Mississippi River-St. Cloud Watershed

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Mississippi River-St. Cloud Watershed Total Maximum Daily Load Report 2024

MINNESOTA POLLUTION CONTROL AGENCY

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Abbreviations

1W1P	One Watershed, One Plan
AUID	assessment unit identification
BMP	best management practice
BOD	biochemical oxygen demand
BWSR	Board of Water and Soil Resources
CAFO	concentrated animal feeding operation
Chl-*a*	chlorophyll-*a*
COD	chemical oxygen demand
CRP	Conservation Reserve Program
CREP	Conservation Reserve Enhancement Program
DNR	Minnesota Department of Natural Resources
DO	dissolved oxygen
E. coli	*Escherichia coli*
EPA	U.S. Environmental Protection Agency
EQuIS	Environmental Quality Information System
HSPF	Hydrologic Simulation Program–Fortran
HUC	Hydrologic Unit Code
ITPHS	imminent threat to public health and safety
IWM	intensive watershed monitoring
LA	load allocation
lb	pound
lb/day	pounds per day
lb/yr	pounds per year
LDC	load duration curve
LUNKERS	Little Underwater Neighborhood Keepers Encompassing Rheotactic Salmonids
MAWQCP	Minnesota Agricultural Water Quality Certification Program
mg/L	milligrams per liter
mL	milliliter
MNDOT	Minnesota Department of Transportation

MOS	margin of safety
MPCA	Minnesota Pollution Control Agency
MRSC	Mississippi River-St. Cloud
MRSCW	Mississippi River-St. Cloud Watershed
MS4	municipal separate storm sewer system
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
PWP	Permanent Wetland Preserve
RIM	Reinvest in Minnesota
SDS	state disposal system
SID	stressor identification
SSTS	subsurface sewage treatment systems
SWCD	soil and water conservation district
SWPPP	Stormwater Pollution Prevention Plan
TMDL	total maximum daily load
TP	total phosphorus
TSS	total suspended solids
WBIF	watershed-based implementation funding
WLA	wasteload allocation
WRAPS	Watershed Restoration and Protection Strategy
WRP	Wetland Reserve Program
WQBEL	water quality-based effluent limit
µg/L	micrograms per liter

Executive summary

The Federal Clean Water Act (CWA), Section 303(d) requires total maximum daily loads (TMDLs) to be produced for surface waters that do not meet applicable water quality standards necessary to support their designated uses (i.e., an impaired water). A TMDL determines the maximum amount of a pollutant a receiving water body can assimilate while still achieving water quality standards and allocates allowable pollutant loads to various sources needed to meet water quality standards. This TMDL study addresses the impairments in the 1,121-square mile Mississippi River–St. Cloud Watershed (MRSCW) in central Minnesota, within the Upper Mississippi River Basin. These impairments include high levels of *Escherichia coli* (*E. coli*), total suspended solids (TSS), and total phosphorus (TP), affecting aquatic recreation and aquatic life designated uses. Seventeen TMDLs are provided: 10 *E. coli* stream TMDLs, 1 TSS stream TMDL, and 6 TP lake TMDLs.

Land cover in the watershed is predominantly agricultural with the dominant crops being corn and soybean. Developed land covers are scattered throughout the watershed, with more densely developed areas near the cities of St. Cloud to the west and Albertville and Otsego to the east, which are on the western fringe of the greater Twin Cities area.

Potential sources of *E. coli* in the watershed include stormwater, wastewater, feedlots, wildlife, pets, septic systems and other human sources, and natural growth. The pollutant load capacity of the *E. coli*-impaired streams was determined using load duration curves (LDCs). These curves represent the allowable pollutant load at any given flow condition. Water quality data were compared with the LDCs to determine load reduction needs. The *E. coli* data, when taken as a whole, indicate that exceedances of the *E. coli* standard occur across all flow regimes, and *E. coli* load reductions are needed to address multiple source types. The estimated percent reductions needed to meet the *E. coli* TMDLs range from 14% to 91% depending on the conditions of the impaired stream reach.

Potential sources of TSS in the watershed include stormwater, wastewater, agricultural operations, and erosion. TSS is a surrogate pollutant for the impairment indicated by fish and macroinvertebrate bioassessment. The surrogate pollutant load capacity of the impaired stream was determined using an LDC. TSS levels during the high flow regime need an estimated 10% reduction to meet the TSS TMDL.

Potential sources of phosphorus in the watershed include stormwater, wastewater, feedlots, septic systems and untreated wastewater, loading from lakebed sediments and in-lake vegetation (referred to as internal load), streambank erosion, and atmospheric deposition. The nutrient loading capacity for each phosphorus-impaired lake was calculated using BATHTUB, an empirical model of reservoir eutrophication developed by the U.S. Army Corps of Engineers. The models were calibrated to existing water quality data. Reductions in phosphorus are presented on an average annual basis and will need to come primarily from agricultural runoff. The estimated percent reductions for the six lake TP TMDLs range from 15% to 76% depending on conditions of the individual lakes.

A 10% explicit margin of safety (MOS) was incorporated into nearly all (TP, TSS, and *E. coli*) TMDLs to account for uncertainty; two lake TP TMDLs did not receive explicit MOS.

The TMDL implementation strategy (Section 8.0) highlights an adaptive management approach to achieving water quality standards and restoring beneficial uses. Implementation strategies include agricultural runoff control and soil improvements (e.g., conservation tillage and cover crops); feedlot runoff control; nutrient management; pasture management; septic system improvements; buffers and filter strips; urban stormwater runoff control; stream restoration; and in-lake management.

Public participation included meetings and information communication with watershed stakeholders at various points during the project. The TMDL study is supported by previous work including the *Mississippi River–St. Cloud Watershed Assessment and Trends Update* (MPCA 2022d), *Mississippi River–St. Cloud Stressor Identification (SID) Report* (MPCA 2013), *Mississippi River–St. Cloud SID Update, 2022* (MPCA 2022c), and the *Mississippi River–St. Cloud HSPF Model Recalibration* (Tetra Tech 2019).

1.0 Project overview

1.1 Introduction

Section 303(d) of the federal Clean Water Act requires that TMDLs be developed for waters that do not support their water quality standards. These waters are referred to as “impaired” and are included in Minnesota’s list of impaired water bodies. The term “TMDL” refers to the maximum amount of a given pollutant a water body can receive on a daily basis and still achieve water quality standards. A TMDL study determines what is needed to attain and maintain water quality standards in waters that are not currently meeting those standards. A TMDL study identifies pollutant sources and allocates pollutant loads among those sources. The total of all allocations, including wasteload allocations (WLAs) for permitted sources, load allocations (LAs) for nonpermitted sources (including natural background), and the MOS, which is implicitly or explicitly defined, cannot exceed the maximum allowable pollutant load.

This TMDL report addresses 10 impairments for *E. coli*, 6 impairments for nutrients, and 1 impairment each for fish and benthic macroinvertebrate bioassessments in the MRSCW (United States Geological Survey [USGS] Hydrologic Unit Code [HUC]-8 07010203) (Figure 1). The MRSCW in central Minnesota is approximately 717,479 acres (1,121 sq. mi.) and is entirely within the North Central Hardwood Forest ecoregion (Figure 2).

Minnesota’s 2022 303(d) list of impaired waters includes 69 Category 5 (impaired and a TMDL study has not been approved by U.S. Environmental Protection Agency [EPA]) impairments for the MRSCW. Three lakes (mercury in fish tissue) and one stream (polychlorinated biphenyls in fish tissue) have aquatic consumption impairments and are not addressed through this TMDL study. Thirty-six of the impaired waters listed are from the 2012 assessment cycle, which were deferred in the Cycle 1 Watershed Restoration and Protection Strategy (WRAPS) for budgetary reasons and for the development of Tiered Aquatic Life Uses. Cycle 2 intensive watershed monitoring (IWM) in the MRSCW occurred in 2019 through 2021. Fifteen impairments in the MRSCW were added with Minnesota’s 2020 303(d) list and another 15 impairments were added with Minnesota’s 2022 303(d) list). Impairments selected for this TMDL study were based on local partner feedback and local water planning priorities as the local partners prepared for entering the One Watershed, One Plan (1W1P) process for the MRSCW starting in 2023.

Figure 1. Impairments in the Mississippi River–St. Cloud Watershed addressed in this report.

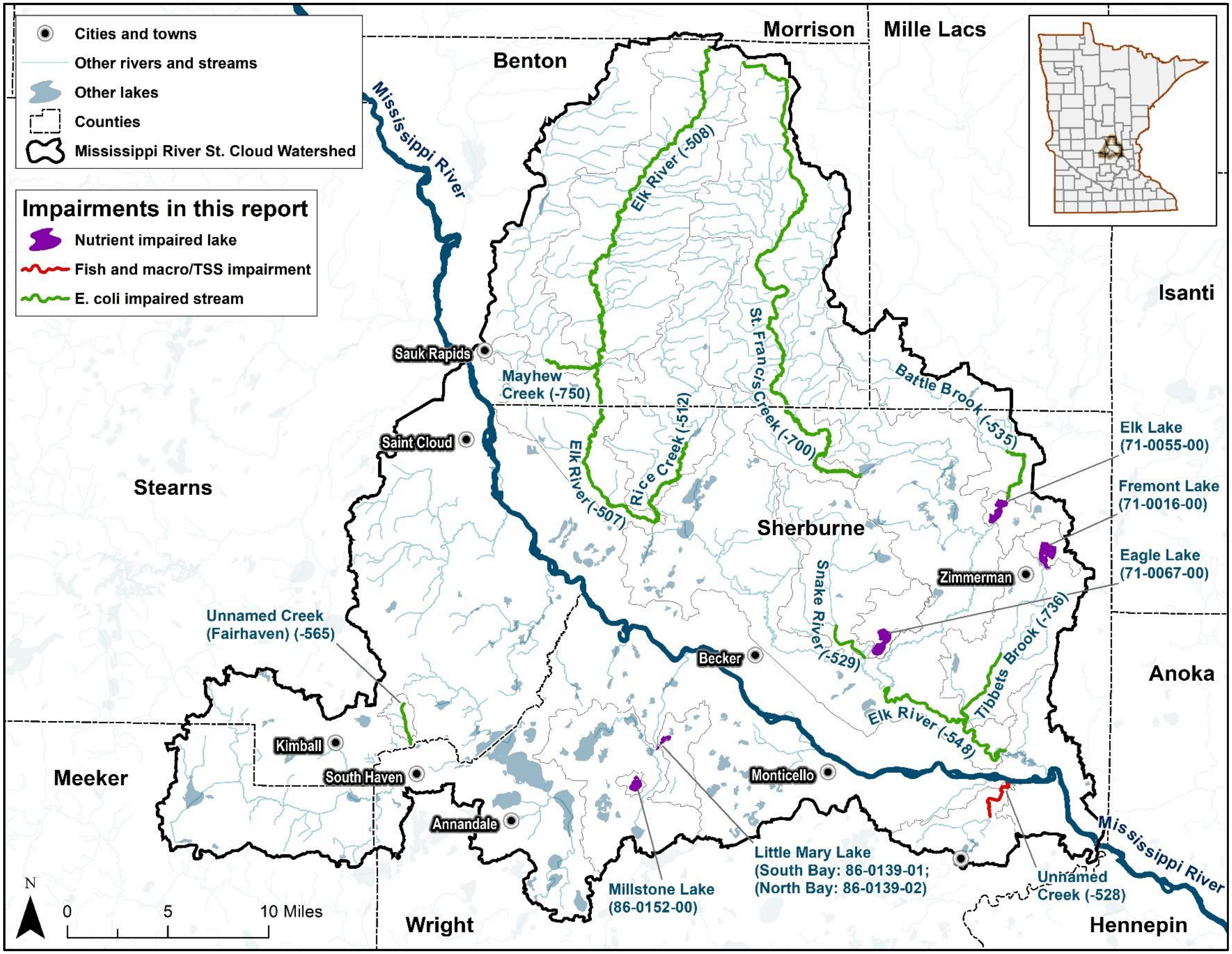
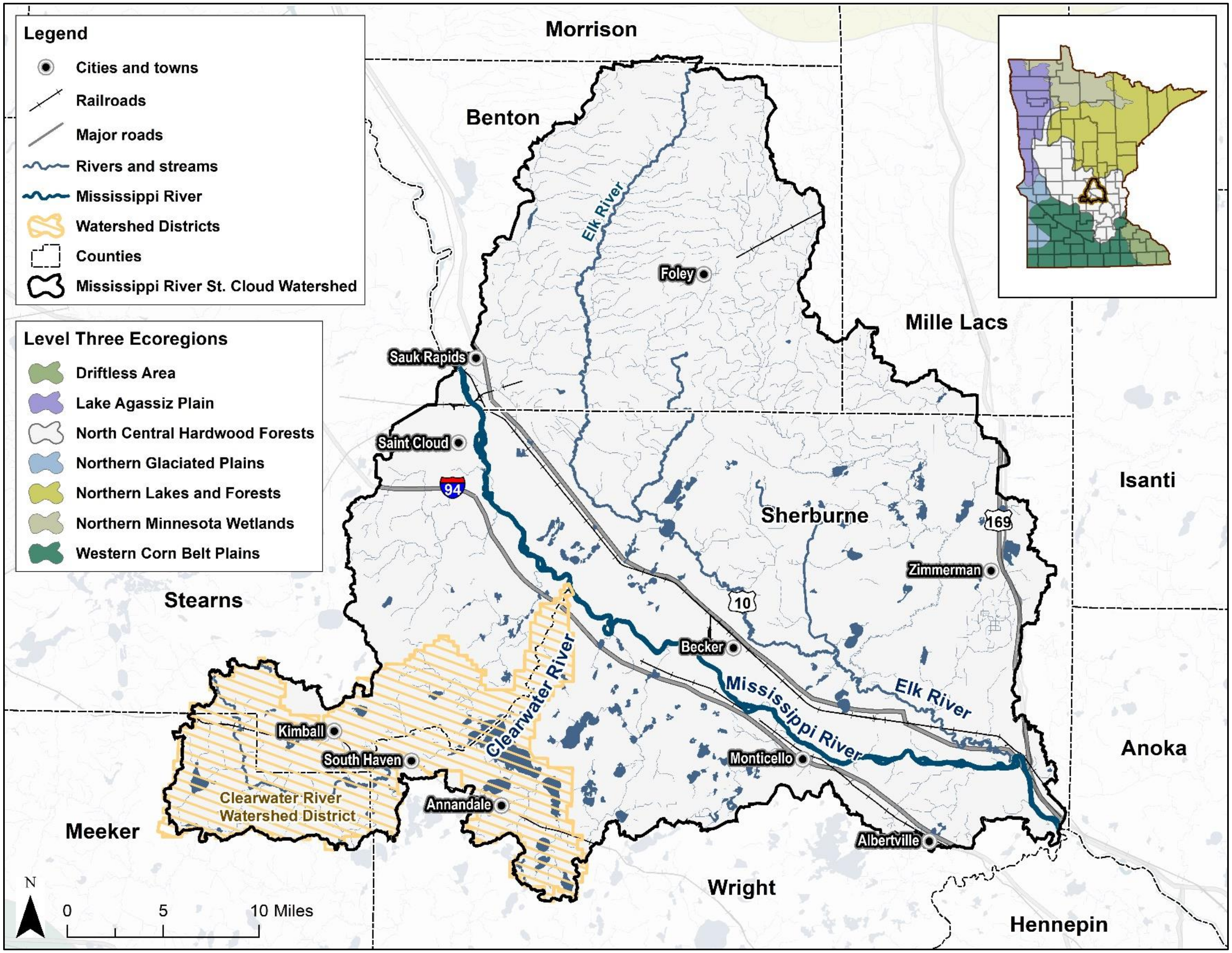


