD	
	Chaska Ck (-803)		Biota nonpollutant stressors: habitat, connectivity, altered hydrology	FIBI = 29.0 - 65.2; MIBI = 14.4	FIBI = 55; MIBI = 37	Habitat & stream connectivity management	Modify/replace dams, culverts & fish passage barriers	--	--	TBD	This reach contains a dam structure. However, significant permanent fish barrier further downstream (long concrete channel) in -804.
	Chaska Ck (-804)		Bacteria /E. coli	Geomean = 523 orgs/100 mL	76% reduction	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	High	--	TBD	
						Urban Stormwater Runoff Control	Stormwater practices to meet TMDL & permit conditions	High	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	High	--	TBD	
	Unnamed Ck (East Ck) (-581)		Sediment /TSS	66 mg/L (90th percentile)	2% reduction	Urban Stormwater Runoff Control	Stormwater practices to meet TMDL & permit conditions	TBD	--	TBD	
						Stream banks, bluffs and ravines protected/restored	Streambanks/shoreline - stabilized or restored [580]	--	--	TBD	
			Biota pollutant stressors: TSS, TP	FIBI = 32.4 - 33.4; MIBI = 20.8 - 29.6	FIBI = 55; MIBI = 37	*See applicable strategies listed for TSS*					
			Biota nonpollutant stressors: habitat, altered hydrology								
			Bacteria /E. coli	Geomean = 372 orgs/100 mL	66% reduction	Urban Stormwater Runoff Control	Stormwater practices to meet TMDL & permit conditions	High	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	High	--	TBD	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
	Unnamed (Assumption Ck) (-582)		Biota pollutant stressors: Stressor ID inconclusive	FIBI = 34.2 - 44.3	FIBI = 50	*Unknown*					
Nine Mile Creek WD	Nine Mile Ck (-807)		Biota nonpollutant stressors: habitat	FIBI = 44.9 - 64.3	FIBI = 55	Stream banks, bluffs & ravines protected/restored	Stream habitat improvement and management [395]	--	--	--	
							Stream restoration using principles such as Natural Channel Design	--	--	--	
	Nine Mile Ck (-808)		Biota nonpollutant stressors: habitat, connectivity, altered hydrology	FIBI = 30.6 - 56.0; MIBI = 19.7	FIBI = 33; MIBI = 24	Stream banks, bluffs & ravines protected/restored	Stream habitat improvement and management [395]	--	--	--	Low DO also ID'ed as stressor, but causation not fully evaluated.
						Urban Stormwater Runoff Control	Infitration BMPs	--	--	--	
	Nine Mile Ck (-809)		Biota pollutant stressors: TP	FIBI = 21.9 - 52.6; MIBI = 23.2	FIBI = 50; MIBI = 37	TBD					Evaluation of needed TP reduction for aquatic life not conducted. Low DO also ID'ed as stressor, but causation not fully evaluated.
			Biota nonpollutant stressors: habitat			Stream banks, bluffs & ravines protected/restored	Stream habitat improvement and management [395]	--	--	--	
			Bacteria /E. coli	Geomean = 212 orgs/100 mL	41% reduction	Urban Stormwater Runoff Control	Stormwater practices to meet TMDL & permit conditions	High	--	TBD	
			Biota pollutant stressors: TP	FIBI = 0 - 69.3; MIBI = 22.2	FIBI = 15 - 50; MIBI = 37	TBD					Evaluation of needed TP reduction for aquatic life

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
	Nine Mile Ck, South Fork (-723)		Biota nonpollutant stressors: habitat, altered hydrology			Stream banks, bluffs & ravines protected/restored	Stream habitat improvement and management [395]	--	--	--	not conducted. Low DO also ID'ed as stressor, but causation not fully evaluated.
							Stream restoration using principles such as Natural Channel Design	--	--	--	
						Urban Stormwater Runoff Control	Infitration BMPs	--	--	--	
	Lk Cornelia (North) (27-0028-01)		Phosphorus	0.158 mg/L; 360 lbs/yr	59% reduction; 214 lbs/yr	Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	TBD	--	110	
						In-lake management	Alum addition - In Lake (563M)	--	--	104	
									Total lbs Reduced	214	
	Lk Cornelia (South) (27-0028-02)		Phosphorus	0.135 mg/L; 410 lbs/yr	61% reduction; 250 lbs/yr	In-lake management	Alum addition - In Lake (563M)	--	--	150	
						Upstream lake reduction	*See Lk Cornelia (North)*	--	--	100	
									Total lbs Reduced	250	
	Lk Edina (27-0029-00)		Phosphorus	0.117 mg/L; 261 lbs/yr	34% reduction; 90 lbs/yr	Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	TBD	--	38	
						Upstream lake reduction	*See Lk Cornelia (South)*	--	--	52	
									Total lbs Reduced	90	
	Penn Lk (27-0004-00)		Phosphorus	0.148 mg/L; 446 lbs/yr		Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	TBD	--	154	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	Waterbody (ID)	Location and Upstream Influence Counties	Pollutant/ Stressor	Current WQ Conditions (conc. / load / biota scores)	Final WQ Goal (% / load to reduce / biota score target)	Strategy Type	BMP	Amount	Unit	Est'd reduction (TSS = tons/yr; TP = lbs/yr)	Notes
					47% reduction; 211 lbs/yr	In-lake management	Alum addition - In Lake (563M)	--	--	57	
									Total lbs Reduced	211	
	Rose Lk (27-0092-00)		Phosphorus	0.110 mg/L; 75 lbs/yr	41% reduction; 31 lbs/yr	Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	TBD	--	7	
						In-lake management	Alum addition - In Lake (563M)	--	--	15	
						Upstream lake reduction	*See Wing Lk*	--	--	9	
									Total lbs Reduced	31	
	Wing Lk (27-0091-00)		Phosphorus	0.098 mg/L; 105 lbs/yr	38% reduction; 40 lbs/yr	In-lake management	Alum addition - In Lake (563M)	--	--	28	
						Upstream lake reduction	*Reductions in unassessed Lk Holiday TBD*	--	--	12	
									Total lbs Reduced	40	
	Bryant Lk (27-0067-00)		Biota pollutant stressors: TP	FIBI = 41.7 - 42.7	FIBI = 45	TBD					Evaluation of needed TP reduction for aquatic life not conducted.
			Biota nonpollutant stressors: nonnative aquatic species, lakeshore development			In-lake management	Aquatic invasive species evaluation/management TBD	--	--	--	
						Riparian lakeshore restoration	Restore/enhance riparian lakeshore habitat complexity, including reestablishment of trees, shrubs, and natural ground cover	--	--	--	
Riley-Purgatory-Bluff	Bluff Ck (-710)		Biota pollutant stressors: TSS, TP	FIBI = 18.2 - 25.2	FIBI = 50	*See Bluff Creek Watershed TMDL Implementation Plan: Turbidity and*					Evaluation of needed TP reduction for aquatic life not conducted, though TSS

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
Creek WD - Bluff Creek						*Fish Bioassessment Impairments (2013)*					strategies will also reduce TP.
			Biota nonpollutant stressors: habitat, connectivity, altered hydrology								
Riley-Purgatory-Bluff Creek WD - Riley Creek	Riley Ck (-511)		Sediment /TSS	530 mg/L (90th percentile)	88% reduction	Urban Stormwater Runoff Control	Stormwater practices to meet TMDL & permit conditions	TBD	--	TBD	
						Stream banks, bluffs and ravines protected/restored	Streambanks/shoreline - stabilized or restored [580]	--	--	TBD	
			Biota pollutant stressors: TSS	FIBI = 0; MIBI = 17.8	FIBI = 55; MIBI = 37	*See applicable strategies listed for TSS*					
			Biota nonpollutant stressors: altered hydrology			Urban Stormwater Runoff Control	Infitration BMPs	--	--	--	
			Bacteria /E. coli	Geomean = 654 orgs/100 mL	81% reduction	Urban Stormwater Runoff Control	Stormwater practices to meet TMDL & permit conditions	High	--	TBD	
	Rice Marsh Lk (10-0001-00)		Phosphorus	0.110 mg/L; 1642 lbs/yr	44% reduction; 729 lbs/yr	Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	TBD	--	205	
						In-lake management	Alum addition - In Lake (563M)	--	--	431	
						Upstream lake reduction	*See Lk Susan*	--	--	93	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
									Total lbs Reduced	729	
	Lk Susan (10-0013-00)		Phosphorus	0.078 mg/L; 1261 lbs/yr	25% reduction; 316 lbs/yr	Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	TBD	--	50	Stormwater eduction already addressed through BMP installation. Alum is being evaluated for additional WQ improvement.
						Stream banks, bluffs and ravines protected/restored	Streambanks/shoreline - stabilized or restored [580]	--	--	266	
						In-lake management	Curly-leaf pondweed management per DNR permit	--	--	0	
									Total lbs Reduced	316	
	Lk Riley (10-0002-00)		Phosphorus	0.048 mg/L; 2701 lbs/yr	30% reduction; 814 lbs/yr	Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	TBD	--	69	
						In-lake management	Alum addition - In Lake (563M)	--	--	446	
						Upstream lake reduction	*See Rice Marsh Lk*	--	--	299	
									Total lbs Reduced	814	
			Biota pollutant stressors: TP	FIBI = 13.2	FIBI = 45	*See phosphorus strategies*					Evaluation of needed TP reduction for aquatic life not conducted.
			Biota nonpollutant stressors: nonnative aquatic species, lakeshore development			In-lake management	Aquatic invasive species evaluation/management TBD	--	--	--	
						Riparian lakeshore restoration	Restore/enhance riparian lakeshore habitat complexity, including reestablishment of trees, shrubs, and natural ground cover	--	--	--	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
Riley-Purgatory-Bluff Creek WD - Purgatory Creek	Purgatory Ck (-828)		Biota pollutant stressors: Stressor ID inconclusive	MIBI = 23.3	MIBI = 37	Unknown					
			Bacteria /E. coli	Geomean = 392 orgs/100 mL	68% reduction	Urban Stormwater Runoff Control	Stormwater practices to meet TMDL & permit conditions	High	--	TBD	
	Silver Lk (27-0136-00)		Phosphorus	0.093 mg/L; 224 lbs/yr	21% reduction; 48 lbs/yr	Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	TBD	--	23	
						Riparian lakeshore restoration	Streambanks/shoreline - stabilized or restored [580]	--	--	4	
						In-lake management	TBD	--	--	21	
									Total lbs Reduced	48	
	Staring Lk (27-0078-00)		Phosphorus	0.094 mg/L; 2339 lbs/yr	34% reduction; 796 lbs/yr	Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	TBD	--	203	
						Stream banks, bluffs and ravines protected/restored	Streambanks/shoreline - stabilized or restored [580]	--	--	89	
						In-lake management	Alum addition - In Lake (563M)	--	--	473	
							Curly-leaf pondweed management per DNR permit				
							Roughfish management				
						Upstream lake reduction	*See Lotus Lk and Silver Lk*	--	--	31	
									Total lbs Reduced	796	
	Hyland Lk (27-0048-00)		Phosphorus	0.095 mg/L; 604 lbs/yr	50% reduction; 320 lbs/yr	In-lake management	TBD	--	--	320	
	Lk Lotus 10-0006-00		Phosphorus	0.055 mg/L; 1140 lbs/yr	47% reduction; 541 lbs/yr	Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	TBD	--	50	
						Stream banks, bluffs and ravines protected/restored	Streambanks/shoreline - stabilized or restored [580]	--	--	6	
						In-lake management	TBD	--	--	485	
									Total lbs Reduced	541	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
			Biota pollutant stressors: TP	FIBI = 28.6	FIBI = 45	*See phosphorus strategies*					Evaluation of needed TP reduction for aquatic life not conducted.
			Biota nonpollutant stressors: nonnative aquatic species, lakeshore development			In-lake management	Aquatic invasive species evaluation/management TBD	--	--	--	
						Riparian lakeshore restoration	Restore/enhance riparian lakeshore habitat complexity, including reestablishment of trees, shrubs, and natural ground cover	--	--	--	
City of Belle Plain Minnesota River HUC-10	Robert Ck (-575)		Sediment /TSS	230 mg/L (90th percentile); 905 tons/yr (per HSPF)	72% reduction; 652 tons/yr	Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	1,363	Acres Treated	103	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	2,302	Acres	99	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	822	Acres draining to	64	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	3,732	Acres	238	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	665	Acres draining to	52	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	1,085	Acres	90	
						Urban Stormwater Runoff Control	Stormwater practices to meet TMDL & permit conditions	TBD	--	TBD	
						Stream banks, bluffs and ravines protected/restored	Streambanks/shoreline - stabilized or restored [580]	--	--	TBD	
									Total tons reduced	646	
			Biota pollutant stressors: TSS, TP, N	FIBI = 14.7 - 55.2; MIBI = 41.9 - 43.3	FIBI = 55; MIBI = 43	*See applicable strategies listed for TSS + nutrient management strategy from watershedwide scenario*					