Figure 2. Mississippi River–St. Cloud Watershed.



Other TMDL reports address impairments in the MRSCW:

- The Clearwater River is a major tributary to the Mississippi River within the MRSC HUC-8. Several TMDL were done in the Clearwater River Watershed from 2009–2010 and are described below.
    - Upper Watershed TMDL Studies for Clearwater River Watershed District (Wenck 2009): This TMDL report addresses six lake nutrient impairments and one river bacteria impairment. Unnamed creek (Fairhaven Creek), addressed in this current TMDL report for *E. coli*, flows into Lake Marie, which is one of the lake nutrient impairments in the 2009 TMDL report. The main strategies for addressing the bacteria impairment are riparian pasture management and agricultural BMPs, and the lake nutrient strategies focus on internal load reduction and watershed management.
    - Clearwater River Watershed District Five Lakes Nutrient TMDL (Wenck 2010a): This TMDL report addresses five lake nutrient impairments. It does not impact this current TMDL report.
    - Clearwater River CD44 to Lake Betsy dissolved oxygen (DO) TMDL Report (Wenck 2010b): This TMDL report addresses one DO impairment in the headwaters of the Clearwater River. It does not impact this current TMDL report.
- Elk River Watershed TMDL Report (Wenck 2012): The Elk River is another major tributary to the Mississippi River in the MRSC. One TMDL report was completed in 2012 for one *E. coli* and one turbidity impairment on the Elk River and two lake nutrient impairments. The Elk River *E. coli* impairment does impact this current TMDL report as it is upstream of Elk River stream reach (548), St. Francis River to Orono Lake. The Becker Wastewater Treatment Facility (WWTF) has a WLA that is the same across all flow regimes with no reductions required. The MS4 WLA varies under flow conditions as does the LA. An explicit MOS of 16% was applied across flow regimes for the *E. coli* TMDL.
- Mississippi River (St. Cloud) Watershed TMDL (MPCA 2015): This TMDL report addresses 2 low DO, 1 aquatic macroinvertebrate, 1 turbidity, and 13 lake eutrophication impairments.
- Lake Pepin and Mississippi River Eutrophication TMDL (MPCA 2021a): This TMDL addresses eutrophication and site-specific TP and chlorophyll-*a* (Chl-*a*) standards in two segments of the Mississippi River and Lake Pepin, which has a complex ecosystem with an expansive watershed that includes the MRSC.
- Minnesota Statewide Mercury TMDL (MPCA 2007a): Some of the water bodies in the MRSC are also impaired due to mercury. Most of the mercury-impaired lakes in the watershed are addressed by a statewide TMDL study approved in 2007 (MPCA 2007a) and supporting updates approved in 2010, 2013, and 2014. For more information on mercury impairments, see the Minnesota Statewide Mercury TMDL (MPCA 2007a).

1.2 Identification of water bodies

Water bodies were assessed for impairment by the Minnesota Pollution Control Agency (MPCA), and results are presented in the *Mississippi River–St. Cloud Monitoring and Assessment Report* (MPCA 2012b). There are 6 impaired lakes and 11 impaired reaches, or assessment units, in the MRSC that do not have approved TMDLs that are included in this report (Table 1). Figure 1 in the previous section displays the impaired assessment units, while Figure 2 in the previous section displays the counties, cities, and Clearwater River Watershed District.

The lakes have aquatic recreation impairments as identified by eutrophication indicators. The stream pathogen (i.e., *E. coli*) impairments affect aquatic recreation. Aquatic consumption impairments are not addressed in this report and therefore are not presented in Table 1.

The *Mississippi River-St. Cloud SID Report* (MPCA 2013) evaluated stressors to the aquatic life (fish and macroinvertebrate bioassessment) impairment on Unnamed creek (07010203-528), which is locally known as Otsego Creek. The primary stressors to aquatic life are bedded sediment and bank erosion, which lead to poor habitat; low DO, driven by habitat; altered hydrology, which also leads to poor quality habitat; and connectivity. During high flows, there is high sediment input due to bank scouring and/or failure, and the streambed is composed primarily of fine material. A TSS TMDL is developed in this report to address the fish and macroinvertebrate bioassessment impairments on this reach.

Figure 3. Battle Brook (-535).
Source: Sherburne SWCD, July 7, 2020.

All stream assessment unit identifications (AUIDs) for streams begin with 07010203, which is the eight-digit HUC for this watershed. The reaches are identified in this report with the last three digits of the full AUID. For example, AUID 07010203-535 is referred to as reach 535. See the example to the right with Figure 3.

Although TMDLs are not developed in this report for nonpollutant stressors to biological impairments, the WRAPS report provides an opportunity to call for environmental improvements in situations where TMDLs alone would not. Nonpollutant stressors include factors such as habitat alteration or flow, and TMDLs typically are not developed for nonpollutant stressors because they are not subject to load quantification.

Table 1 below and Table 78 in Appendix A (which includes all impairments in this watershed) summarize MRSCW impairments and those addressed by TMDLs in this document.

Table 1. Impaired water bodies in the Mississippi River-St. Cloud Watershed addressed in this TMDL report.

AUID	Water body name	Water body description	Use class	Listing year	Target completion year	Affected designated use	Listing Parameter	TMDL Pollutant	Category 4A upon TMDL approval [a]
07010203-535	Battle Brook	CD 18 to Elk Lk	2Bg	2012	2023	AQR	*E. coli*	*E. coli*	Yes
07010203-507	Elk River	Mayhew Cr to Rice Cr	2Bg	2012	2023	AQR	*E. coli*	*E. coli*	Yes
07010203-508	Elk River	Headwaters to Mayhew Cr	2Bg	2012	2023	AQR	*E. coli*	*E. coli*	Yes
07010203-548	Elk River	St Francis R to Orono Lk	2Bg	2012	2023	AQR	*E. coli*	*E. coli*	Yes
07010203-750	Mayhew Creek	T36 R30W S21, west line to Elk R	2Bg	2012	2023	AQR	*E. coli*	*E. coli*	Yes
07010203-512	Rice Creek	Rice Lk to Elk R	2Bg	2012	2023	AQR	*E. coli*	*E. coli*	Yes
07010203-529	Snake River	Unnamed Cr to Eagle Lk outlet	1B, 2Ag	2012	2023	AQR	*E. coli*	*E. coli*	Yes
07010203-700	St. Francis River	Headwaters to Unnamed Lk (71-0371-00)	2Bg	2012	2023	AQR	*E. coli*	*E. coli*	Yes
07010203-736	Tibbets Brook	Unnamed ditch to Elk R	2Bg	2012	2023	AQR	*E. coli*	*E. coli*	Yes
07010203-565	Unnamed Creek (Fairhaven Creek)	Headwaters to Lk Marie	1B, 2Ag	2012	2023	AQR	*E. coli*	*E. coli*	Yes
07010203-528	Unnamed creek [b]	T121 R23W S19, south line to Mississippi R	2Bg	2012	2023	AQL	Benthic macroinvertebrates bioassessment	TSS	Yes
				2012	2023	AQL	Fish bioassessments		
71-0067-00	Eagle Lake	Sherburne County	2B	2022	2023	AQR	Nutrients	TP	Yes
71-0055-00	Elk Lake	Sherburne County	2B	2012	2023	AQR	Nutrients	TP	Yes
71-0016-00	Fremont Lake	Sherburne County	2B	2012	2023	AQR	Nutrients	TP	Yes
86-0139-02	Little Mary (North Bay)	Wright County	2B	2012	2023	AQR	Nutrients	TP	Yes

AUID	Water body name	Water body description	Use class	Listing year	Target completion year	Affected designated use	Listing Parameter	TMDL Pollutant	Category 4A upon TMDL approval [a]
86-0139-01	Little Mary (South Bay)	Wright County	2B	2012	2023	AQR	Nutrients	TP	Yes
86-0152-00	Millstone Lake	Wright County	2B	2012	2023	AQR	Nutrients	TP	Yes

AQR: aquatic recreation; AQL: aquatic life; TP: total phosphorus; TSS: total suspended solids.

Elk Lake, Fremont Lake, Little Mary–North Bay, Little Mary–South Bay, and Millstone Lake are shallow lakes.

a. Impairment will be categorized as 4A (impaired and a TMDL study has been approved by EPA) upon approval of this TMDL and will appear as 4A in the next impaired waters list. For a biological impairment to be categorized as 4A, TMDLs for all stressors needed to achieve attainment of applicable water quality standards must be approved by EPA. If there are remaining conclusive stressors, the impairment will remain in category 5 until TMDLs are developed for all conclusive pollutant stressors.

b. Unnamed creek (-528) is locally known as Otsego Creek.