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
			Biota nonpollutant stressors: habitat								
			Bacteria /E. coli	Geomean = 570 orgs/100 mL	78% reduction	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	Low	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	Low	--	TBD	
	Unnamed Ck (Brewery) (-830)		Biota nonpollutant stressors: habitat, connectivity, altered hydrology	FIBI = 48.8 - 55.9; MIBI = 24.1	FIBI = 55; MIBI = 37	Habitat & stream connectivity management	Streambanks/shoreline - stabilized or restored [580]	--	--	TBD	
							Culvert replacement	--	--	TBD	
			Bacteria /E. coli	Geomean = 1353 orgs/100 mL	91% reduction	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	High	--	TBD	
						Urban Stormwater Runoff Control	Stormwater practices to meet TMDL & permit conditions	High	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	Low	--	TBD	
			Biota pollutant stressors: N	FIBI = 49.7; MIBI = 28.6	FIBI = 55; MIBI = 37	*See watershedwide SAM scenario strategies*					

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
	Unnamed Ck (-798) (in Sibley Co.)		Biota nonpollutant stressors: habitat, connectivity, altered hydrology								
	Unnamed Cks (-746, -753)		Bacteria /E. coli	Geomean = 153 - 850 orgs/100 mL	18% (-746); 85% (-753) reduction	Septic system improvements	Septic System Improvement [126M]	Low	--	TBD	
	Unnamed Ck (-756)		Bacteria /E. coli	Geomean = 431 orgs/100 mL	71% reduction	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	High	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	Low	--	TBD	
Sand Creek HUC-10	Sand Ck (-839)		Sediment /TSS	89 mg/L (90th percentile); 2877 tons/yr (per HSPF)	27% reduction; 777 tons/yr	Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	5,127	Acres	241	Scenario predicts a higher-than-needed load reduction. Thus, efforts can be scaled back (except for buffers).
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	12,916	Acres	355	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	638	Acres draining to	27	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	13,227	Acres	531	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	3,391	Acres draining to	167	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	4,182	Acres	218	
						Stream banks, bluffs and ravines protected/restored	Streambanks/shoreline - stabilized or restored [580]	--	--	TBD	
									Total tons reduced	1,539	
			Phosphorus	0.453 mg/L; 18,533 lbs/yr (per HSPF)	67% reduction; 12,417 lbs/yr	Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	6,477	Acres	345	TMDL met by upstream lakes meeting their TMDL plus WWTP limits to address low flow TP
						Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	1,323	Acres	408	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	3,775	Acres	498	concerns. Watershed BMPs included here for reference since needed for TSS impairment.
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	332	Acres draining to	31	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	4,140	Acres	437	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	994	Acres draining to	337	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	1,306	Acres	404	
						Stream banks, bluffs and ravines protected/restored	Streambanks/shoreline - stabilized or restored [580]	--	--	TBD	
						Wastewater Point Source Management	Wastewater phos. reductions to meet TMDL & permit conditions	--	--	(Not calculated)	
						Upstream reduction	*See Phelps, Pepin, Sanborn lakes*	--	--	11,471	
									Total lbs Reduced	13,931	
			Biota pollutant stressors: TSS, TP	FIBI = 0	FIBI = 35	*See applicable strategies listed for TSS/TP*					
			Biota nonpollutant stressors: habitat, altered hydrology								
	Hatch Lk (66-0063-00), Cody Lk (66-0061-00), Phelps Lk (66-0062-00)		Phosphorus	0.356 - 0.493 mg/L; 27,644 lbs/yr	93% reduction; 25,652 lbs/yr	Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	10,443	Acres	724	These lakes are combined in the scenario because they are in one HSPF drainage catchment. Feedlot actions are included for the Cody Lake watershed.
						Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	3,006	Acres	965	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	6,866	Acres	1,092	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	106	Acres draining to	24	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	6,591	Acres	913	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	1,797	Acres draining to	739	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	2,089	Acres	845	
						Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	--	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	5 (est.)	Systems	8	
						In-lake management	TBD	--	--	17,268	
									Total lbs reduced	22,578	
	Lk Pepin (40-0028-00)		Phosphorus	0.328 mg/L; 14,411 lbs/yr	91% reduction; 13,119 lbs/yr	Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	3,015	Acres	77	
						Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	616	Acres	72	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	1,757	Acres	102	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	154	Acres draining to	13	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	1,927	Acres	96	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	463	Acres draining to	69	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	608	Acres	90	
						Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	--	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	4 (est.)	Systems	4	
						In-lake management	TBD	--	--	9,887	
									Total lbs reduced	10,410	
			Phosphorus			Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	890	Acres	63	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	Waterbody (ID)	Location and Upstream Influence Counties	Pollutant/ Stressor	Current WQ Conditions (conc. / load / biota scores)	Final WQ Goal (% / load to reduce / biota score target)	Strategy Type	BMP	Amount	Unit	Est'd reduction (TSS = tons/yr; TP = lbs/yr)	Notes
	Lk Sanborn (40-0027-00)			0.185 mg/l; 2727 lbs/yr	80% reduction; 2174 lbs/yr	Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	182	Acres	59	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	518	Acres	84	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	46	Acres draining to	12	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	569	Acres	80	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	137	Acres draining to	57	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	179	Acres	74	
						Septic system improvements	Septic System Improvement [126M]	1 (est.)	Systems	1	
						In-lake management	TBD	--	--	1,236	
									Total lbs reduced	1,666	
	Sand Ck (-840)		Sediment /TSS	165 mg/L (90th percentile); 4123 tons/yr (per HSPF)	61% reduction; 2515 tons/yr	Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	1,553	Acres	62	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	4,431	Acres	93	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	390	Acres draining to	9	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	4,861	Acres	142	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	1,166	Acres draining to	44	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	1,533	Acres	58	
						Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	TBD	--	TBD	
						Stream banks, bluffs and ravines protected/restored	Streambanks/shoreline - stabilized or restored [580]	--	--	TBD	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
						Upstream reduction	*See Sand Ck (-839)*	--	--	777	
									Total tons reduced	1,185	
			Phosphorus	0.458 mg/l; 24,244 lbs/yr (per HSPF)	67% reduction; 16,244 lbs/yr	Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	7,333	Acres	365	Cedar Lk reductions were not separately included in the upstream reduction total; Cedar reductions are part of the direct watershed (SAM scenario) numbers here.
						Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	1,498	Acres	347	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	4,274	Acres	488	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	376	Acres draining to	67	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	4,688	Acres	466	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	1,125	Acres draining to	332	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	1,479	Acres	430	
						Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	TBD	--	TBD	
						Stream banks, bluffs and ravines protected/restored	Streambanks/shoreline - stabilized or restored [580]	--	--	TBD	
						Upstream reduction	*See Pleasant Lk + Sand Ck (-839)*	--	--	12,444	
									Total lbs Reduced	14,939	
			Biota pollutant stressors: TSS, TP	FIBI = 28.9 - 39.0; MIBI = 22.5 - 37.5	FIBI = 50; MIBI = 43	*See applicable strategies listed for TSS/TP*					Low DO also ID'ed as stressor, but causation not fully evaluated.
			Biota nonpollutant stressors: habitat								
	Pleasant Lk (70-0098-00)		Phosphorus	0.100 mg/L; 1039 lbs/yr	66% reduction; 688 lbs/yr	Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	270	Acres	2	
						Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	55	Acres	2	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	157	Acres	3	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	14	Acres draining to	0.3	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	173	Acres	3	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	41	Acres draining to	2	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	54	Acres	2	
						Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	--	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	16 (est.)	Systems	21	
						In-lake management	TBD	--	--	486	
									Total lbs reduced	521	
	Sand Ck (-538)		Sediment /TSS	No TSS data; 6686 tons/yr (per HSPF)	Not calculated	Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	5,310	Acres	152	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	12,863	Acres	217	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	2,605	Acres draining to	83	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	21,809	Acres	546	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	3,505	Acres draining to	106	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	6,145	Acres	199	
						Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	TBD	--	TBD	
						Stream banks, bluffs and ravines protected/restored	Streambanks/shoreline - stabilized or restored [580]	--	--	TBD	
						Upstream reduction	*See Sand Ck (-840)*	--	--	2,515	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
									Total tons reduced	3,818	
			Biota pollutant stressors: TSS	FIBI = 29.2	FIBI = 50	*See applicable strategies listed for TSS*					
	Raven Str, W Br (-842)		Biota pollutant stressors: TP, N	FIBI = 29.5; MIBI = 28.1 - 29.5	FIBI = 50; MIBI = 43	*See applicable strategies listed for TSS/TP (reaches -513, -538)*					Low DO also ID'ed as stressor, but causation not fully evaluated.
			Biota nonpollutant stressors: habitat								
			Bacteria /E. coli	2420 orgs/100 mL	High reduction	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	High	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	Low	--	TBD	
	CD 10 (-628)		Biota pollutant stressors: N	MIBI = 23.6	MIBI = 30	*See applicable strategies listed for TSS/TP (reaches -513, -538)*					
			Biota nonpollutant stressors: habitat								
			Bacteria /E. coli	Geomean = 364 orgs/100 mL	65% reduction	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	High	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	Low	--	TBD	
	Unnamed Ck (-822)		Biota pollutant stressors: TP, Cl	FIBI = 46.4 - 48.9; MIBI = 20.2 - 21.0	FIBI = 55; MIBI = 37	*See applicable strategies listed for TSS/TP (reaches -513, -538)*					Chloride source not identified.
			Biota nonpollutant stressors: habitat								

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
	Raven Str (-716)		Biota pollutant stressors: TSS, TP, N	FIBI = 40.5; MIBI = 33.1	FIBI = 50; MIBI = 37	*See applicable strategies listed for TSS/TP (reaches -513, -538)*					
			Biota nonpollutant stressors: habitat								
			Bacteria /E. coli	Geomean = 545 orgs/100 mL	77% reduction	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	High	--	TBD	
						Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	Low	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	High	--	TBD	
	Sand Ck (-513)		Sediment /TSS	616 mg/L (90th percentile); 13,027 tons/yr (per HSPF)	89% reduction; 11,594 tons/yr	Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	2,465	Acres	109	Upstream reduction is a total of the amount shown reduced for -538 (since a needed amount not available for that reach) and the amount of reduction needed for -817.
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	6,902	Acres	183	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	0	Acres draining to	21	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	7,891	Acres	309	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	1,911	Acres draining to	88	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	2,609	Acres	125	
						Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	TBD	--	TBD	
						Stream banks, bluffs and ravines protected/restored	Streambanks/shoreline - stabilized or restored [580]	--	--	TBD	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
						Upstream reduction	*See Sand Ck (-538, -817)*	--	--	5,756	
									Total tons reduced	6,591	
			Phosphorus	0.456 mg/l; 78,876 lbs/yr (per HSPF)	67% reduction; 52,847 lbs/yr	Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	53,689	Acres	3,355	
						Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	9,572	Acres	2,765	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	27,243	Acres	3,852	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	2,605	Acres draining to	708	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	36,059	Acres	4,524	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	7,355	Acres draining to	2,690	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	10,860	Acres	3,950	
						Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	TBD	--	TBD	
						Stream banks, bluffs and ravines protected/restored	Streambanks/shoreline - stabilized or restored [580]	--	--	TBD	
						Wastewater Point Source Management	Wastewater phos. reductions to meet TMDL & permit conditions	--	--	(Not calculated)	
						Upstream reduction	*See Cynthia Lake + Sand Ck (-840)*	--	--	19,767	
									Total lbs reduced	41,611	
			Biota pollutant stressors: TSS, TP	FIBI = 27.9 - 39.9; MIBI = 27.3 - 38.9	FIBI = 50; MIBI = 37 - 43	*See applicable strategies listed for TSS/TP*					

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
			Biota nonpollutant stressors: habitat, connectivity, altered hydrology								
			Bacteria /E. coli	Geomean = 388 orgs/100 mL	68% reduction	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	High	--	TBD	
						Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	High	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	Low	--	TBD	
	Unnamed Ck (-732)		Biota nonpollutant stressors: habitat	FIBI = 33.8 - 43.5; MIBI = 30.7 - 33.6	FIBI = 55; MIBI = 37	*See applicable strategies listed for TSS (reach -513)*					
	Picha Ck (-580)		Biota nonpollutant stressors: habitat	FIBI = 39.3 - 59.9	FIBI = 55	*See applicable strategies listed for TSS/TP (reach -513)*					
	Picha Ck (-579)		Biota pollutant stressors: TP	FIBI = 16.3 - 48.1; MIBI = 27.2 - 33.8	FIBI = 55; MIBI = 37	*See applicable strategies listed for TSS/TP (reach -513)*					Low DO also ID'ed as stressor, but causation not fully evaluated.
			Biota nonpollutant stressors: habitat, connectivity, altered hydrology								

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
						Habitat & stream connectivity management	Culvert replacement	--	--	--	
	Porter Ck (-817)		Sediment /TSS	123 mg/L (90th percentile); 4123 tons/yr (per HSPF)	47% reduction; 1938 tons/yr	Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	980	Acres	36	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	4,991	Acres	96	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	0	Acres draining to	0	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	4,270	Acres	121	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	1,312	Acres draining to	45	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	1,403	Acres	52	
						Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	TBD	--	TBD	
						Stream banks, bluffs and ravines protected/restored	Streambanks/shoreline - stabilized or restored [580]	--	--	TBD	
						Upstream reduction	*See Porter Ck (-815)*	--	--	605	
									Total tons reduced	955	
			Biota pollutant stressors: TSS	FIBI = 27.2 - 41.3; MIBI = 17.0	FIBI = 50; MIBI = 37	*See applicable strategies listed for TSS*					

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
			Biota nonpollutant stressors: habitat								
			Bacteria /E. coli	Geomean = 420 orgs/100 mL	70% reduction	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	High	--	TBD	
						Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	Low	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	Low	--	TBD	
	Porter Ck (-815)		Sediment /TSS	163 mg/L (90th percentile); 1009 tons/yr (per HSPF)	60% reduction; 605 tons/yr	Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	1,453	Acres	60	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	6,048	Acres	147	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	0	Acres draining to	0	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	5,143	Acres	186	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	1,568	Acres draining to	69	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	1,703	Acres	80	
						Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	TBD	--	TBD	
						Stream banks, bluffs and ravines protected/restored	Streambanks/shoreline - stabilized or restored [580]	--	--	TBD	
									Total tons reduced	542	
	Unnamed Ck (-849)		Biota nonpollutant stressors: habitat	FIBI = 32.9	FIBI = 33	*See applicable strategies listed for TSS (reach -817)*					Low DO also ID'ed as stressor, but causation not fully evaluated.
			Phosphorus			Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	4,998	Acres	304	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	Waterbody (ID)	Location and Upstream Influence Counties	Pollutant/ Stressor	Current WQ Conditions (conc. / load / biota scores)	Final WQ Goal (% / load to reduce / biota score target)	Strategy Type	BMP	Amount	Unit	Est'd reduction (TSS = tons/yr; TP = lbs/yr)	Notes
	St. Catherine Lk (70-0029-00), Cynthia Lk (70-0052-00)			0.288 - 0.342 mg/l; 27,936 lbs/yr	94% reduction; 26,214 lbs/yr	Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	636	Acres	179	These lakes are combined in the scenario because they are in one HSPF drainage catchment. Feedlot actions are included for the St. Catherine Lake watershed.
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	3,561	Acres	495	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	0	Acres draining to	0	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	3,054	Acres	370	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	941	Acres draining to	339	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	1,000	Acres	355	
						Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	--	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	17 (est.)	Systems	22	
						In-lake management	TBD	--	--	23,701	
									Total lbs reduced	25,765	
Credit River watershed and other Minnesota River HUC-10 watershed areas in Scott County WMO	Credit R (-811)		Chloride	Exceedence avg = 328 m/L	43% reduction	*See Twin Cities Metropolitan Area Chloride Management Plan (2016)*					
			Biota pollutant stressors: DO, TP	FIBI = 42.0 - 61.6; MIBI = 30.0	FIBI = 50 - 55; MIBI = 37	*See watershedwide SAM scenario strategies*					Low DO also ID'ed as stressor, but causation not fully evaluated.
			Bacteria /E. coli	Geomean = 435 orgs/100 mL	71% reduction	Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	High	--	TBD	
						Urban Stormwater Runoff Control	Stormwater practices to meet TMDL & permit conditions	High	--	TBD	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
						Septic system improvements	Septic System Improvement [126M]	Low	--	TBD	
	Cleary Lk (70-0022-00)		Phosphorus	0.1732mg/L; 2097 lbs/yr	79% reduction; 1663 lbs/yr	Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	635	Acres	23	
						Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	99	Acres	17	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	445	Acres	37	
						Open tile inlet and side inlet improvements	Alternative tile intake - Perforated riser pipe [171M]	0	Acres draining to	0.0	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	332	Acres	24	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	111	Acres draining to	24	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	127	Acres	27	
						Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	TBD	--	161	
						Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	--	--	TBD	
						In-lake management	Alum addition - In Lake (563M)	--	--	633	
							Curly-leaf pondweed management per DNR permit	--	--		
									Total lbs Reduced	946	
	Eagle Ck (-519)		Bacteria /E. coli	Geomean = 137 orgs/100 mL	8% reduction	Urban Stormwater Runoff Control	Stormwater practices to meet TMDL & permit conditions	High	--	TBD	
	Thole Lk (70-0120-01)		Phosphorus	0.118 mg/l; 1204 lbs/yr	69% reduction; 825 lbs/yr	Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	257	Acres	4	
						Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	49	Acres	3	
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	163	Acres	5	
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	133	Acres	4	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	41	Acres draining to	3	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	51	Acres	4	
						Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	TBD	--	18	
						Septic system improvements	Septic System Improvement [126M]	29 (est.)	Systems	42	
						In-lake management	TBD	--	--	728	
						Upstream lake reduction	*Reduction in unassessed Schneider Lake (70-0120-02) TBD*	--	--	35	
									Total lbs reduced	846	
	O'Dowd Lk (70-0095-00)		Biota pollutant stressors: TP	FIBI = 30.8 - 31.6	FIBI = 45	TBD					Evaluation of needed TP reduction for aquatic life not conducted.
Prior Lake-Spring Lake WD (+ downstream)	Unnamed ck (CD 13), (-604)		Biota pollutant stressors: DO, TP	FIBI = 25.3	FIBI = 33	*See Spring and Upper Prior Lake TMDL Implementation Plan (2012) + SAM scenario strategies*					Low DO also ID'ed as stressor, but causation not fully evaluated.
			Biota nonpollutant stressors: habitat, altered hydrology								
	Unnamed ck (Prior Lake Outlet Channel) (-728)		Biota pollutant stressors: TP	FIBI = 31.1; MIBI = 24.4	FIBI = 50; MIBI = 37	Improvements to Dean Lake	TBD	--	--	TBD	Habitat improvement opportunites are very limited.
			Biota nonpollutant stressors: habitat			Unknown					
	Fish Lk (70-0069-00)		Phosphorus	0.042 mg/l; 582 lbs/yr	14% reduction; 80 lbs/yr	Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	128	Acres	2	Internal load could not be separated from the watershed load in the TMDL analysis.
						Buffers and filters, field edge	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	17	Acres	1	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
						Tillage/residue management	Conservation tillage - >30% residue cover [345, 346, 329B]	67	Acres	2	Collectively, they need a 54 lb/year reduction.
						Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	76	Acres	3	
						Designed erosion control and trapping	Water and Sediment Control Basin (cropland) [638]	18	Acres draining to	2	
						Perennial cover for harvest and/or conservation	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	26	Acres	2	
						Feedlot runoff controls	Feedlot runoff reduction/treatment (635, 784)	--	--	TBD	
						Septic system improvements	Septic System Improvement [126M]	16 (est.)	Systems	25	
						In-lake management	TBD	--	--	unknown	
									Total lbs reduced	37	
	Pike Lk (70-0076-00)		Phosphorus	0.203 mg/l; 5287 lbs/yr	69% reduction; 3662 lbs/yr	Urban Stormwater runoff control	Stormwater practices to meet TMDL & permit conditions	TBD	--	763	
						In-lake management	TBD	--	--	2,898	
									Total lbs reduced	3,661	
	Spring Lk (70-0054-00)		Biota pollutant stressors: TP	FIBI = 7.8 - 24.3	FIBI = 45	*See Spring and Upper Prior Lake TMDL Implementation Plan (2012)*					Evaluation of needed TP reduction for aquatic life not conducted
			Biota nonpollutant stressors: lakeshore development			Riparian lakeshore restoration	Restore/enhance riparian lakeshore habitat complexity, including reestablishment of trees, shrubs, and natural ground cover	--	--	--	