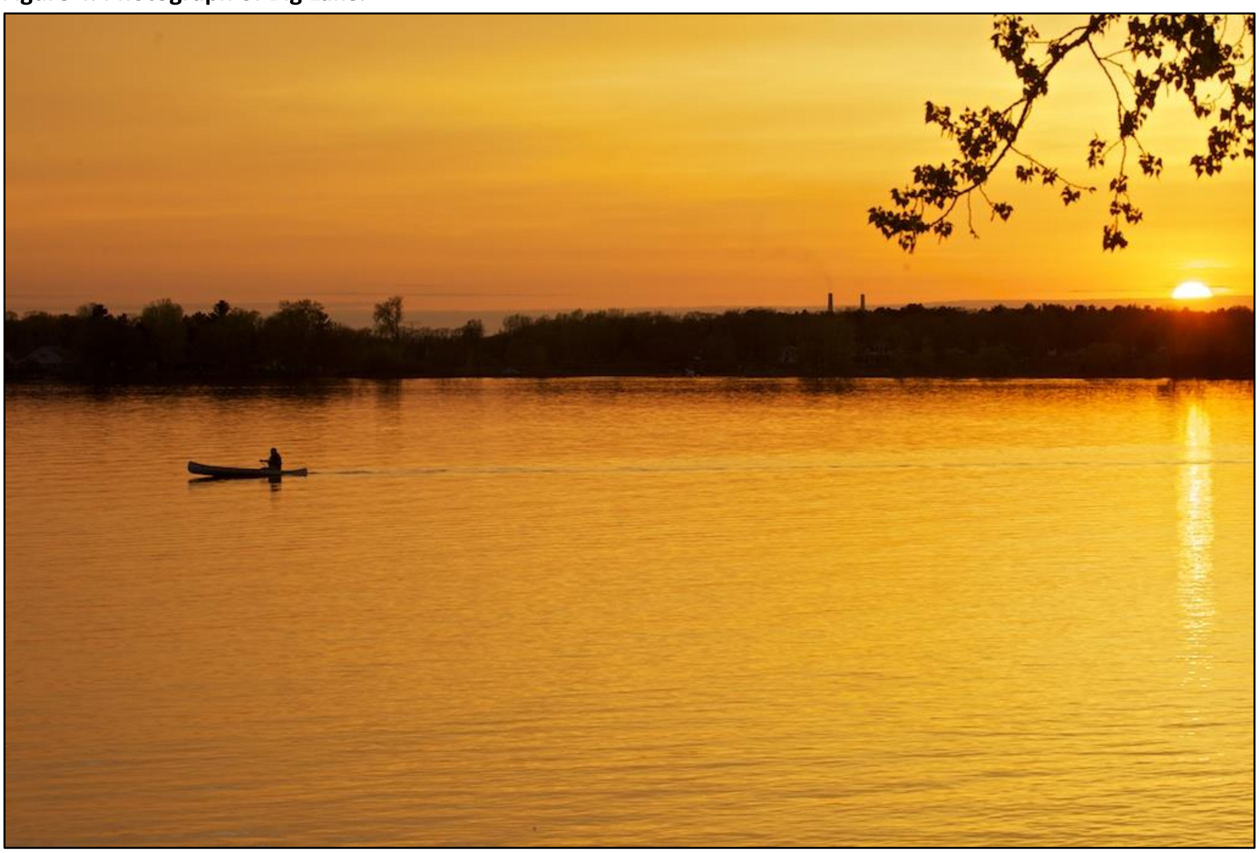
1.3 Tribal lands

The MRSCW is located on the traditional homelands of the Dakota Oyate and Ojibwe. However, no part of the MRSCW is located within the boundary of federally recognized Tribal land, and the TMDL does not allocate pollutant load to any federally recognized Indian Nation in this watershed.

1.4 Priority ranking

The MPCA's schedule for TMDL completions, as indicated on Minnesota's Section 303(d) impaired waters list, reflects Minnesota's priority ranking of these TMDLs. The MPCA has aligned TMDL priorities with the watershed approach. The schedule for TMDL completion corresponds to the WRAPS report completion following the 10-year IWM cycle. The MPCA developed a TMDL priority framework (MPCA 2022) to meet the needs of EPA's national measure (WQ-27) under *EPA's Long-Term Vision for Assessment, Restoration and Protection under the CWA Section 303(d) Program* (EPA 2013), which was updated in 2022 (*2022–2032 Vision for the Clean Water Act Section 303(d) Program* (EPA 2022). As part of these efforts, the MPCA identified water quality impaired segments to be addressed by TMDLs through the watershed approach.

Figure 4. Photograph of Big Lake.



Source: Sherburne SWCD, May 11, 2011.

2.0 Applicable water quality standards and numeric water quality targets

The federal Clean Water Act requires states to designate beneficial uses for all waters and develop water quality standards to protect each use. Water quality standards consist of several parts:

- Beneficial uses—Identify how people, aquatic communities, and wildlife use our waters.
- Numeric criteria—Amounts of specific pollutants allowed in a body of water that still protect it for the beneficial uses.
- Narrative criteria—Statements of unacceptable conditions in and on the water.
- Antidegradation protections—Extra protection for high-quality or unique waters and existing uses.

Together, the beneficial uses, numeric and narrative criteria, and antidegradation protections provide the framework for achieving Clean Water Act goals. Minnesota's water quality standards are in Minnesota Administrative Rules chapters (Minn. R. chs.) 7050 and 7052.

2.1 Beneficial uses

The beneficial uses for waters in Minnesota are grouped into one or more classes as defined in Minn. R. 7050.0140. The classes and associated beneficial uses are:

- Class 1 – domestic consumption
- Class 2 – aquatic life and recreation
- Class 3 – industrial consumption
- Class 4 – agriculture and wildlife
- Class 5 – aesthetic enjoyment and navigation
- Class 6 – other uses and protection of border waters
- Class 7 – limited resource value waters

The Class 2 aquatic life beneficial use includes a tiered aquatic life uses framework for rivers and streams. The framework contains three tiers—exceptional, general, and modified uses.

All surface waters are protected for multiple beneficial uses, and numeric and narrative water quality criteria are adopted into rule to protect each beneficial use. TMDLs are developed to protect the most sensitive use of a water body.

2.2 Narrative and numeric criteria and state standards

Narrative and numeric water quality criteria for all uses are listed for four common categories of surface waters in Minn. R. 7050.0220. The four categories are:

- Cold water aquatic life and habitat, also protected for drinking water: Classes 1B; 2A, 2Ae, or 2Ag; 3; 4A and 4B; and 5
- Cool and warm water aquatic life and habitat, also protected for drinking water: Classes 1B or 1C; 2Bd, 2Bde, 2Bdg, or 2Bdm; 3; 4A and 4B; and 5
- Cool and warm water aquatic life and habitat and wetlands: Classes 2B, 2Be, 2Bg, 2Bm, or 2D; 3; 4A and 4B; and 5
- Limited resource value waters: Classes 3; 4A and 4B; 5; and 7

The narrative and numeric water quality criteria for the individual use classes are listed in Minn. R. 7050.0221 through 7050.0227. The procedures for evaluating the narrative criteria are presented in Minn. R. 7050.0150.

The MPCA assesses individual water bodies for impairment for Class 2 uses—aquatic life and recreation. Class 2A waters are protected for the propagation and maintenance of a healthy community of cold water aquatic life and their habitats. Class 2B waters are protected for the propagation and maintenance of a healthy community of cool or warm water aquatic life and their habitats. Protection of aquatic life entails the maintenance of a healthy aquatic community as measured by fish and macroinvertebrate indices of biotic integrity. Fish and invertebrate indices scores are evaluated against criteria established for individual monitoring sites by water body type and use subclass (exceptional, general, and modified).

Both Class 2A and 2B waters are also protected for aquatic recreation activities including bathing and swimming, and the consumption of fish and other aquatic organisms. In streams, aquatic recreation is assessed by measuring the concentration of *E. coli* in the water, which is used as an indicator species of potential waterborne pathogens. To determine if a lake supports aquatic recreational activities, its trophic status is evaluated using TP, Secchi depth, and Chl-*a* as indicators. The ecoregion standards for aquatic recreation protect lake users from nuisance algal bloom conditions fueled by elevated phosphorus concentrations that degrade recreational use potential.

2.3 Antidegradation policies and procedures

The purpose of the antidegradation provisions in Minn. R. ch. 7050.0250 through 7050.0335 is to achieve and maintain the highest possible quality in surface waters of the state. To accomplish this purpose:

- Existing uses and the level of water quality necessary to protect existing uses are maintained and protected.
- Degradation of high water quality is minimized and allowed only to the extent necessary to accommodate important economic or social development.
- Water quality necessary to preserve the exceptional characteristics of outstanding resource value waters is maintained and protected.

- Proposed activities with the potential for water quality impairments associated with thermal discharges are consistent with Section 316 of the Clean Water Act, United States Code, title 33, Section 1326.

2.4 Mississippi River-St. Cloud Watershed water quality standards

Water quality standards for class 1 waters are defined in Minn. R. 7050.0221 and standards for class 2 waters are defined in Minn. R. 7050.0222. Water quality standards for *E. coli*, TSS, and eutrophication (phosphorus) are presented in Table 2 and Table 3, respectively.

In Minnesota, *E. coli* is used as an indicator species of potential waterborne pathogens. There are two *E. coli* criteria for class 2 waters—one is applied to monthly *E. coli* geometric mean concentrations, and the other is applied to individual samples. Exceedances of either *E. coli* criterion in class 2 waters indicate that a water body does not meet the aquatic recreation designated use. The class 2 criteria for *E. coli* apply from April through October. The *E. coli* TMDLs in this report are based on the monthly geometric mean criterion of 126 org/100 mL It is assumed that practices implemented to meet the geometric mean criterion will also address the individual sample criterion (1,260 org/100 mL), and that the individual sample criterion will also be met. Although the TMDLs are based on the monthly geometric mean criterion, both criteria apply.

To be delisted from the impaired waters list, a lake must meet the TP standard and either the chl-*a* or Secchi transparency standards (MPCA 2022). In developing the lake nutrient standards for Minnesota lakes (Minn. R. ch. 7050), the MPCA evaluated data from a large cross-section of lakes within each of the state’s ecoregions (MPCA 2005). Clear relationships were established between the causal factor TP and the response variables Chl-*a* and Secchi transparency. Based on these relationships there is a reasonable probability that by meeting the phosphorus standard in each lake, the Chl-*a* and Secchi standards will likewise be met.

The numeric water quality standards for these parameters (Table 2 and Table 3) serve as targets for the applicable MRSC TMDLs.

Table 2. Water quality standards for *E. coli* and TSS parameters in class 1 and class 2 streams.

Steam Class	Water Quality Standard	Numeric Standard/Target
Class 1, Class 2 (A and B Streams) – *E. coli*	Not to exceed 126 organisms per 100 milliliters (org/100 mL) as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than 10% of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies only between April 1 and October 31.	≤ 126 organisms / 100 mL water (monthly geometric mean) ≤1,260 organisms / 100 mL water (individual sample)
Class 2Bg – TSS	30 mg/L, may be exceeded for no more than 10% of the time, April 1 through September 30	≤ 30 mg/L TSS

Table 3. Eutrophication standards for class 2B lakes in the North Central Hardwood Forest Ecoregion.

Parameter	Lakes	Shallow Lakes
Phosphorus, total (micrograms per liter [µg/L])	≤40	≤60
Chlorophyll-*a* (µg/L)	≤14	≤20
Secchi transparency (meters [m])	>1.4	>1.0

Minn. R. 7050.0222, subp. 4. (Class 2B Waters).

3.0 Watershed and water body characterization

The MRSCW (HUC 07010203) covers 1,121 square miles of central Minnesota in the Upper Mississippi River Basin. The watershed drains portions of Benton, Meeker, Mille Lacs, Morrison, Sherburne, Stearns, and Wright counties and is entirely contained within the North Central Hardwood Forests Ecoregion (Figure 2).

The MRSCW originates at the confluence of the Sauk and Mississippi rivers near the city of St. Cloud and terminates where the Mississippi River meets the North Fork Crow River, approximately 50 miles downstream to the southeast. The watershed contains approximately 907 total miles of rivers, streams, and other tributaries and 374 lakes, totaling 21,398 acres. Major tributaries connecting the northern and southern portions of the watershed to the Mississippi River include the Elk River and Clearwater River, respectively.

The watershed is in the drinking water supply management areas (DWSMA) for surface water intakes, with most of the watershed in the St. Paul – Mississippi and Minneapolis Priority B areas. Smaller portions of the watershed are also in the Saint Cloud Priority A and St. Cloud Priority B areas.

3.1 Streams

Impaired streams receiving TMDLs and associated subwatershed areas are summarized in Table 4. Impaired streams and associated impairment subwatersheds are identified in Figure 5 in Section 3.3. The Snake River (-529) is a maintained ditch (MPCA 2022c).