Waterbody and Location			Water Quality (see text for interim targets and timeframes)			Strategies to Achieve Final Water Quality Goal					
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. / load / biota scores)	**Final WQ Goal** (% / load to reduce / biota score target)	**Strategy Type**	**BMP**	**Amount**	**Unit**	**Est'd reduction (TSS = tons/yr; TP = lbs/yr)**	**Notes**
	Lower Prior Lk (70-0026-00)		Biota nonpollutant stressors: nonnative aquatic species, lakeshore development	FIBI = 7.7 - 19.8	FIBI = 45	In-lake management	Aquatic invasive species evaluation/management TBD	--	--	--	
						Riparian lakeshore restoration	Restore/enhance riparian lakeshore habitat complexity, including reestablishment of trees, shrubs, and natural ground cover	--	--	--	

Table 15: Strategies and Best Management Practices for the Lower Minnesota River Watershed.

Agricultural	Urban, Forest, In-stream/lake and other
* currently in SAM; ** adding to SAM	* currently in SAM; ** adding to SAM
Underlined headings = strategy types, with BMPs below each	Underlined headings = strategy types, with BMPs below each
Agricultural tile drainage water treatment/storage	**Forestry Management**
*Tile line bioreactors (747)	**Forest erosion control on harvested lands
*Wetland Restoration or Creation for treatment (657, 658)	Roads and trails improvement
*Controlled tile drainage water management (554)	Reforestation on non-forested land and after cutting
**Saturated buffers (604)	**Riparian zone forestry management
Tile water storage with re-use on crops (636)	Forestry management - comprehensive (147M)
	Maintain existing forest cover
Buffers and filters - field edge	
*Riparian Buffers, 16+ ft (perennials replace tilled) (390, 391, 327)	**Habitat & stream connectivity management**
*Riparian Buffers, 50+ ft (perennials replace tilled) (390, 391, 327)	Wetland Wildlife Habitat Management (644)
*Riparian Buffers, 100+ ft wide (perennials replace tilled) (390, 391, 327)	Upland Wildlife Habitat Management (645, 643)
*Riparian Buffers, 50+ ft wide (replacing *pasture*) (390, 391, 327)	Wetland Restoration for habitat (657)
Field Border (393, 327)	Wetland Creation for habitat (658)
	Modify/replace dams, culverts & fish passage barriers
Changing rotations to less-erosive crops	Culvert replacement

Agricultural	Urban, Forest, In-stream/lake and other
Conservation Crop Rotation - adding small grains (328)	Riparian tree planting to improve shading (390, 612)
*Conservation Crop Rotation - add more perennials (328)	Riparian plantings to reduce nuisance waterfowl levels (390, 612)
	Protection of vulnerable ecosystems & habitats
Perennial cover for harvest and/or conservation	Stream restoration (go to strategy "Stream banks, bluffs & ravine…")
*Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	
*Conservation Cover Perennials (327, 327M, 342, 612)	**In-Lake Management**
*Convert cultivated land to pasture	Alum addition - In Lake (563M)
	Dredging
Add cover crops for living cover in fall/spring	Roughfish management
*Cover Crops with Corn & Soybeans (340)	Curly-leaf pondweed management per DNR permit
*Cover crops after early-harvest crops (340)	Drawdown and hypolimnetic withdrawal
	Watercraft restrictions
Designed erosion control & trapping	
*Water and Sediment Control Basin (cropland) (638)	**Septic System Improvements**
Sediment Basin (350)	**Septic System Improvement (126M)
**Terrace (600)	Sanitary sewer system extended to septic system community
**Grassed waterway (412)	
*Filter Strips (386)	**Stream banks, bluffs & ravines protected/restored**
**Contour Buffer Strips (332)	Lined Waterway or Outlet (468)
**Stripcropping (585)	Ravine stabilization (410)

Agricultural	Urban, Forest, In-stream/lake and other
	Re-meander channelized stream reaches (582)
Drainage ditch modifications	Restore riffle substrate
Two stage ditch -open channel (582)	Riparian bluffs stabilized or restored (580)
Grade stabilization structure - in ditch (410)	Riparian herbaceous cover [390]
	Stream Channel Stabilization (584)
Feedlot runoff controls	Stream habitat improvement and management [395]
**Feedlot runoff reduction/treatment (635, 784)	Stream restoration using principles such as Natural Channel Design
**Feedlot manure/runoff storage addition (313, 784)	**Streambanks/shoreline - stabilized or restored (580)
	Structure for Water Control (587)
Integrated Pest Management	
Integrated Pest Management	Urban Stormwater Runoff Control
	Stormwater practices to meet TMDL & permit conditions
Nutrient management (cropland)	*Constructed Stormwater Pond (urban) (155M)
*Nutrient Management (fertilizer, soil, manure) (590)	Constructed Wetland (urban) (658)
Precision Nutrient Timing & Management (beyond 590 standard)	*Infiltration Basin (urban) (803M)
**Manure/fertilizer incorporation (within 24 hrs)	*Bioretention/Biofiltration (urban) (712M)
Fertilizer rates match U of MN rec's (without gov't funding)	Enhanced Road Salt Management
	Permeable surfaces and pavements (800M, 804M)
Open tile inlet & side inlA58:A71et improvements	Improved lawn/turf vegetation & soil practices

Agricultural	Urban, Forest, In-stream/lake and other
*Alternative tile intake - Perforated riser pipe (171M)	Supplemental Street Sweeping
Alternative tile inlet - blind, rock, sand filter (606, 170M, 172M, 173M)	Chemical Treatment of stormwater
**Side inlet improvement (410)	Sand Filter
Pasture management	**Wastewater Point Source Management**
**Conventional pasture to prescribed rotational grazing (528)	*Wastewater phos. reductions to meet TMDL & permit conditions
Pasture improvement (101)	*Wastewater nitrate reductions
**Livestock access control (472)	
	Mitigating flow extremes (high or low)
Tillage/residue management	Irrigation Water Management
*Conservation tillage - >30% residue cover (345, 346, 329B)	Permeable Surfaces & Pavement (go to strategies: urban runoff stormwater control*)*
*No-till/ridge till (329, 329A)	Retain & increase perennial cover *(go to strategies: Perennial cover for harvest and/or conservation)*
Contour tillage/farming (330)	Soil health buildup *(go to strategies: cover crops, tillage/residue management, changing rotation, Perennial cover for harvest and/or conservation)*
	Increase cropland water infiltration/evapotranspiration *(go to strategies: tillage/residue management; Perennial cover for harvest and/or conservation, cover crops,)*
	Reducing or storing tile flow waters *(go to strategies: Agricultural tile drainage water treatment/storage)*
	Small to larger off-channel impoundment dikes
	Modify culvert sizing

Table 16: Best management practices associated to strategies along with the NRCS practice codes.

Code	BMP	Strategy
606,170M,172M,173M	Alternative tile inlet - blind, rock, sand filter [606, 170M, 172M, 173M]	Open tile inlet & side inlA58:A71et improvements
171M	Alternative tile intake - Perforated riser pipe [171M]	Open tile inlet & side inlA58:A71et improvements
563M	Alum addition - In Lake [563M]	In Lake Management
712M	Bioretention/Biofiltration (urban) [712M]	Urban Stormwater Runoff Control
none	Chemical Treatment of stormwater	Urban Stormwater Runoff Control
327, 327M, 342, 612	Conservation Cover Perennials [327, 327M, 342, 612]	Perennial cover for harvest and/or conservation
328	Conservation Crop Rotation - add more perennials [328]	Changing rotations to less erosive crops
328	Conservation Crop Rotation - adding small grains [328]	Changing rotations to less erosive crops
345,346,329B	Conservation tillage - >30% residue cover [345, 346, 329B]	Tillage/residue management
115M	Constructed Stormwater Pond (urban) [155M]	Urban Stormwater Runoff Control
658	Constructed Wetland (urban) [658]	Urban Stormwater Runoff Control
332	Contour Buffer Strips [332]	Designed erosion control & trapping
330	Contour tillage/farming [330]	Tillage/residue management
554	Controlled tile drainage water management [554]	Agricultural tile drainage water treatment/storage
528	Conventional pasture to prescribed rotational grazing [528]	Pasture management
none	Convert cultivated land to pasture	Perennial cover for harvest and/or conservation
340	Cover crops after early-harvest crops [340]	Add living cover to annual crops in fall/spring
340	Cover Crops with Corn & Soybeans [340]	Add living cover to annual crops in fall/spring
none	Culvert replacement	Habitat & stream connectivity management
none	Curly-leaf pondweed management per DNR permit	In Lake Management
none	Drawdown and hypolimnetic withdrawal	In Lake Management
none	Dredging	In Lake Management
none	Dry swales	Urban Stormwater Runoff Control
none	Enhanced Road Salt Management	Urban Stormwater Runoff Control
313,784	Feedlot manure/runoff storage addition [313, 784]	Feedlot runoff controls
635,784	Feedlot runoff reduction/treatment [635, 784]	Feedlot runoff controls
none	Fertilizer rates match U of MN rec's (without gov't funding)	Nutrient management (cropland)

Code	BMP	Strategy
393,327	Field Border [393, 327]	Buffers and filters - field edge
386	Filter Strips [386]	Designed erosion control & trapping
none	Forest erosion control on harvested lands	Forestry Management
147M	Forestry management - comprehensive [147M]	Forestry Management
410	Grade stabilization structure - in ditch [410]	Drainage ditch modifications
412	Grassed waterway [412]	Designed erosion control & trapping
none	Green Roofs	Urban Stormwater Runoff Control
none	Improved lawn/turf vegetation & soil practices	Urban Stormwater Runoff Control
none	Increase cropland water infiltration/evapotranspiration *(go to strategies: tillage/residue management; Perennial cover for harvest and/or conservation, cover crops)*	Mitigating flow extremes (high or low)
803M	Infiltration Basin (urban) [803M]	Urban Stormwater Runoff Control
none	Irrigation Water Management	Mitigating flow extremes (high or low)
468	Lined Waterway or Outlet [468]	Stream banks, bluffs & ravines protected/restored
472	Livestock access control [472]	Pasture management
none	Maintain existing forest cover	Forestry Management
none	Manure/fertilizer incorporation (within 24 hrs)	Nutrient management (cropland)
none	Modify culvert sizing	Mitigating flow extremes (high or low)
none	Modify/replace dams, culverts & fish passage barriers	Habitat & stream connectivity management
329,329A	No-till/ridge till [329, 329A]	Tillage/residue management
590	Nutrient Management (fertilizer, soil, manure) [590]	Nutrient management (cropland)
101	Pasture improvement [101]	Pasture management
none	Permanent conservation cover, Restoration and Management of Declining Habitats, Tree/Shrub Establishment [327, 643, 612]	Perennial cover for harvest and/or conservation
none	Permeable Surfaces & Pavement (go to strategies: urban runoff stormwater control*)*	Mitigating flow extremes (high or low)
800M,804M	Permeable surfaces and pavements [800M, 804M]	Urban Stormwater Runoff Control
none	Precision Nutrient Timing & Management (beyond 590 standard)	Nutrient management (cropland)
none	Protection of vulnerable ecosystems & habitats	Habitat & stream connectivity management

Code	BMP	Strategy
410	Ravine stabilization [410]	Stream banks, bluffs & ravines protected/restored
none	Reducing or storing tile flow waters *(go to strategies: Agricultural tile drainage water treatment/storage)*	Mitigating flow extremes (high or low)
none	Reforestation on non-forested land and after cutting	Forestry Management
582	Re-meander channelized stream reaches [582]	Stream banks, bluffs & ravines protected/restored
	Restore riffle substrate	Habitat & stream connectivity management
none	Retain & increase perennial cover *(go to strategies: Perennial cover for harvest and/or conservation)*	Mitigating flow extremes (high or low)
580	Riparian bluffs stabilized or restored [580]	Stream banks, bluffs & ravines protected/restored
390,391,327	Riparian Buffers, 100+ ft wide (perennials replace tilled) [390, 391, 327]	Buffers and filters - field edge
390,391,327	Riparian Buffers, 16+ ft (perennials replace tilled) [390, 391, 327]	Buffers and filters - field edge
390,391,327	Riparian Buffers, 50+ ft (perennials replace tilled) [390, 391, 327]	Buffers and filters - field edge
390,391,327	Riparian Buffers, 50+ ft wide (replacing pasture) [390, 391, 327]	Buffers and filters - field edge
390	Riparian herbaceous cover [390]	Habitat & stream connectivity management
390,612	Riparian plantings to reduce nuisance waterfowl levels [390, 612]	Habitat & stream connectivity management
390,612	Riparian tree planting to improve shading [390, 612]	Habitat & stream connectivity management
none	Riparian zone forestry management	Forestry Management
none	Roads and trails improvement	Forestry Management
none	Roughfish management	In Lake Management
none	Sand Filter	Urban Stormwater Runoff Control
none	Sanitary sewer system extended to septic system community	Septic System Improvements
604	Saturated buffers [604]	Agricultural tile drainage water treatment/storage
350	Sediment Basin [350]	Designed erosion control & trapping
126M	Septic System Improvement [126M]	Septic System Improvements
410	Side inlet improvement [410]	Open tile inlet & side inlA58:A71et improvements
none	Small to larger off-channel impoundment dikes	Mitigating flow extremes (high or low)
none	Soil health buildup *(go to strategies: cover crops, tillage/residue management, changing rotation, Perennial cover for harvest and/or conservation)*	Mitigating flow extremes (high or low)

Code	BMP	Strategy
none	Stormwater practices to meet TMDL & permit conditions	Urban Stormwater Runoff Control
584	Stream Channel Stabilization [584]	Stream banks, bluffs & ravines protected/restored
none	Stream restoration *(go to strategy "Stream banks, bluffs & ravines protected/restored")*	Habitat & stream connectivity management
none	Stream restoration using principles such as Natural Channel Design	Stream banks, bluffs & ravines protected/restored
580	Streambanks/shoreline - stabilized or restored [580]	Stream banks, bluffs & ravines protected/restored
585	Stripcropping [585]	Designed erosion control & trapping
587	Structure for Water Control [587]	Stream banks, bluffs & ravines protected/restored
none	Supplemental Street Sweeping	Urban Stormwater Runoff Control
600	Terrace [600]	Designed erosion control & trapping
747	Tile line bioreactors [747]	Agricultural tile drainage water treatment/storage
636	Tile water storage with re-use on crops [636]	Agricultural tile drainage water treatment/storage
none	Tree trenches and boxes	Urban Stormwater Runoff Control
582	Two stage ditch - open channel [582]	Drainage ditch modifications
645,643	Upland Wildlife Habitat Management [645, 643]	Habitat & stream connectivity management
none	Wastewater nitrate reductions	Wastewater Point Source Management
none	Wastewater phos. reductions to meet TMDL & permit conditions	Wastewater Point Source Management
638	Water and Sediment Control Basin (cropland) [638]	Designed erosion control & trapping
none	Watercraft restrictions	In Lake Management
658	Wetland Creation for habitat [658]	Habitat & stream connectivity management
657	Wetland Restoration for habitat [657]	Habitat & stream connectivity management
657,658	Wetland Restoration or Creation for treatment [657, 658]	Agricultural tile drainage water treatment/storage
644	Wetland Wildlife Habitat Management [644]	Habitat & stream connectivity management
none	Integrated Pest Management	Integrated Pest Management

4. Monitoring

Ongoing monitoring is expected to occur at many scales in multiple watersheds in the LMRW. Improving water quality depends on many factors, and improvements might take several years to show a positive trend.

Monitoring is also a critical component of an adaptive management approach, and can be used to help determine when a change in management is needed. Six basic types of monitoring can be important to measuring success.

Baseline monitoring—identifies the environmental condition of the water body to determine if water quality standards are being met and identifies temporal trends in water quality.

Implementation monitoring—tracks implementation of conservation practices using BWSR's eLink or other tracking mechanisms.

Flow monitoring— combined with water quality monitoring at stream sites to allow for the calculation of pollutant loads.

Effectiveness monitoring—determines whether a practice or combination of practices are effective in improving water quality.

Trend monitoring—allows the statistical determination of whether water quality conditions are improving.

Validation monitoring—validates the source analysis and linkage methods in source tracking to provide additional certainty regarding study findings. For instance monitoring above and below knickpoints rather than just at the watershed outlet to help constrain and identify sediment sources.

There are many monitoring efforts in place to address each of the six basic types of monitoring. Several key monitoring programs will provide the information to track trends in water quality and evaluate compliance with TMDLs:

- Intensive monitoring and assessment of both chemical and biological parameters in lakes and streams at the HUC-8 scale (part of Minnesota's watershed approach) will continue. This monitoring effort is conducted every 10 years for each HUC-8 and, thus, will come up again in 2024-2025 for the LMRW.
- The MPCA's Watershed Pollutant Load Monitoring Network (WPLMN) measures and compares data on pollutant loads from Minnesota's rivers and streams and tracks water quality trends. WPLMN data will be used to assist with assessing impaired waters, watershed modeling, determining pollutant source contributions, developing watershed and water quality reports, and measuring the effectiveness of water quality restoration efforts. In this watershed, monitoring stations exist on High Island Creek and along the main stem of the Minnesota River.
- The Metropolitan Council Environmental Services (MCES) conducts biweekly monitoring of approximately 6 to 12 lakes in the TCMA per year on a rotating schedule. Monitoring focuses on trophic status indicators such as TP, chlorophyll-*a*, Secchi transparency, and DO. In MCES's Citizen-Assisted Monitoring Program (CAMP), volunteers monitor lake surface water quality on a biweekly basis. Also, MCES monitors several streams in the LMRW as part of their Minnesota

River Tributary Streams Assessment. This has provided a long-term dataset for ongoing trend evaluation.