Table 4. Summary of subwatersheds of impaired streams receiving TMDLs.

HUC-10 Name	Water body Name	AUID	Impairment Subwatershed Area (acres)
Elk River	Elk River	07010203-548	382,584
	Rice Creek	07010203-512	29,319
	Snake River	07010203-529	28,443
	Tibbets Brook	07010203-736	24,205
Headwaters Elk River	Elk River	07010203-507	109,833
	Elk River	07010203-508	53,499
	Mayhew Creek	07010203- 750	32,871
St. Francis River	St. Francis River	07010203-700	62,675
	Battle Brook	07010203-535	21,673
Clearwater River	Unnamed creek (Fairhaven creek)	07010203-565	1,570
Silver Creek – Mississippi River	Unnamed Creek [a]	07010203-528	7,541

a. Unnamed creek (-528) is locally known as Otsego Creek.

3.2 Lakes

Lake morphometry information and watershed areas for the impaired lakes are presented in Table 5; much of the information was obtained from Minnesota Department of Natural Resources (DNR 2022b*)* *Lake Finder*. Impaired lakes and associated impairment subwatersheds are identified in Figure 1.

Empirical models were developed for these six impaired lakes, which is discussed in Appendix B. Detailed information about each lake is presented in the discussion of model development (Appendix B Section B.1), especially in the discussions of lake physical parameters (Section B.1.2.1).

Table 5. Summary of lake morphometry and watershed area.

Lake Name	Lake ID	HUC-12 Name	Surface Area (acres)	Mean Depth (feet)	Max Depth (feet)	Percent Littoral Area (%) [a]	Watershed Area (incl. lake surface area; acres) [b]	Watershed Area: Surface Area Ratio [b]
Eagle Lake [c]	71-0067-00	Snake River	462	10.7	18.0	71	5,114	11:1
Elk Lake	71-0055-00	Battle Brook	362	7.0	15.0	100	26,108	72:1
Fremont Lake	71-0016-00	Tibbets Brook	493	5.2	8.0	100	2,584	5:1
Little Mary–North Bay	86-0139-02	Silver Creek	89	2.6	6.0	100	5,207	59:1
Little Mary–South Bay	86-0139-01		16	1.6	15	100	28,209	1,762:1
Millstone Lake	86-0152-00	Silver Creek	200	4.2	8.5	100	710	4:1

Source: *Lake Finder* (DNR 2022b)

Elk Lake, Fremont Lake, Little Mary–North Bay, Little Mary–South Bay, and Millstone Lake are shallow lakes.

a. Percent lake surface area less than 15 feet deep. Calculated by Tetra Tech using surface area and littoral area presented in *Lake Finder*.

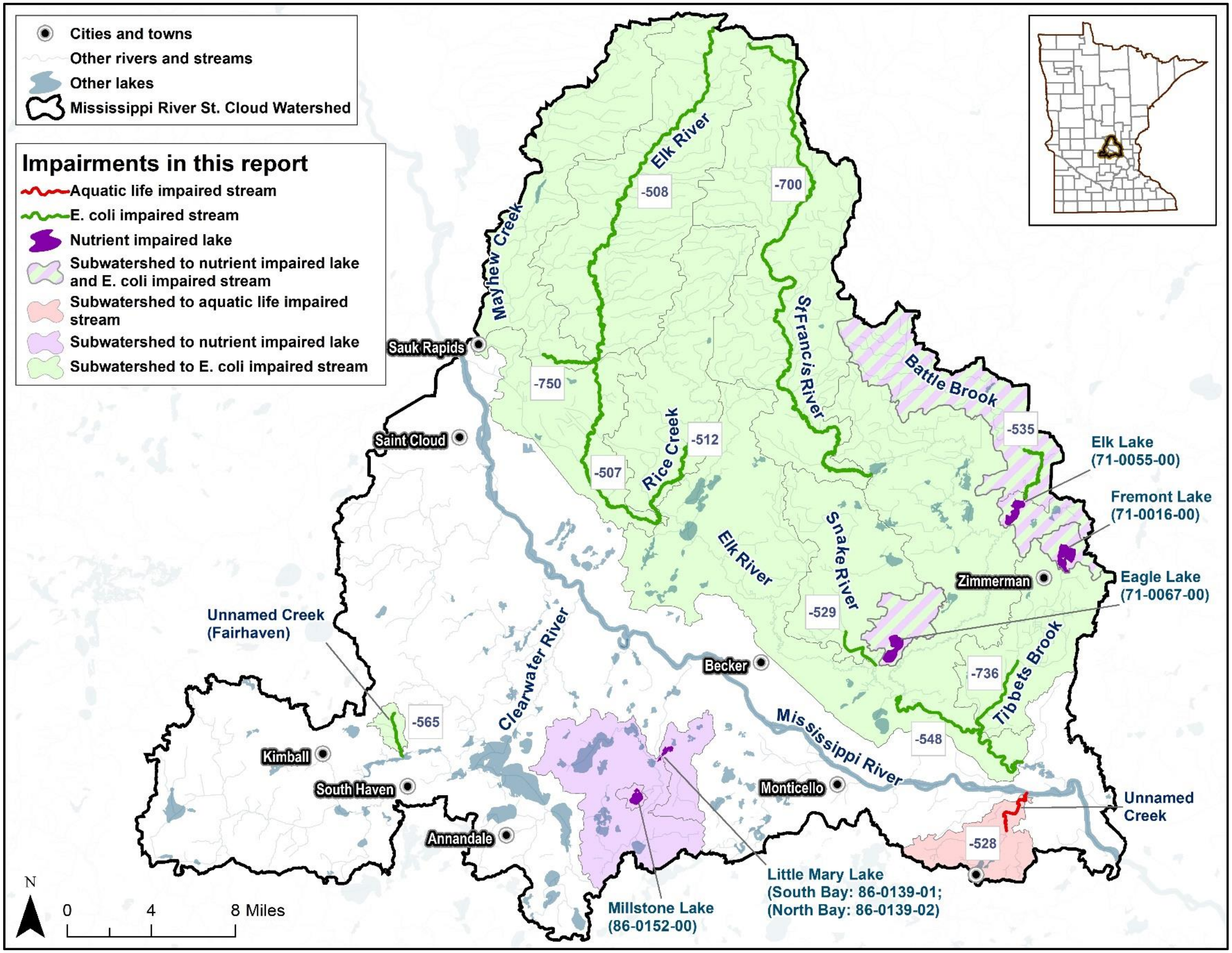
b. Tetra Tech calculated the watershed areas (see Section 3.3) and watershed area to surface area ratios.

c. The Eagle Lake Watershed was estimated as 4,792 acres using satellite topographic imagery and LIDAR contours in WSB (2020). Small differences in watershed boundaries are expected with different technical approaches.

3.3 Subwatersheds

The subwatersheds of the impaired water bodies (Figure 5) were developed using multiple data sources, starting with watershed delineations from the MPCA's Hydrologic Simulation Program – Fortran (HSPF) model application of the MRSCW (Tetra Tech 2019). The model subwatershed boundaries are based on DNR Level 8 watershed boundaries and modified with a 30-meter digital elevation model. Where additional watershed breaks were needed to define the impairment subwatersheds, DNR Level 9 watershed boundaries and the USGS StreamStats program (Version 4.0) were used. StreamStats was developed by the USGS as a web-based geographic information systems application for use in informing water resource planning and management decisions. The tool allows users to locate gages and define drainage basins to determine upstream drainage basin area and other useful parameters. There was a discrepancy noted between the HSPF model subbasins for Little Mary North Bay and South Bay relative to the DNR catchments, so the DNR catchment boundaries were used directly for those total drainages. The subwatershed for Unnamed creek (-528) was modified based on drainage information received from the cities of Otsego and Albertville. Areas for each impairment subwatershed are provided in Table 4 for streams and Table 5 for lakes.

Figure 5. MRSC TMDL impairment subwatersheds.



3.4 Land use

Land use in the MRSCW is primarily agricultural. The dominant land use type in the MRSCW is cropland (40%), primarily cultivated corn and soybeans (NLCD 2019). Pockets of development are scattered throughout the watershed, particularly around the cities of Sartell and St. Cloud to the west and Albertville and Otsego to the east. Other significant land use types are pastureland (14%) and forested lands (14%). The Sherburne National Wildlife Refuge holds 30,700 acres of oak savanna, prairie openings, forest, wetland, and riverine habitats in the eastern portion of the watershed (Fish and Wildlife Service 2022). Land cover within the refuge and nearby areas is primarily forestland, wetlands, and natural areas.

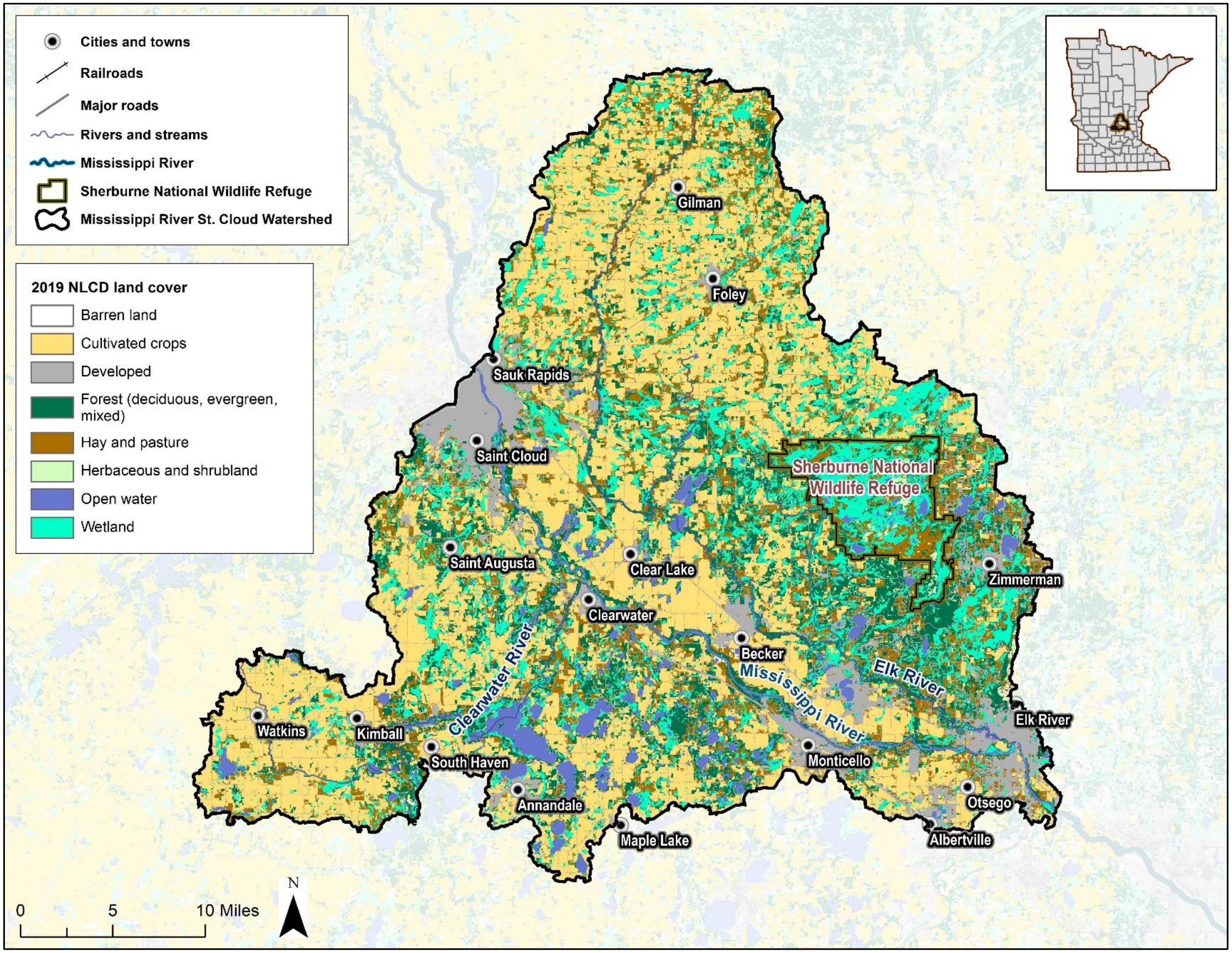
Prior to European settlement, the MRSCW was heavily forested, with patches of prairie and bog/swamps. Oak stands, prairies, and barren lands were dominant in riparian areas along the Mississippi River, transitioning into denser, hardwood forests in upstream areas. European settlement in the 1800s resulted in loss of many ecosystems including prairie systems, oak openings, and oak savannas in the MRSC. In addition, many hardwood forest species were cleared to create new agricultural fields.