- All metro WDs and WMOs as well as Three Rivers Park District monitor waters in the LMRW. Typically, due to the large number of lakes, responsibility for lake monitoring rotates between the organizations.
- Implementation tracking is conducted by both BWSR (i.e., eLink) and NRCS. Both agencies track the locations of BMP installations. Tillage transects and crop residue data are collected periodically and reported through the Tillage Transect Survey Data Center. In addition, the MPCA documents (integrating data from eLink and NRCS, among other sources) actions taken in Minnesota's watersheds to meet water quality goals and outcomes on the Healthier Watersheds webpage. This report includes the status of WRAPS/TMDLs, wastewater loading, BMP, and spending for implementation projects.
- Discharges from permitted municipal and industrial wastewater sources are reported through discharge monitoring records; these records are used to evaluate compliance with NPDES permits. Summaries of discharge monitoring records are available through the MPCA's Wastewater Data Browser.

For the purpose of establishing water quality progress benchmarks for monitoring, it can be assumed that reductions in pollutant concentrations over time will generally align with the desired load reductions established in Section 3.4. In other words, if 1% to 2% of the overall needed reduction occurs per year on average, then a similar change in water quality pollutant concentration will result. For example, for a lake with a long-term growing season TP concentration of 90 µg/L, by year 10 it would range from 72 to 81 µg/L.

5. References and further information

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Lower Minnesota River Watershed Project Reports

All Lower Minnesota River Watershed project reports referenced in this watershed report are available at the project webpage: https://www.pca.state.mn.us/water/watersheds/lower-minnesota-river

Appendices

Appendix 1: Index Table of Stream AUIDs by County and 10 Digit HUC.

County	HUC-10 Number	HUC 10 Name	auid	Stream Name	Location
Carver	702001207	Bevens Creek	07020012-514	Bevens Creek	Silver Cr to Minnesota R
			07020012-522	County Ditch 4A	Unnamed ditch to Bevens Cr
			07020012-533	Unnamed ditch	T115 R26W S14, north line to CD 4A
			07020012-584	Unnamed ditch	Headwaters to T115 R26W S11, south line
			07020012-629	Judicial Ditch 22	Unnamed cr to Silver Cr
			07020012-657	Unnamed creek (Maria Lake Outlet)	Unnamed cr to Unnamed cr
			07020012-813	Silver Creek	-93.769 44.687 to Bevens Cr
			07020012-843	Bevens Creek	Headwaters (Washington Lk 72-0017-00) to 154th St
			07020012-844	Bevens Creek	154th St to -93.8615 44.7265
			07020012-845	Bevens Creek	-93.8615 44.7265 to -93.8455 44.7327
			07020012-846	Bevens Creek	-93.8455 44.7327 to Unnamed cr
			07020012-847	Bevens Creek	Unnamed cr to -93.7156 44.7438
			07020012-848	Bevens Creek	-93.7156 44.7438 to Silver Cr
	702001210	Carver Creek	07020012-526	Unnamed creek	Headwaters to Carver Cr
			07020012-527	Unnamed ditch	Burandt Lk to Unnamed cr
			07020012-565	Unnamed ditch	T115 R25W S16, west line to Winkler Lk
			07020012-566	Unnamed ditch	Meuwissen Lk to Lk Benton
			07020012-568	Unnamed creek	Benton Lk to Carver Cr
			07020012-618	Unnamed creek	Goose Lk (10-0089-00) to Unnamed wetland
			07020012-619	Unnamed creek (Lake Waconia Inlet)	Unnamed wetland to Lk Waconia
			07020012-621	Unnamed creek	Reitz Lk to Unnamed cr
			07020012-622	Unnamed creek	Unnamed cr to Carver Cr (CD 2 & 3)
			07020012-623	Unnamed creek	Lk Waconia to Burandt Lk
			07020012-805	Carver Creek	Headwaters to MN Hwy 284
			07020012-806	Carver Creek	MN Hwy 284 to Minnesota R
			07020012-907	Unnamed creek (Goose Lake Inlet)	to Goose Lk (10-0089-00)
	702001211	Minnesota River	07020012-528	Unnamed creek	Headwaters to Minnesota R
			07020012-581	Unnamed creek (East Creek)	Unnamed cr to Minnesota R
			07020012-582	Unnamed creek (Assumption Creek)	Headwaters to Minnesota R
			07020012-664	Unnamed creek	Unnamed cr to Unnamed cr
			07020012-671	Unnamed creek	Hazeltine Lk to Unnamed lk (10-0216-00)
			07020012-710	Bluff Creek	Headwaters to Rice Lk
			07020012-803	Chaska Creek	US Hwy 212 to Creek Rd
			07020012-804	Chaska Creek	Creek Rd to Minnesota R
			07020012-835	Unnamed creek	Gaystock Lk to Unnamed cr
Dakota	702001211	Minnesota River	07020012-625	Unnamed creek	Black Dog Lk to Minnesota R
			07020012-652	Unnamed creek	Black Dog Lk to Minnesota R
Hennepin	702001211	Minnesota River	07020012-511	Riley Creek	Riley Lk to Minnesota R
			07020012-719	Ninemile Creek, South Fork	Minnetoga Lk (27-0088-00) to Bryant Lk
			07020012-723	Ninemile Creek, South Fork	Smetana Lk to Ninemile Cr
			07020012-736	Unnamed creek	Headwaters to Purgatory Cr
			07020012-807	Ninemile Creek	Headwaters to Metro Blvd
			07020012-808	Ninemile Creek	Metro Blvd to end of unnamed wetland
			07020012-809	Ninemile Creek	Unnamed wetland to Minnesota R
			07020012-828	Purgatory Creek	Staring Lk to Minnesota R
Le Sueur	702001205	City of Le Sueur-Minnesota River	07020012-758	Unnamed creek	Headwaters to culvert
			07020012-761	Unnamed creek	Unnamed cr to JD 2
	702001201	Le Sueur Creek	07020012-547	County Ditch 51	Headwaters to Le Sueur Cr
			07020012-724	Le Sueur Creek	Forest Prairie Cr to Minnesota R
			07020012-725	Forest Prairie Creek	CD 29 to Le Sueur Cr
			07020012-762	Unnamed ditch	Unnamed ditch to CD 51
			07020012-763	Unnamed ditch	Unnamed ditch to Forest Prairie Cr
			07020012-764	County Ditch 34	Unnamed ditch to Forest Prairie Cr
			07020012-766	County Ditch 8/53	Unnamed ditch to CD34
			07020012-767	Judicial Ditch 4	Unnamed ditch to Forest Prairie Cr
			07020012-768	Unnamed creek	CD 56 to Le Sueur Cr
			07020012-772	County Ditch 42	School Lk to Clear Lk outlet
			07020012-823	Le Sueur Creek	CD 23 to W Prairie St
			07020012-824	Le Sueur Creek	W Prairie St to Forest Prairie Cr
	702001208	Sand Creek	07020012-542	County Ditch 22	T111 R23W S10, south line to CD 30
			07020012-661	County Ditch 30 (County Ditch 54)	CD 22 to T112 R23W S26, north line
			07020012-663	Unnamed creek	Rice Lk to Lk Sanborn
			07020012-773	County Ditch 48	Headwaters to Eggert Lk
			07020012-839	Sand Creek	T112 R23W S23, south line to -93.5454 44.5226
			07020012-840	Sand Creek	-93.5454 44.5226 to Raven Str
			07020012-841	Raven Stream, West Branch	Headwaters (Rennenberg Lk 40-0088-00) to 270th St