Table 6. Land cover in impaired subwatersheds (2019 NLCD).

HUC-10 Name	Water body Name	Stream AUID/ Lake ID	Percent of Watershed (%)						
			Open Water	Developed	Forest	Natural Areas [a]	Hay & Pasture	Cropland	Wetlands
Elk River	Elk River	548	2	8	15	1	17	37	20
	Rice Creek	512	1	7	10	1	16	49	16
	Snake River	529	4	8	30	1	15	18	24
	Tibbets Brook	736	3	16	24	1	20	8	28
	Eagle Lake	71-0067-00	10	11	42	2	12	11	12
	Fremont Lake	71-0016-00	19	21	17	<1	26	7	10
Headwaters Elk River	Elk River	507	1	8	8	<1	15	55	13
	Elk River	508	<1	5	8	<1	16	60	11
	Mayhew Creek	750	<1	6	7	<1	15	58	14
St. Francis River	St. Francis River	700	<1	5	9	<1	18	51	17
	Battle Brook	535	<1	9	10	<1	15	36	30
	Elk Lake	71-0055-00	3	10	12	<1	17	30	28
Silver Creek – Mississippi River	Unnamed Creek [b]	528	3	32	2	<1	10	47	6
	Little Mary (South Bay)	86-0139-01	12	7	13	2	10	45	12
	Little Mary (North Bay)	86-0139-02	6	4	29	2	11	29	19
	Millstone Lake	86-0152-00	28	6	6	<1	4	54	2
Clearwater River	Unnamed Creek (Fairhaven)	565	<1	4	21	3	19	39	14

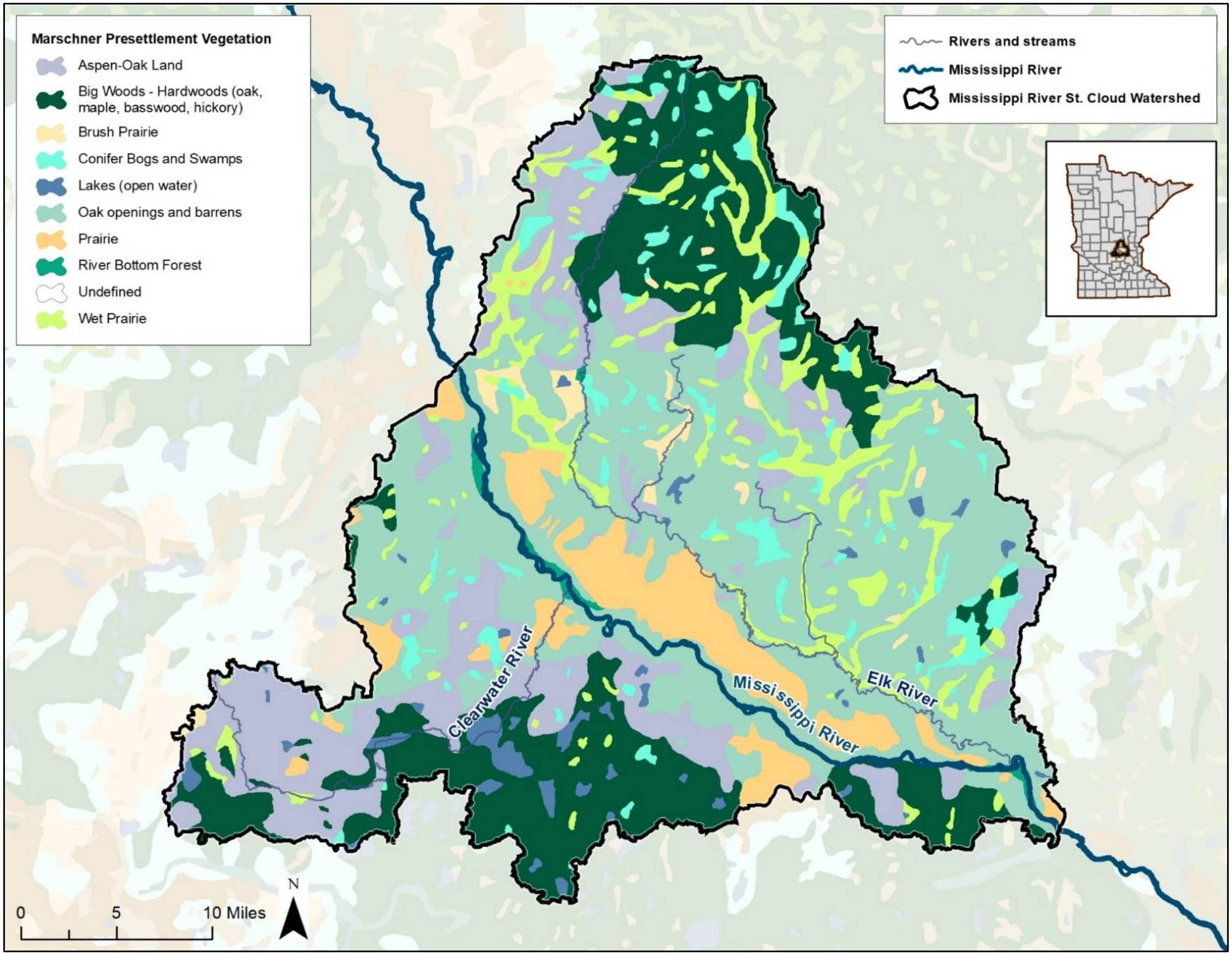
a. Natural areas land cover category includes barren, shrublands, and herbaceous areas.
b. Unnamed creek (-528) is locally known as Otsego Creek.

Figure 6. Land use in the Mississippi River – St. Cloud Watershed.



2019 National Land Cover Database.

Figure 7. Pre-settlement land cover in the Mississippi River – St. Cloud Watershed.



Native Vegetation at the time of the Public Land Survey 1847-1907 (DNR 1994)

3.5 Water quality

Figure 8. Water sample collection along the Elk River.
Source: Sherburne SWCD, June 25, 2019.

Flow and water quality data are presented to evaluate the impairments and trends in water quality. Data from the last ten years (2012 through 2021) were used in the water quality summary tables; most of the data are grab samples (Figure 8). Data from 2012 through 2021 were not available for Unnamed creek (Fairhaven Creek; - 565); new data were collected in 2022 that were then used to evaluate Unknown Creek. Water quality data from the Environmental Quality Information System (EQuIS) database were used for the analysis. The following describes the analyses completed for impaired lakes and streams.

3.5.1 Streams

The analyses used the following sources of flow data (Table 7):

- The MPCA provided flow data from Water Information Systems KISTERS (WISKI), a database that stores MPCA and DNR stream gaging data.
- Daily average flows were simulated with the MPCA's HSPF model application for the MRSCW. The simulated flows were calibrated and validated with data from seven flow gaging stations. Simulated flows are available at the downstream end of each model reach. The model report (Tetra Tech 2019 and references within) describes the framework and the data that were used to develop the model and includes information on the calibration.

Because the simulated flows from the HSPF model integrate flow monitoring data and provide long-term, continuous flow estimates, simulated flows were used in developing the stream TMDLs.

Table 7. Model reaches used to simulate stream flow in impaired reaches.
Reach numbers refer to the MRSCW HSPF model (Tetra Tech 2019). The simulation is from 1995–2015.

Reach Name	AUID	Model Reach ID
Elk River	507	490
Elk River	508	450
Mayhew Creek	750	457
Rice Creek	512	495
Unnamed creek [a]	528	377
Snake River	529	639
Battle Brook	535	681
Elk River	548	730
Unnamed creek (Fairhaven Creek)	565	181
Saint Francis River	700	671
Tibbets Brook	736	699

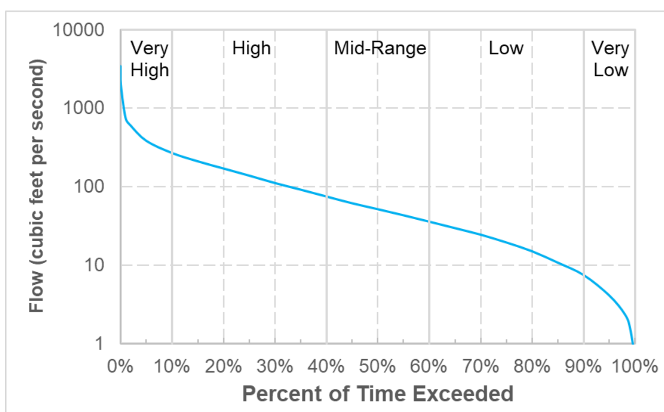
a. Unnamed creek (-528) is locally known as Otsego Creek.

Water quality data from 2012 to 2021 were summarized for the *E. coli* impairments; except for one impaired segment (reach 565), all of the *E. coli* data in this 10-year period were from 2019 and 2020. *E. coli* data were only available at one of several monitoring sites on each impaired segment. Data were summarized by month to evaluate seasonal variation. The frequency of exceedances represents the percentage of samples that exceed the water quality standard.

LDCs are provided in Section 4.1.8: *TMDL Summary* for each impaired stream. Water quality is often a function of stream flow, and LDCs are used to evaluate the relationships between hydrology and water quality. For example, *E. coli* concentrations can increase with rising flows if manure applied to cropland, is a substantial source. Other parameters may be more concentrated at low flows and diluted by increased water volumes at higher flows. The LDC approach provides a visual display of the relationship between stream flow and water quality. LDCs were developed as follows.

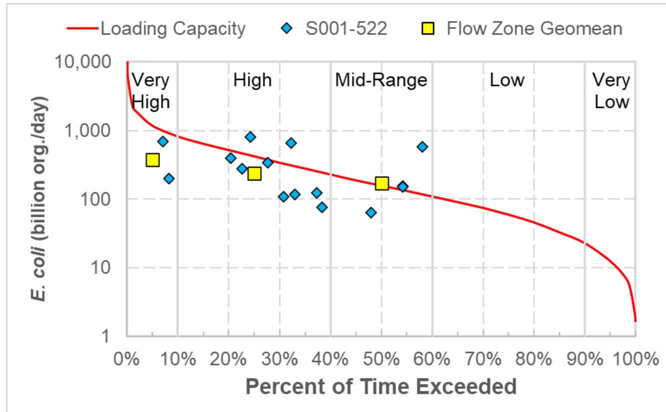
<u>Develop flow duration curves</u>: Flow duration curves relate mean daily flow to the percent of time those values have been met or exceeded. For example, an average daily flow at the 50% exceedance value is the midpoint or median flow value; average daily flow in the reach equals the 50% exceedance value 50% of the time. The curve is divided into flow zones, including very high flows (0% to 10%), high flows (10% to 40%), mid-range flows (40% to 60%), low flows (60% to 90%), and very low flows (90% to 100%).

Figure 9. Example of a flow duration curve.



Flow duration curves were developed using daily average flow (1995 through 2015) from HSPF modeling (Tetra Tech 2019). Figure 9 presents an example of a flow duration curve developed for this project. Table 7 presents the modeled stream segment number used to develop the flow duration curve for each impaired segment. Simulated flows from all months (even those outside of the time period that the standard is in effect) were used to develop the flow duration curves.

Figure 10. Example of a load duration curve.



Develop LDCs: To develop LDCs, all average daily flows were multiplied by the water quality standard (i.e., 126 org/100 mL *E. coli*) and converted to a daily load to create "continuous" LDCs that represent the load in the stream when the stream meets its water quality standard under all flow conditions. Loads calculated from water quality monitoring data are also plotted on the LDC chart, based on the concentration of the sample multiplied by the simulated flow on the day that the sample was taken. One nearby gage (Elk River near Big Lake, Minnesota; USGS 05275000, MPCA S000-278, DNR 17046001) was used to estimate the flow exceedance to plot water quality samples from 2019 and 2020, which are not simulated in the HSPF model. The flow exceedance was then used to determine the corresponding HSPF flow (at that flow exceedance) for which to calculate a load for the water quality sample. Each load calculated from a water quality sample that plots above the LDC represents an exceedance of the water quality target whereas those that plot below the LDC are less than the water quality target. An example of the LDC and observed loads is presented in Figure 10.

3.5.1.1 *E. coli* water quality data

Water quality summary tables and LDCs are presented for each impairment in Section 4.1.8, and Table 8 summarizes the *E. coli* water quality data.

The number of *E. coli* samples per impaired reach ranges from 10 to 16. The maximum recorded *E. coli* concentration per reach ranges from 85 to 24,196 org/100 mL. The frequencies of exceedance of the monthly geometric mean standard range from 25% to 100%, and the frequencies of exceedance of the individual sample standard range from 0% to 40% (Table 8).

There is not a strong relationship between *E. coli* concentration and flow zone across all the reaches with *E. coli* impairments. Exceedances of the single sample standard occur across two monitored flow conditions (Figure 11, Table 9) - high flow (12%) and mid-range flows (12%).

Sampling across all the reaches impaired by *E. coli* was limited to the months of June through September. Exceedances of the single sample standard occur across three months (Figure 12, Table 10) - June (5%), July (9%), and August (19%). Besides a general increase over the course of the summer, no temporal patterns with *E. coli* concentration were identified through cursory analyses of individual reaches. Dates with high concentrations at one impaired reach typically did not correspond to high concentrations at other impaired reaches, which may indicate that local factors are more important than watershed-scale factors.

Table 8. Summary of *E. coli* data (2019–2020) for impaired reaches.

Summaries include data from months during which the standard applies (see Section 2.4). *E. coli* units are org/100 mL.

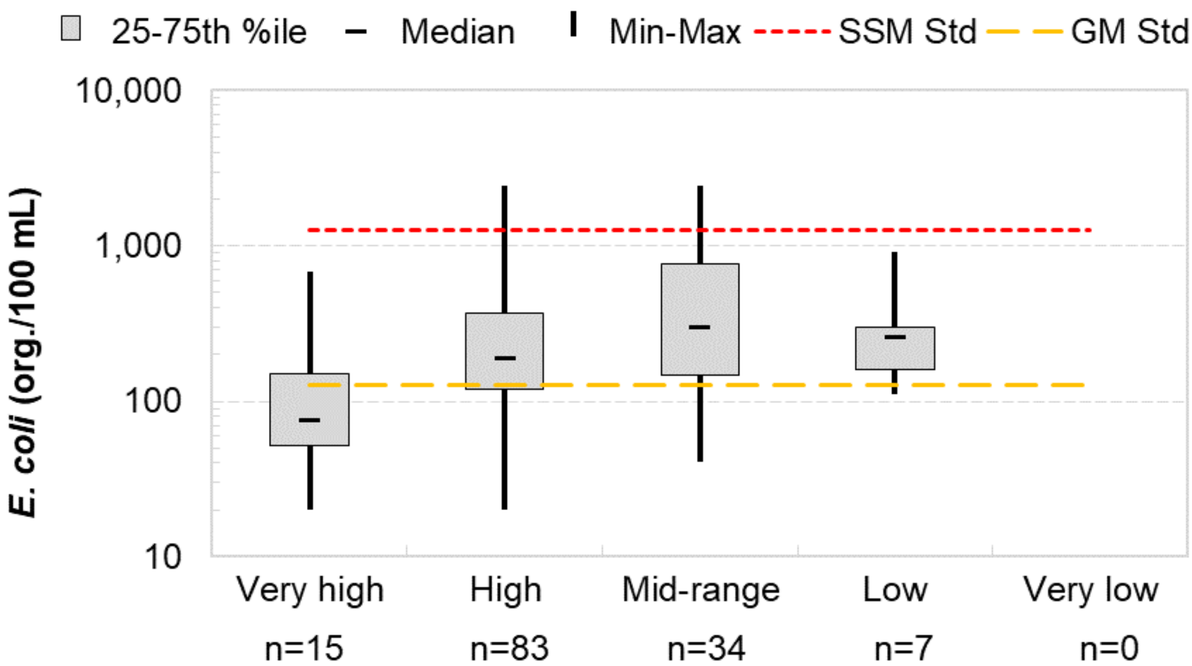
Reach Name (Description)	AUID	Sample Count	Geometric Mean	Max-imum [a]	Number of Exceedances of Individual Standard	Frequency of Exceedance [b]
Elk River (Mayhew Cr to Rice Cr)	507	15	185	1,274	1	100% / 7%
Elk River (Headwaters to Mayhew Cr)	508	14	367	17,329	3	100% / 21%
Mayhew Creek (T36 R30W S21, west line to Elk R)	750	15	1,129	24,196	6	100% / 40%
Rice Creek (Rice Lk to Elk R)	512	15	204	1,317	1	100% / 6%
Snake River (Unnamed Cr to Eagle Lk outlet)	529	15	327	2,987	2	100% / 13%
Battle Brook (CD 18 to Elk Lk)	535	16	178	771	0	50%/ 0%
Elk River (St Francis R to Orono Lk r)	548	16	85	1,012	0	0%/ 0%
Unnamed creek (Fairhaven Creek) (Headwaters to Lk Marie) [c]	565	10	476	3,654	1	– / 6%
St. Francis River (Headwaters to Unnamed Lk (71-0371-00))	700	16	239	2,098	1	67% / 6%
Tibbets Brook (Unnamed ditch to Elk R)	736	15	172	1,124	0	100% / 0%

a. The maximum recordable value for *E. coli* concentration depends on the extent of sample dilution and is often 2,420 org/100 mL. Concentrations that are noted as 2,420 org/100 mL are likely higher, and the magnitude of the exceedances is not known.

b. For *E. coli* impairments, the frequencies of exceedance are presented first for the monthly geometric mean standard and second for the individual sample standard. The monthly frequencies of exceedance are calculated as the number of months (aggregated across all years of data) when the monthly standard was exceeded divided by the number of months that have five or more samples. When no months have five or more samples, an N-dash ("–") is presented.

c. Sherburne SWCD collected 10 samples from Unnamed creek (Fairhaven Creek; -565) in June to September 2022.

Figure 11. Box plot of *E. coli* concentration by flow zone for all reaches with *E. coli* impairments (2019–2020).



Data from nine assessment units were compiled. Unnamed creek (Fairhaven Creek; -565) is excluded because this stream is geographically isolated from the other nine streams and data were collected in 2022 under different weather conditions.

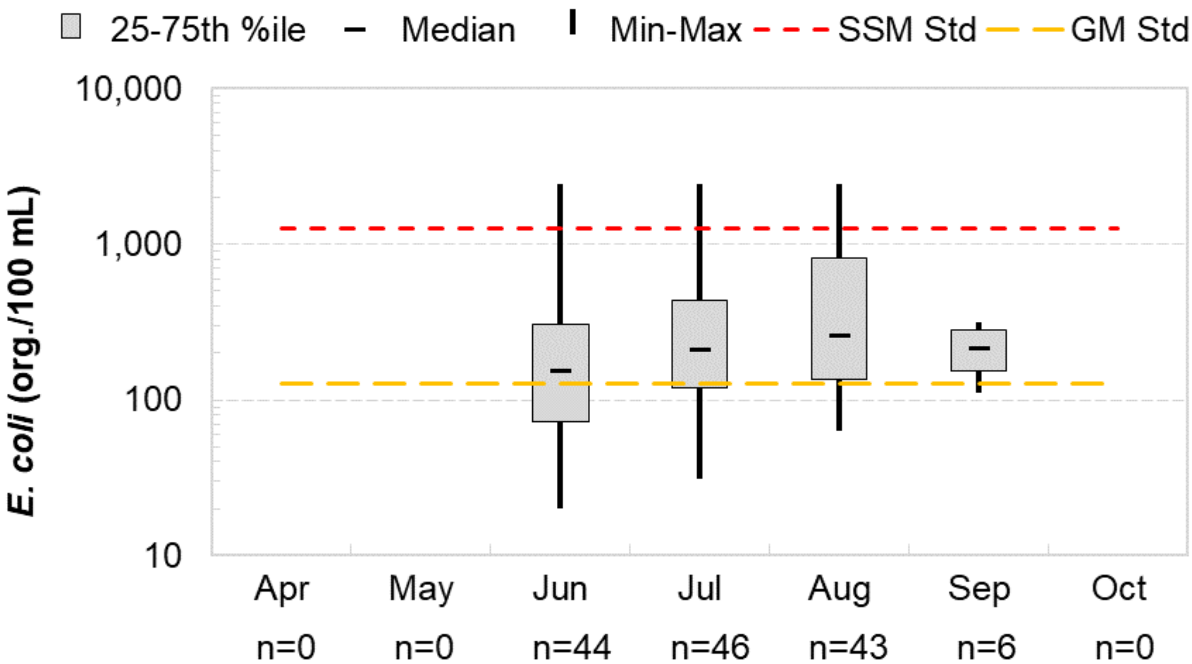
The maximum recordable *E. coli* concentration depends on the extent of sample dilution and is often 2,420 org/100 mL. However, 7 samples in this data set were diluted before the laboratory analysis, and high *E. coli* concentrations are reported. In this figure, concentrations > 2,420 were lowered to 2,420 to remove the influence that the diluted samples have on the overall statistics of each group.

The single sample maximum (SSM) water quality standard is 1,260 organisms per 100 milliliters. The geometric mean (GM) water quality standard is 126 organisms per 100 milliliters.

Table 9. Number of individual standard exceedances by flow zone (2019–2020).
Data from nine assessment units were compiled. Unnamed creek (Fairhaven Creek; -565) is excluded because this stream is geographically isolated from the other nine streams and data were collected in 2022 under different weather conditions.

Flow Zone	Number of Single Sample Standard Exceedances	Sample Count	Percent of Single Sample Standard Exceedances
Very High	0	15	0%
High	10	83	12%
Mid-Range	4	34	12%
Low	0	7	0%
Very Low	–	0	–
Total	*14*	*139*	*10%*

Figure 12. Box plot of *E. coli* concentration by month for all reaches with *E. coli* impairments (2019–2020).



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The single sample maximum (SSM) water quality standard is 1,260 organisms per 100 milliliters. The geometric mean (GM) water quality standard is 126 organisms per 100 milliliters.

Table 10. Number of individual standard exceedances by month (2019–2020).
Data from nine assessment units were compiled. Unnamed creek (Fairhaven Creek; -565) is excluded because this stream is geographically isolated from the other nine streams and data were collected in 2022 under different weather conditions.

Month	Number of Single Sample Standard Exceedances	Sample Count	Percent of Single Sample Standard Exceedances
April	–	0	–
May	–	0	–
June	2	44	5%
July	4	46	9%
August	8	43	19%
September	0	6	0%
October	–	0	–
Total	*14*	*139*	*10%*

3.5.1.2 Sediment-related water quality data

One TSS sample is available from reach 528: 33.2 mg/L on 6/19/2019 at S007-014, which exceeds the standard of 30 mg/L for Class 2Bg streams. The sample was collected under high flow conditions.

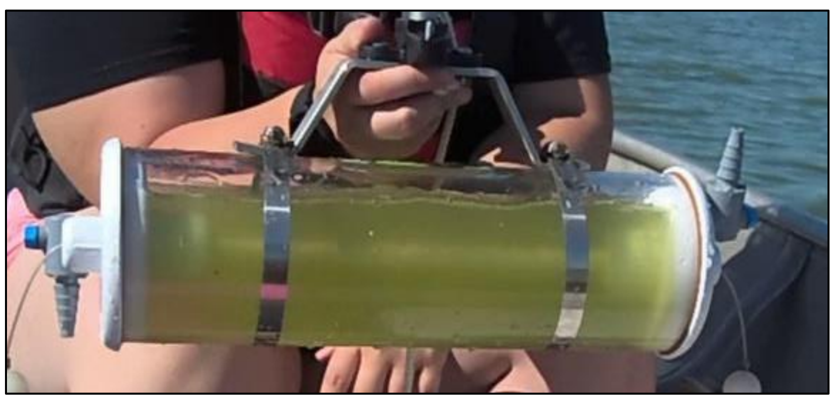
Transparency tube (T-tube) was measured twice in 2019: 22 cm on 6/19/2019 and 28.5 cm on 8/19/2019. The 6/19 measurement does not meet the 25 cm T-tube surrogate threshold for impairment (MPCA 2022a), and the 8/19 measurement falls between the “exceeds” and “meets” thresholds (25 and 35 cm).