McLeod	702001206	High Island Creek	07020012-561	Unnamed ditch (Bakers Lake Inlet)	Headwaters to Bakers Lk
			07020012-591	Judicial Ditch 24	Headwaters to JD 11
			07020012-593	Judicial Ditch 11	CD 10 to JD 24
			07020012-594	Unnamed creek (County Ditch 30)	Headwaters to Bakers Lk
			07020012-596	Judicial Ditch 19 (High Island Lake Inlet)	Headwaters to High Island Lk
			07020012-648	Unnamed creek	Unnamed cr to Mud Lk
			07020012-653	High Island Creek	JD 15 to Bakers Lk
			07020012-682	Judicial Ditch 15	CD 31 to High Island Cr
			07020012-683	County Ditch 39	Unnamed ditch to High Island Cr
			07020012-837	High Island Creek	Bakers Lk to -94.2538 44.6574
	702001202	North Branch Rush River	07020012-555	Rush River, North Branch (Judicial Ditch 18)	Headwaters to Titlow Lk
Nicollet	702001205	City of Le Sueur-Minnesota River	07020012-602	Barney Fry Creek	CD 47A to CD 35
			07020012-792	County Ditch 47A	Unnamed ditch to CD 75
			07020012-793	County Ditch 75	Unnamed ditch to CD 47A
	702001203	South Branch Rush River	07020012-509	Judicial Ditch 1A	CD 40A to S Br Rush R
			07020012-574	Judicial Ditch 6	Unnamed ditch to S Br Rush R
			07020012-585	County Ditch 40A	Headwaters to T111 R29W S18, east line
			07020012-607	County Ditch 40A	Unnamed ditch to JD 1A
			07020012-783	County Ditch 32A	CD 32 to Unnamed ditch
			07020012-784	County Ditch 9	Unnamed ditch to JD 1A
			07020012-801	County Ditch 30A	Unnamed ditch to JD 1A
			07020012-825	Rush River, South Branch	Unnamed ditch to -94.0478 44.4761
Renville	702001206	High Island Creek	07020012-590	Judicial Ditch 11	CD 103 to CD 10
			07020012-731	Unnamed ditch	Unnamed ditch to JD 11
Rice	702001208	Sand Creek	07020012-686	Unnamed creek	Unnamed cr to Cody Lk
			07020012-705	Unnamed creek	Headwaters to Porter Cr
			07020012-706	Unnamed creek	Unnamed cr to Unnamed cr
			07020012-739	Unnamed ditch	Headwaters to Unnamed ditch
			07020012-740	Unnamed ditch	Unnamed ditch to Unnamed ditch
			07020012-760	Unnamed creek	Unnamed cr to Unnamed ditch
			07020012-815	Porter Creek	Fairbanks Ave to 250th St E
Scott	702001209	City of Belle Plain-Minnesota River	07020012-575	Robert Creek	Unnamed cr to Unnamed cr (at Belle Plaine Sewage Ponds)
			07020012-746	Unnamed creek	Headwaters to Unnamed cr
			07020012-748	Unnamed creek	Headwaters to Robert Cr
			07020012-749	Big Possum Creek	Unnamed cr to Minnesota R
			07020012-752	Unnamed creek	Unnamed cr to Minnesota R
			07020012-753	Unnamed creek	Headwaters to Unnamed cr
			07020012-830	Unnamed creek (Brewery Creek)	US Hwy 169 to Minnesota R
	702001205	City of Le Sueur-Minnesota River	07020012-756	Unnamed creek	Headwaters to Minnesota R
			07020012-757	Unnamed creek	Headwaters to Minnesota R
			07020012-758	Unnamed creek	Headwaters to culvert
	702001211	Minnesota River	07020012-519	Eagle Creek	Headwaters to Minnesota R
			07020012-599	Unnamed creek	Spring Lk to Upper Prior Lk
			07020012-604	Unnamed creek (County Ditch 13)	Unnamed ditch to Spring Lk (70-0054-00)
			07020012-660	Unnamed creek	Unnamed cr to Credit R
			07020012-726	Unnamed creek (Prior Lake Outlet Channel)	Unnamed cr to Dean Lk
			07020012-728	Unnamed creek (Prior Lake Outlet Channel)	Dean Lk to Blue Lk
			07020012-733	Unnamed creek	Headwaters (Clearly Lk 70-0022-00) to Unnamed cr
			07020012-734	Unnamed creek	Headwaters to Credit River
			07020012-735	Unnamed creek	Headwaters to Credit River
			07020012-810	Credit River	Headwaters to -93.3526 44.7059
			07020012-811	Credit River	-93.3526 44.7059 to Minnesota R
	702001208	Sand Creek	07020012-513	Sand Creek	Porter Cr to Minnesota R
			07020012-538	Sand Creek	Raven Str to Porter Cr
			07020012-579	Unnamed creek (Picha Creek)	Unnamed cr to Unnamed cr
			07020012-580	Unnamed creek (Picha Creek)	Unnamed cr to Sand Cr
			07020012-628	County Ditch 10	CD 3 to Raven Str
			07020012-684	Unnamed creek	Unnamed cr to Sand Cr
			07020012-685	Unnamed creek	Unnamed lk (70-0039-00) to Cedar Lk
			07020012-703	Unnamed creek	Headwaters to Unnamed cr
			07020012-704	Unnamed creek	Headwaters to Unnamed cr
			07020012-705	Unnamed creek	Headwaters to Porter Cr
			07020012-706	Unnamed creek	Unnamed cr to Unnamed cr
			07020012-716	Raven Stream	E Br Raven Str to Sand Cr
			07020012-732	Unnamed creek	Headwaters to Sand Cr
			07020012-737	County Ditch 3	Headwaters to Unnamed ditch
			07020012-738	County Ditch 3	Unnamed ditch to CD 10
			07020012-815	Porter Creek	Fairbanks Ave to 250th St E
			07020012-816	Porter Creek	250th St E to Langford Rd/ MN Hwy 13
			07020012-817	Porter Creek	Langford Rd/MN Hwy 13 to Sand Cr
			07020012-819	Raven Stream, East Branch	-93.6106 44.5532 to 255th St W
			07020012-822	Unnamed creek	RR bridge to E Br Raven Str
			07020012-840	Sand Creek	-93.5454 44.5226 to Raven Str
			07020012-841	Raven Stream, West Branch	Headwaters (Rennenberg Lk 40-0088-00) to 270th St
			07020012-842	Raven Stream, West Branch	270th St to E Br Raven Str
			07020012-849	Unnamed creek	Unnamed ditch to -93.4251 44.6206
			07020012-850	Unnamed creek	-93.4251 44.6206 to St Catherine Lk

			07020012-826	Rush River, South Branch	-94.0478 44.4761 to Rush R

Appendix 2: ET Rate Data & Calculation

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

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

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

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

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

Appendix 3: Minnesota State Government Review of Internal Phosphorus Load Control

Minnesota State Government Review of Internal Phosphorus Load Control

An important option in the lake management toolbox

This document is intended to serve as a jumping off point for investigating different methods of reducing internal phosphorus loads, as there are many considerations and information needed to review before making the most informed decision for lake management.

This provides an overview of known practices for internal lake load control as reviewed by Minnesota Pollution Control Agency, Minnesota Department of Natural Resources, Board of Soil and Water Resources, and the Metropolitan Council staff. The audience is state and local lake practitioners as well as agency staff issuing permits or reviewing grant proposals when considering the use of internal phosphorus load reduction practices.

For a more detailed examination of particular practices, including costs and phosphorus loading in general, readers can look to the references provided as well as Appendix A.

Introduction

Internal loading is often identified in Total Maximum Daily Load (TMDL) studies and lake management plans as a significant source of phosphorus to Minnesota lakes and a cause of poor water quality. Internal loading of phosphorus has been described as a "wicked problem" in aquatic science and management (Oriehl et al, 2017; Rittel and Webber, 1973) because it is ill defined, complex and has a changing nature. Release of sediment bound phosphorus can result in high lake phosphorus concentrations even in the absence of significant external phosphorus loads.

The following conclusions have been agreed upon by the state agencies that authored the report.

- Internal loading is often a significant source of phosphorus to Minnesota lakes and a cause, or potential cause, of lake eutrophication;
- The State of Minnesota recognizes addressing sources of phosphorus within a lake's basin will be an appropriate and necessary part of many lake restoration plans and potentially some lake protection plans;
- There is no "one size fits all" formula that can be used to predict internal phosphorus load reductions achieved from application of control methods. Internal phosphorus loads depend on a multitude of factors including the physical, chemical and/or biological attributes of a particular lake, on the size and shape of the lake relative to its watershed, as well as the geographical location and associated land-use of the lake's watershed. Lake-specific plans need to be developed to quantify the internal load reductions that could be expected from applying phosphorus reduction methods. Lake data and modeling will be critical to develop feasible and cost-effective management strategies;
- There are currently no specific thresholds that outline how external phosphorus load and internal phosphorus load reduction efforts should be balanced or timed for Minnesota lakes. As mentioned above, there are too many lake-specific variables as well as an insufficient history of in-lake treatment efforts in Minnesota to create such criteria or thresholds. The Board of Water and Soil Resources (BWSR) has solicited input from various consulting companies that are helping develop/design internal phosphorus control management plans on how such criteria or thresholds might be designed and the State may develop specific criteria and/or thresholds in

the future. Again, lake data and modeling will be critical to develop and justify how to phase and balance proposed internal vs. external load reduction efforts;

- Scientific literature suggests the duration of internal load control effectiveness can be variable, ranging from 1-20 years depending on the lake morphology, external loads and the phosphorus reduction method employed. Scaling the approach as appropriate for a particular lake (e.g. proper dosing of alum) and external nutrient control will increase the effectiveness and longevity of internal load control methods.
- The State and/or other government units have regulatory authority over many of the actions or activities that would be part of an internal phosphorus load reduction plan. However, there may be multiple other partners that have a vested interest in what actions/activities are planned or phased over time. It is the State's expectation that the planning process will be sufficiently broad-based to include the input of all interested partners.

Planning considerations for internal phosphorus load controls

Prior to considering an internal phosphorus treatment plan, lake managers should perform an analysis of a lake's overall phosphorus budget. Some information such as a phosphorus source assessment and source reduction targets may be available if a TMDL for the lake has been developed. However, additional investigation such as lake sediment coring will often be needed to directly measure and quantify the contributions of internal loading processes. If internal load has been identified as a significant source of phosphorus, which threatens the quality of a lake, lake managers should consider incorporating measures to control internal phosphorus loading into an overall phosphorus reduction plan. The following are additional considerations when determining the appropriateness of employing internal phosphorus load reductions practices.

External vs. internal load

A lake is a reflection of its watershed as drainage area, land use, topography and geology impact the phosphorus budget of a lake. A significant proportion of the watershed phosphorus load will likely need to be reduced to achieve long-term water quality improvement. Unless external loading has been adequately addressed, in-lake treatment will have short-term benefits at best.

No threshold of external phosphorus reduction has been identified to trigger the use of internal load measures. Based on our current knowledge regarding the application of internal load controls, the use of "rule of thumb" management decisions over simplifies the complex and unique nature of individual lakes. However, when proposing internal phosphorus load controls, lake managers should be able to demonstrate through modeling or other means how combined efforts at reducing external and internal loads will collectively achieve lake management goals.

Lake type

Lake type will influence the success of internal load control treatments. Depth, hydrologic connections, watershed: surface area ratio, and other factors influence the outcome and duration of treatments. For example, seepage lakes, maintained primarily by groundwater inflow, typically have small watersheds and consequently long residence times. Drainage lakes, fed by inflowing streams, have larger watersheds and shorter residence times. Drainage lakes are more difficult to manage for phosphorus than seepage lakes because inflowing streams will carry the nutrients and sediment of the entire watershed. Lakes with small watershed: surface area ratios are best suited for in-lake treatment.

Lake depth is also important to consider when choosing among internal load reduction strategies. In deep lakes, phosphorus is released from bottom sediments when the lake is stratified and oxygen at the water/lake bottom interface is depleted. Therefore, strategies preventing anoxic conditions or anoxic release of phosphorus could be effective in deeper lakes (e.g. alum, hypolimnetic aeration). Conversely, physical removal of phosphorus-laden sediments (dredging) or hardening of bottom sediments and rough fish control (drawdown), though impractical in deep lakes, may be effective in shallow lakes.

Comprehensive lake management

Lakes are complex ecological systems. Methods for reducing internal phosphorus load can have unintended consequences that impact aquatic plant and animal communities and abundance. For example, moving a lake from a turbid state to a clear state will result in increased vegetation. This is especially prevalent in shallow lakes with relatively large littoral areas. Therefore, it is important to propose or review internal phosphorus treatment plans within the context of a more comprehensive and customized lake management plan. This should incorporate the perspectives of watershed management, water quality, fisheries, recreational opportunities and development pressures.

Internal load reduction methods used in Minnesota lakes

Typical internal load reduction methods used in Minnesota lakes can be broken down into three main categories: chemical, physical and biological. Chemical methods generally involve the application of a substance that reduces or inactivates the release of sediment bound phosphorus in a lake making less phosphorus available for algal growth. Chemical applications can be applied to an entire lake or just those areas that have been identified as heavily laden with sediment bound phosphorus. Physical load reduction methods range from removal of phosphorus rich sediment (dredging) to hydrologic alterations such as lake level drawdowns and aeration. Dredging is generally limited to specific areas with phosphorus rich sediments as indicated by sediment cores. Hydrologic alterations act to reduce the availability of phosphorus through hardening of sediments or preventing anoxic release of phosphorus. Biological methods involve harvesting of vegetation to remove plant bound phosphorus in the lake and managing the fish community to reduce disturbance of phosphorus rich lake sediments by rough fish. The tools or best management practices to reduce in-lake phosphorus can be adapted and used in combination or sequentially to meet management goals.

Table 1 lists different internal phosphorus load reduction strategies available for consideration. While not exhaustive, the table lists many of the most commonly applied internal phosphorus load reduction methods used in Minnesota lakes. The reader can use the table to narrow down potential load reduction options for a particular lake based on its morphology and potential side-effects. Once the list is narrowed, the reader is directed to Appendix A where additional detail and links to case studies are provided for the different treatments. Table 1 does not include cost estimates, as these can be highly variable and only meaningful within the context of a specific lake. Lewtas et al (2015) includes a range of cost estimates for most of the options presented in Table 1 providing lake specific context such as cost per hectare, cost per pound of phosphorus reduced, cost per year, costs associated with equipment maintenance and costs of disposal of waste materials.

Table 1. Internal loading management options (see Appendix A for additional information on each treatment option).

Type of treatment	Treatment	Lake Morphology	Longevity	Permits Required*	Impacts to Biological community: x-direct, 0-indirect**, z-more study needed			Problems or considerations
					Fish	Invertebrates	Aquatic Macrophytes	
Chemical	Alum additions	shallow/deep	4 - 21 years - stratified 1 - 11 years - shallow	MPCA (approval letter)	0 - Macroalgae is primary fish habitat. May impact community composition and abundance	x - Short term impacts related to the settling of the floc layer 0-macroalgae are habitat for invertebrates	x - Toxic to macroalgae 5.0 g Al m^{-3}	To be effective might require pH buffering. Whole lake treatments generally limited to smaller basins (<500 acres). Larger lakes might require targeting of higher loading areas in the lake.
	Iron filings	shallow/deep	Short term, iron tends to bind P only in the presence of O2 so first anoxic period may release large quantity of bound P	MPCA (approval letter)	z	z	z	Used in low sulfate waters (sulfide competes with phosphate for precipitation with Fe). Aeration or artificial circulation may have to accompany applications to prevent the breakdown of the oxidized barrier.
	Ferric Chloride	deep	Variable effective time, O_2 depletion can limit longevity	MPCA (approval letter)	z	z	z	May work better combined with O_2 injection.
	Lanthanum	shallow	Unclear, but P inactivation treatments typically are not effective for more the 15 years	MPCA (approval letter)	z	x - Short term impacts related to the settling of the floc layer	z	Works well under anoxic conditions. Turbidity increases immediately after application - turbidity decreases after settling. Not as common as Alum or Iron.
Physical	Dredging	shallow	Depends on incoming loads and material removed	MDNR public waters work permit; MPCA management of dredge material permit	x - Impact community composition and/or abundance	x - Impact community composition and/or abundance	x - Impact community composition and/or abundance	Goal to remove high P sediments. High cost and placement of dredged materials. Potentially toxic materials such as trace elements and organic pesticides.
	Drawdown	shallow	Depends on macrophyte community, area exposed and reintroduction of rough fish	ACoE Section 404 permit; MDNR public waters work permit, water appropriation permit and aquatic plant management permit; MPCA 401 certification, NPDES construction permit and management of dredge materials permit; MNDOT work in ROW permit	x - Impact community composition and/or abundance	x - Impact community composition and/or abundance	x - Impact community composition and/or abundance	Disposal of water from drawdown. Expensive, engineering costs. Manually remove accumulations of dead fish as basins are dewatered. Vegetation maintenance.
	Dilution	shallow/deep	Long term although not very practical, limited conditions where possible	MDNR public waters work permit; ACoE Section 404 permit	z	z	z	Costs for pumping or rerouting waters; effects of altering water sources and flows; generally limited to small lakes.
	O_2 injection	deep	Continual treatment	MDNR aeration permit	z	0 - Could alter community composition/abundance by changing area of lake bottom that has higher D.O. levels	z	Costs for initial setup; sizing system to lake for desired effect. Can create thin ice areas in winter months.
	Hypolimnetic withdrawal	deep	Depends on magnitude and duration of TP transport from hypolimnion	MDNR water appropriation permit and public waters work permit	z	0 - Could impact community composition and/or abundance depending on withdrawal severity and changes in D.O. and/or nutrient availability	z	Multiple options: withdrawal and return, withdrawal and discharge, withdrawal and treat and return; winter aeration causes ice instability.
	Hypolimnetic aeration	deep	Continual treatment	MDNR aeration permit	z	0 - May alter community composition and abundance	0 - May alter community composition and abundance	Goal to eliminate the loss of O_2, either by injecting O_2 or increasing mixing of water column. Can create thin ice areas in winter months.
	Circulation and aeration	shallow/deep	Continual treatment	MDNR aeration permit	x - Decreases winterkill, may alter community composition and abundance	0 - May alter community composition and abundance	z	Can create thin ice conditions in winter months; used to prevent winterkill.
Biological	Bio-manipulation	shallow/deep	Depends on the re-introduction of rough fish	MDNR permit	x - Typically designed to reduce disturbance of lake sediments and includes removing common carp; black and brown bullheads are also considered	0 - Increasing bluegill numbers to eat common carp eggs can increase predation of invertebrates	0 - May alter community composition and abundance (for positive or negative)	More cost effective if removal can be done without paying for the removal; without interested fish netter costs rise as does the costs for getting rid of fish remains.
	Mechanical aquatic plant removal	shallow/deep	Continuous, multiyear obligation; removes nutrients directly from system	MDNR aquatic plant management permit	x - Direct mortality - Fish, amphibians are often unintended targets of harvesting 0 - May alter community composition and abundance - predator/prey and depending on scale of application - oxygen depletion could lead to fish kill	0 - May alter community composition and abundance	0 - May alter community composition and abundance	Curlyleaf pondweed, Eurasian Milfoil, other invasive plants

* List of permit requirements not intended to be comprehensive. Permit requirements could vary by method and local jurisdiction. Please contact identified state and federal agencies as well as local authority to obtain required permits/approvals prior to beginning work.

** Successful treatments will result in less available nutrients in a waterbody increasing water clarity. Increasing water clarity will have indirect impacts on all aquatic biological communities. Submersed aquatic macrophytes will increase in abundance, which will expand habitat for invertebrates and provide additional food sources and cover for fish. Predator prey relationships may be altered as well as shifts in population composition and abundance.

Important information for determining the most appropriate load control option

The following information should be considered by lake managers when determining the appropriateness of internal phosphorus load control options. This information would be included in a feasibility study, when required:

1. Internal load control vs external load reductions
    a. What information exists that is directing the desired work?
    b. Has a model been completed and validated?
    c. Has a TMDL been calculated?

2. History of projects completed in the watershed and in the lake
    a. What was done?
    b. Where was it done?
    c. What are the limitations to further reductions in the watershed?

3. Cost benefit analysis of treatment options including the status quo option
    a. Estimated load reduction and treatment effectiveness longevity
    b. Decision making process to determine the best options
    c. Expected effects of treatment on the lake in addition to load reductions (e.g. increased vegetation, altered fish assemblage, thin winter ice)

4. Lake and watershed information
    a. Lake water quality data (chemistry data, trends, loading information)
    b. Watershed land use, especially on-going land use changes
    c. Watershed: lake surface area ratio
    d. Fish community (stocking history, changes to fish community, historic species control)
    e. Plant community (presence of invasive species, non-natives, and historic treatments)

5. Social dynamics
    a. Engagement of lake shore residents and watershed residents
    b. Presence of lake association
    c. Plan for educating public on possible outcomes

Managing expectations

An important aspect of any lake improvement project is managing the expectations of those involved, including lakeshore and watershed residents. As indicated in Table 1, phosphorus reduction treatments can have unintended consequences ranging from thin winter ice to increased “nuisance” vegetation to changing fish community composition. These possibilities should be clearly communicated to lake stakeholders prior to proceeding on a lake improvement project.

Factors influencing effectiveness and longevity of treatment

1. External phosphorus load – if external load is a major source of phosphorus, the effectiveness and longevity of internal reductions could be compromised
2. Dosing of chemical treatments – using the proper dose of chemical treatment (e.g. alum) is important for limiting the availability of phosphorus for algal growth

3. Watershed to lake area ratio – longevity of treatment effectiveness tends to be greater for lakes with a smaller watershed relative to lake surface area
4. Lake morphology – treatment effectiveness and longevity tend to be greater for deep lakes and less for shallow lakes
5. Abundance of benthic feeding fish – large populations of bottom feeding fish (e.g. carp) can stir up sediment releasing phosphorus into the water column

Socio-economic considerations

1. Cost and long-term management – treatment costs can be significant and might need to be repeated to maintain improvements; cost analyses of treatment options should consider longevity of effectiveness in addition to the cost per pound of phosphorus removal
2. Impaired water status – treatments, even if deemed successful, do not guarantee removal from the impaired waters list
3. Timing of treatment - treatments will not provide immediate remedy for an active algal bloom
4. Lakes as living ecosystems – improvements to water clarity will likely enhance aquatic plant growth
5. Robust monitoring effort – a long-term pre and post-project monitoring effort is needed to inform treatment requirements and effectiveness
6. Urban vs rural expectations – the geographic setting of the lake is often associated with different perceptions of clean water and responsibilities for implementing solutions

Regulatory considerations

1. Permit/authorization requirements – the internal load treatments identified in this guidance require federal and/or state and/or local permits or authorizations; it is the responsibility of the local practitioner to obtain all necessary permits
2. Wasteload allocation – internal load treatments do not count toward wasteload reductions assigned to a municipal stormwater permittee through a TMDL study

Summary/Conclusions

In summary, the unique circumstances of any particular lake dictate the appropriateness of utilizing internal phosphorus load controls. Lake morphology, lake phosphorus balance, watershed landuse, downstream impacts, budgetary restrictions, permitting requirements and public expectations are just some of the factors that need to be weighed when considering internal phosphorus control practices.

As mentioned earlier, practices employed to reduce internal loading should only be considered in the context of a comprehensive lake management plan. Ideally, lake management plans reflect the agreed upon goals of diverse stakeholders. The methods for protecting and/or restoring a lake and its watershed, which could include internal phosphorus controls, are derived from those goals. A holistic approach to lake management that incorporates watershed and in-lake practices is more likely to lead to long-term success and sustainability.

Appendix A

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