In May through October 2010 and June through October 2011, stream physical appearance was visually assessed on 21 occasions at monitoring site S006-148. The stream was reported most frequently as tea-colored (n=12, 57%), followed by clear (n=6, 29%), muddy (n=2, 10%), and cloudy (n=1, 5%). These data indicate that suspended materials such as sediment and organic materials were more often present in the water column than not.

3.5.2 Lakes

Water quality data from 2012 to 2022 were summarized for TP, chl-*a*, and Secchi transparency; however, most TP and chl-*a* data were only collected during one or two years during this timeframe. Data collected in 2012 through 2021 were obtained from EQuIS. As no data were available in 2012 through 2021 for three lakes in Wright County, new data were collected in 2022 and provided from the laboratory. Figure 13 shows an example of water sample collection in 2022.

Figure 13. Water collected from Millstone Lake.
Source: Wright SWCD, August 9, 2022.



Data were summarized over the entire period to evaluate compliance with the water quality standards to evaluate trends in water quality. The summaries include monitoring data from the growing season (June through September); the water quality standards apply to growing season means. Results are presented in Section 4.3.9: TMDL Summary and are summarized in Table 11. For five of six impaired lakes, the average TP concentrations exceed the relevant standards; Fremont Lake meets the standard. The average chl-a concentrations exceed the relevant standards in all six lakes. The Secchi standard is violated in three of the five impaired lakes with available data but not in Fremont Lake. Although Fremont Lake is on the impaired waters list, recent data show the lake meeting the TP standard (Table 66). A TP TMDL was developed to help inform efforts to ensure that TP remains below the TP standard (Section 4.3.9.3).

Table 11. Lakes water quality data summary, 2012–2022.

Lake	Parameter	Years	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard [a]
Eagle Lake (71-0067-00-204)	TP (µg/L)	2019–2020	**54**	≤40
	Chl *a* (µg/L)	2019–2020	**37**	≤14
	Secchi (m)	2019–2020	**1.2**	>1.4
Elk Lake (71-0055-00-202) [b]	TP (µg/L)	2019	**89**	≤60
	Chl *a* (µg/L)	2019	**48**	≤20
	Secchi (m)	2012–2021	**0.88**	>1.0
Fremont Lake (71-0016-00-202) [b]	TP (µg/L)	2019–2020	46	≤60
	Chl *a* (µg/L)	2019–2020	**21**	≤20
	Secchi (m)	2015–2021	1.1	>1.0
Little Mary (North Bay) (86-0139-02-201) [c]	TP (µg/L)	2022	**138**	≤60
	Chl *a* (µg/L)	2022	**92**	≤20
	Secchi (m)	2022 [d]	**0.34**	>1.0
Little Mary (South Bay) (86-0139-01-201) [c]	TP (µg/L)	2022	**143**	≤60
	Chl *a* (µg/L)	2022	**92**	≤20
	Secchi (m)	2022	**0.46**	>1.0
Millstone Lake (86-0152-00-201) [b]	TP (µg/L)	2022 [d]	**223**	≤60
	Chl *a* (µg/L)	2022 [d]	**126**	≤20
	Secchi (m)	2022 [d]	**0.20**	>1.0

a. North Central Hardwood Forest ecoregion lake standard.

b. Lake is considered shallow because the maximum depth is less than or equal to 15-feet and the littoral zone is greater than or equal to 80%.

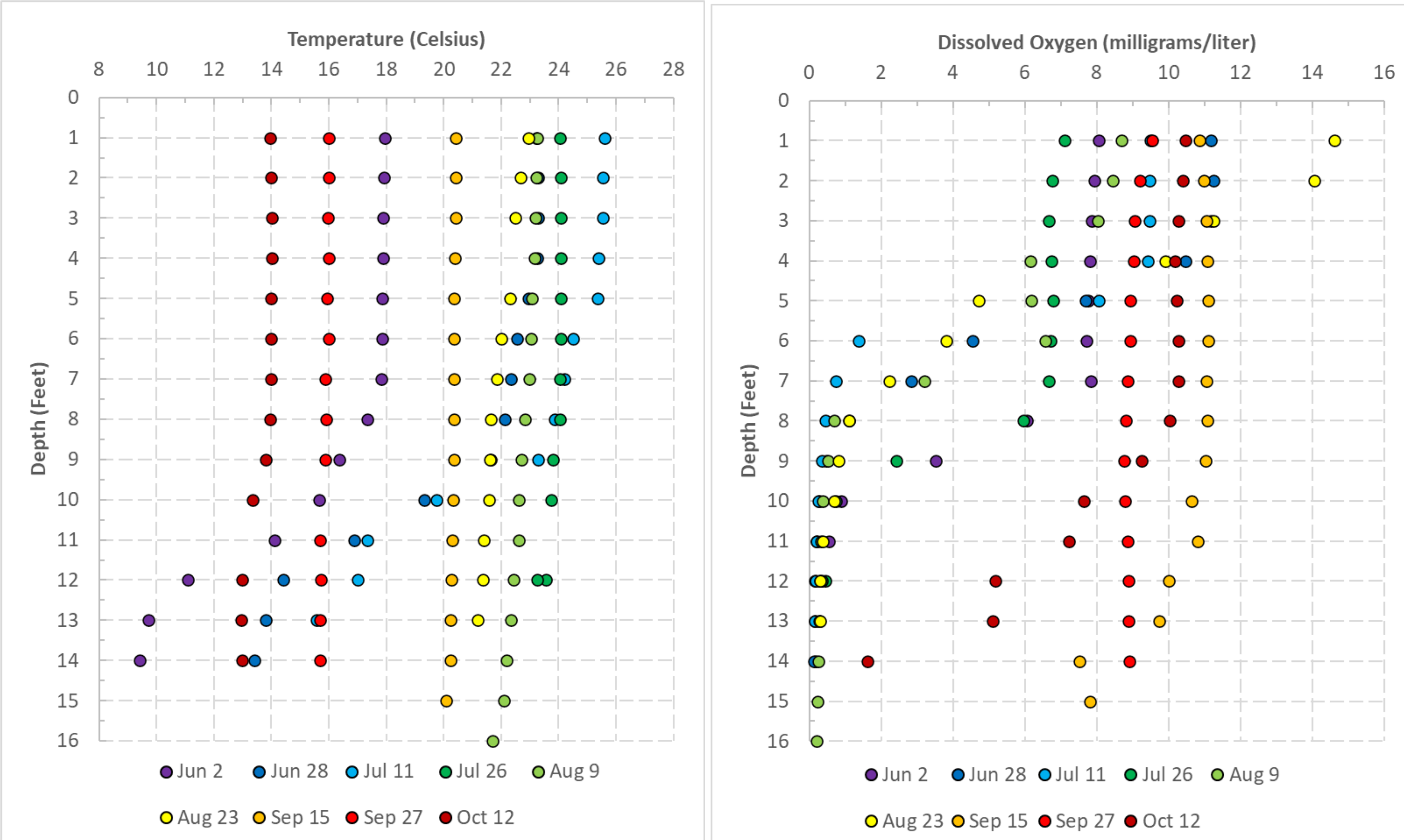
c. Lake is considered shallow because the littoral zone is greater than or equal to 80%.

d. One sample was omitted from each calculation: July 17, 2016, at Little Mary (North Bay) and June 25, 2014, at Millstone Lake. One sample is not sufficient to represent a growing season mean. Each of the four sample results was significantly different from the 2022 datasets, and thus assumed to be nonrepresentative of current conditions. Both Secchi depths were extreme outliers an order of magnitude greater than the 2022 growing season averages.

Big Eagle Lake Improvement Association (BELIA), Sherburne SWCD, and WSB Engineering (WSB) collaborated to collect and assess water quality data for Eagle Lake and its tributaries in 2019 and 2020. WSB (2020) determined that the in-lake growing season averages of TP (46 µg/L), Chl-*a* (40 µg/L), and Secchi disk depth (1.3 meters) exceeded standards. Analysis of depth profiles of DO and water temperature indicate that Eagle Lake stratified during the 2019 growing season (WSB 2020). Based on water temperature and DO profiles, spring turnover (mixing) occurred near May 25, 2019, and Eagle Lake was stratified from May 29 through August 21, 2019. Weak mixing and stratification also occurred in September and October (WSB 2020). Refer to Section 4.6 of WSB (2020) for a review of historical water quality, including water temperature and DO depth profile charts.

The Wright SWCD collected water quality data in 2022 to support TMDL development at Little Mary Lake North and South bays and Millstone Lake. Wright SWCD collected depth-profiles for water temperature, pH, conductivity, and DO. Visual analysis of these data indicated that Little Mary Lake South Bay may stratify (Figure 14). Little Mary Lake North Bay and Millstone Lake did not thermally stratify; DO did not vary by depth in late September or October and DO sometimes decrease to near zero as depth increased during June, July, and August.

Figure 14. Temperature and dissolved oxygen depth-profiles for Little Mary Lake South Bay, 2022.



3.6 Pollutant source summary

Sources of pollutants in the MRSCW include permitted sources such as wastewater, stormwater, and permitted concentrated animal feeding operations (CAFOs); and nonpermitted sources such as watershed runoff, subsurface sewage treatment systems (SSTSs), and internal loading (lakes only). The permitted sources discussed here are pollutant sources that require a National Pollutant Discharge Elimination System (NPDES)/State Disposal System (SDS) permit. Data on permitted sources was received from the MPCA data desk on March 4, 2022. Nonpermitted sources are pollutant sources that do not require an NPDES permit. All Minnesota NPDES permits are also SDS permits (e.g., NPDES/SDS); however, some pollutant sources require SDS permit coverage alone without NPDES permit coverage (e.g., spray irrigation, large septic systems, land application of biosolids, and some feedlots). The phrase "nonpermitted" does not indicate that the pollutants are illegal, but rather that they do not require an NPDES/SDS permit. Some nonpermitted sources are unregulated, and some nonpermitted sources are regulated through non-NPDES/SDS programs and permits such as state and local regulations. Pollutant specific information on pollutant sources of *E. coli* is provided in Section 3.6.1, TSS in Section 3.6.2, and phosphorus in Section 3.6.3.

3.6.1 *E. coli*

E. coli sources evaluated in this study are permitted wastewater and stormwater, permitted feedlots, land application of wastewater, nonpermitted watershed runoff (feedlots, pastures, wildlife, domestic pets, stormwater), SSTSs, and natural growth of *E. coli*. *E. coli* is unlike other pollutants in that it is a living organism and can multiply and persist in soil and water environments (Ishii et al. 2006, Chandrasekaran et al. 2015, Sadowsky et al. n.d., and Burns & McDonnell 2017). 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 primary sources of *E. coli*, with a focus on the sources that can be effectively reduced with management practices.

3.6.1.1 Permitted sources

Permitted source categories within the subwatersheds for this TMDL include municipal and industrial wastewater, municipal separate storm sewer systems (MS4s), NPDES/SDS permitted animal feedlots, and SDS permitted land application of wastewater.

Municipal and industrial wastewater

Permitted wastewater in the watershed includes municipal/domestic and industrial wastewater. Both municipal/domestic and industrial wastewater dischargers must obtain NPDES/SDS permits.

Municipal/domestic wastewater is the domestic sewage and wastewater collected and treated by municipalities and other private entities prior to being discharged to surface waters or groundwater. There are five facilities impacting impaired subwatersheds. Two facilities are pond systems with controlled discharges (Gilman WWTP and Foley WWTP), while the other three facilities are continuous dischargers (Table 12). No permittee is known to have combined or sanitary sewer overflows.

Industrial wastewater is wastewater generated from industries, businesses, and other privately owned facilities that is collected and, if necessary, treated prior to being discharged to surface waters or groundwater. There are no permitted industrial wastewater discharges impacting impaired subwatersheds.

Municipal wastewater dischargers and industrial facilities whose effluents contain enteric bacteria that operate under NPDES/SDS permits are required to disinfect wastewater to reduce fecal coliform concentrations to 200 organisms/100 mL or less as a monthly geometric mean. Like *E. coli*, fecal coliform is an indicator of fecal contamination. The primary function of a fecal bacteria effluent limit is to assure that the effluent is being adequately treated with a disinfectant to assure a complete or near complete kill of fecal bacteria prior to discharge. Dischargers to class 2 waters are required to disinfect from April 1 through October 31. Monthly geometric means of effluent monitoring data are used to determine compliance with permits. There are five wastewater dischargers with fecal coliform limits in the impaired subwatersheds (Table 12). There are no permitted combined sewer overflows in the impaired subwatersheds.

Of these facilities, one facility (Aspen Hills WWTF) has documented fecal coliform permit exceedances as provided in discharge monitoring reports (DMRs) for the time period between 2012 and 2021 (Table 13). MPCA is working with Aspen Hills WWTF to resolve the noncompliance. In-stream data are not available to determine how much Aspen Hills WWTF may cause or contribute to impairment on Tibbets Brook (-736) or the Elk River (-548)[1].

Effluent data from the Aspen Hills WWTF were compared with in-stream data collected from Tibbets Brook upstream of the WWTF. In July 2019 and July 2020, effluent loads (calculated with the monthly average effluent flow and monthly geometric mean fecal coliform) were 106 and 21 billion counts fecal coliform per day, respectively. In Tibbets Brook, at a monitoring site upstream of the Aspen Hills WWTF, in-stream *E. coli* loads in July 2019 ranged from 60 to 163 billion *E. coli* counts per day and in July 2020 ranged from 59 to 88 billion *E. coli* counts per day. These data indicate that the Aspen Hills WWTF effluent load that can be equivalent or larger to the in-stream load upstream of the WWTF.

Table 12. NPDES/SDS permitted facilities in impaired recreation use subwatersheds.

Note: Foley WWTP and Gilman WWTP are pond systems with controlled discharges.

Wastewater Facility	NPDES/SDS Permit #	Impaired water body Name	Impaired water body AUID
Aspen Hills WWTF	MN0066028	Tibbets Brook	736
Becker WWTP	MN0025666	Elk River	548
Foley WWTP	MN0023451	Rice Creek (via Stony Brook)	512 (via 520)
Gilman WWTP	MNG580021	Elk River (via unnamed ditch)	508 (via 730)
Zimmerman WWTP	MN0042331	Tibbets Brook	736

[1] Aspen Hills discharges to a ditch that is tributary to Tibbets Brook and the only monitoring site with Cycle 2 (2019-2020) *E. coli* data on Tibbets Brook (S005-538) is upstream of the ditch. The most downstream monitoring site with Cycle 2 *E. coli* data on the Elk River (S000-278) is upstream of the confluence of Tibbets Brook.

Table 13. Summary of fecal coliform DMR data, 2012–2021 (monthly geometric means).

Wastewater Facility	# of records	Minimum Geomean (#/100mL)	Maximum Geomean (#/100mL)	Median Geomean (#/100mL)	Documented fecal coliform exceedances (>200/100mL)	
					Number	Percent
Aspen Hills WWTF	70	1	336,221	48	26	37%
Becker WWTP	70	<10	121	10	0	0%
Foley WWTP – 001 – 002	32[a] 30[a]	1 1	117 61	7 8	0 0	0% 0%
Gilman WWTP	24[a]	1	148	2	0	0%
Zimmerman WWTP	70	<2	43	3	0	0%

a. Foley WWTP and Gilman WWTP are pond systems with controlled discharges. They are not authorized to discharge in July and August during the summer recreation season. Monthly geometric means are only reported for months with discharges.

Municipal separate storm sewer systems

In 1990, the EPA adopted rules governing incorporated places and counties that operate MS4s; medium and large MS4s were designated at this time. Later, in 1999, the EPA adopted additional rules (Phase II stormwater rules) that regulate small MS4s, which are designated because they are within an urbanized area identified in a decennial census. Additionally, the Phase II stormwater rules allow state regulatory agencies to designate Phase II MS4s that are outside of the urbanized area. Under Phase II of the NPDES/SDS stormwater program, MS4 communities outside of urbanized areas with populations greater than 10,000 (or greater than 5,000 if they discharge to or have the potential to discharge to an outstanding value resource, trout lake, trout stream, or impaired water) and MS4 communities within urbanized areas are permitted MS4s.

MS4s are defined by the EPA as stormwater conveyance systems owned or operated by an entity such as a state, city, township, county, district, or other public body having authority over disposal of stormwater or other wastes. The Phase II General NPDES/SDS Municipal Stormwater Permit for MS4s has been issued to cities, townships, correctional facilities, educational institutions, and counties in the watershed. The Minnesota Department of Transportation (MNDOT) also is a permitted MS4 in the watershed. The municipal stormwater permit holds permittees responsible for stormwater discharging from the conveyance system they own and/or operate. The conveyance system includes ditches, roads, storm sewers, stormwater ponds, etc. Under the NPDES/SDS stormwater program, permitted MS4 entities are required to obtain a permit, then develop and implement an MS4 Stormwater Pollution Prevention Program (SWPPP), which outlines a plan to reduce pollutant discharges, protect water quality, and satisfy water quality requirements in the Federal CWA. An annual report is submitted to the MPCA each year by the permittee documenting progress on implementation of the SWPPP.

Permitted MS4s can be a source of pollutants to surface waters through the impact of urban systems on stormwater runoff. The entire jurisdictional boundary of one permitted MS4 community (Minden Township) is within the subwatersheds with impairments. Portions of seven more communities are within the subwatersheds draining to *E. coli* impaired streams (Table 14). Benton and Sherburne counties are also regulated MS4 entities for county-owned roads within U.S. Census defined urban areas in the watershed. Portions of the Outstate District of MNDOT's regulated MS4 is within impaired subwatersheds. Finally, Minnesota Correctional–St. Cloud and St. Cloud University are regulated, nontraditional MS4s. (Note that the specific areas that are regulated through the MS4 permit are estimated in Section 4.1.3.2 and Figure 24.)

Four additional communities in Sherburne County (Baldwin Township, Becker Township, Livonia Township, and the city of Zimmerman) are currently unregulated MS4s but have exceeded the 5,000-population threshold and potentially discharge to impaired waters, so the MPCA anticipates that the MS4s will come under permit coverage in the near future. As such, these communities are included in Table 14, Section 4.1.3.2, and Figure 24.

Table 14. Regulated MS4s in impaired aquatic recreation use subwatersheds.

Note: Impaired subwatersheds and MS4s are sorted alphabetically top to bottom and left to right, respectively.

Impaired subwatershed	Baldwin Township *	Becker Township *	Benton County (MS400067)	Big Lake City (MS400249)	Big Lake Township (MS400234)	Elk River City (MS400089)	Livonia Township *	Minden Township (MS400147)	Minnesota Correctional–St. Cloud (MS400179)	MNDOT Outstate District (MS400180)	Sauk Rapids City (MS400118)	Sauk Rapids Township (MS400153)	Sherburne County (MS400155)	St. Cloud City (MS400052)	St. Cloud State University (MS400197)	Watab Township (MS400161)	Zimmerman City *
Battle Brook (-525)	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Elk River (-507)	–	–	X	–	–	–	–	X	X	X	X	X	X	X	X	X	–
Elk River (-508)	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–
Elk River (-548)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Mayhew Creek (-750)	–	–	X	–	–	–	–	X	–	X	X	X	–	X	–	X	–
Rice Creek (-512)	–	–-	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–
Snake River (-529)	–	X	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–
St. Francis River (-700)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Tibbets Brook (-736)	X	–	–	X	–	X	X	–	–	–	–	–	X	–	–	–	X

*These communities are not currently regulated but are expected to come under MS4 permit coverage in the near future.

NPDES and SDS permitted animal feedlots

Feedlots, manure storage areas, and manure land application sites can be a source of *E. coli* and nutrients due to runoff from the animal holding areas or the manure storage areas. Although TMDL reports typically consider only NPDES permitted sources in discussions of permitted sources, this discussion of permitted feedlots includes NPDES and SDS permitted feedlots because of similar discharge requirements.

CAFO is a federal definition that implies not only a certain number of animals but also specific animal types. The MPCA uses the federal definition of a CAFO in its permit requirements of animal feedlots along with the state definition of an animal unit (AU). In Minnesota, all CAFOs and non-CAFOs that have 1,000 or more AUs must operate under an NPDES or SDS permit. CAFOs with fewer than 1,000 AUs and that are not required by federal law to maintain NPDES permit coverage may choose to operate without an NPDES permit.

A current manure management plan that complies with Minn. R. 7020.2225 and the respective permit is required for all permitted CAFOs and feedlots with 1,000 or more AUs.

CAFOs and feedlots with 1,000 or more AUs must be designed to contain all manure, manure contaminated runoff, process wastewater, and the precipitation from a 25-year, 24-hour storm event. Having and complying with an NPDES or SDS permit authorizes discharges to waters of the United States and waters of the state (with NPDES permits) or waters of the state (with SDS permits) due to a 25-year, 24-hour precipitation event (approximately 4.83 inches in the MRSCW (from St. Cloud Municipal Airport weather station)) when the discharge does not cause or contribute to nonattainment of applicable state water quality standards. Large CAFOs with fewer than 1,000 AUs that have chosen to forego NPDES permit coverage are not authorized to discharge and must contain all runoff, regardless of the precipitation event. Large CAFOs permitted with an SDS permit are authorized to discharge to waters of the state, although they are not authorized to discharge to waters of the U.S. Therefore, many large CAFOs in Minnesota have chosen to obtain an NPDES permit, even if discharges have not occurred at the facility.

CAFOs are inspected by the MPCA in accordance with the MPCA NPDES Compliance Monitoring Strategy approved by the EPA. All CAFOs (NPDES permitted, SDS permitted, and not required to be permitted) are inspected by the MPCA on a routine basis (once every 5 years) with an appropriate mix of field inspections (e.g., complaint follow up), records review, and compliance assistance being completed as needed.

For feedlots with NPDES permits, surface applied solid manure is prohibited during the month of March. Winter application of manure (December through February) requires fields are approved in their manure management plan and the feedlot owner/operator must follow a standard list of setbacks and BMPs. Winter application of surface applied liquid manure is prohibited except for emergency manure application as defined by the NPDES permit. “Winter application” refers to application of manure to frozen or snow-covered soils, except when manure can be applied below the soil surface.

There are 146 animal feedlots (3 are NPDES/SDS-permitted CAFOs; Figure 15) within the drainage areas to impaired streams and lakes addressed in this TMDL study. About 90% of these feedlots are for one of three animals: beef cattle (74 feedlots), dairy cattle (41 feedlots), and chickens (15 feedlots).

Of the approximately 114 animal feedlots in the drainage areas to *E. coli*-impaired streams, there are 3 CAFOs with NPDES or SDS permits. Animal units in CAFOs in the *E. coli*-impaired stream subwatersheds are summarized in Table 15. Twenty-one non-CAFO feedlots are also covered by SDS permits. Table 16 summarizes animal units in NPDES/SDS-permitted operations, including CAFOs and non-CAFOs.

All NPDES and SDS permitted feedlots are designed to contain all manure, manure-contaminated runoff, process wastewater, and the precipitation from a 25-year, 24-hour storm event, and as such they are not considered a significant source of *E. coli*. All other feedlots are considered nonpermitted sources for the purposes of this TMDL report. In addition, the land application of all manure, regardless of whether the source of the manure originated from permitted (e.g., CAFOs) or nonpermitted feedlots, is also considered nonpermitted source and discussed in Section 3.6.1.2.

Table 15. Animal units in CAFOs in *E. coli* impairment subwatersheds.

The CAFOs in the Rice Creek (-512) and Elk River (-508) subwatersheds are upstream of the Elk River (-548) subwatershed.

NPDES ID	Impaired Water body Name	Impaired Water body AUID	Livestock	No. of animals
MNG440909	Elk River	07010203-548	Beef cattle–Feeder/heifer	1,300
MNG441989	Rice Creek	07010203-512	Dairy cattle > 1000 lb	1,213
MNG442120	Elk River	07010203-508	Beef cattle–Slaughter/stock	1,540

Table 16. Number of animals in NPDES/SDS-permitted operations in *E. coli* impairment subwatersheds.

Impaired Water body Name	Impaired Water body AUID	Bovine [a]	Swine	Horses, mini horses, and ponies	Poultry [b]	Goat and sheep [c]
Battle Brook	07010203-535	–	–	–	–	–
Elk River	07010203-508	3,829	–	–	88,000	–
	07010203-507	4,484	–	1	221,500	50
	07010203-548	9,829	–	1	517,900	50
Mayhew Creek	07010203-750	655	–	1	133,500	50
Rice Creek	07010203-512	1,935	–	–	200,000	–
Snake River	07010203-529	–	–	–	–	–
St. Francis River	07010203-700	860	–	–	43,400	–
Tibbets Brook	07010203-736	–	–	–	–	–
Unnamed creek (Fairhaven Creek)	07010203-565	–	–	–	–	–

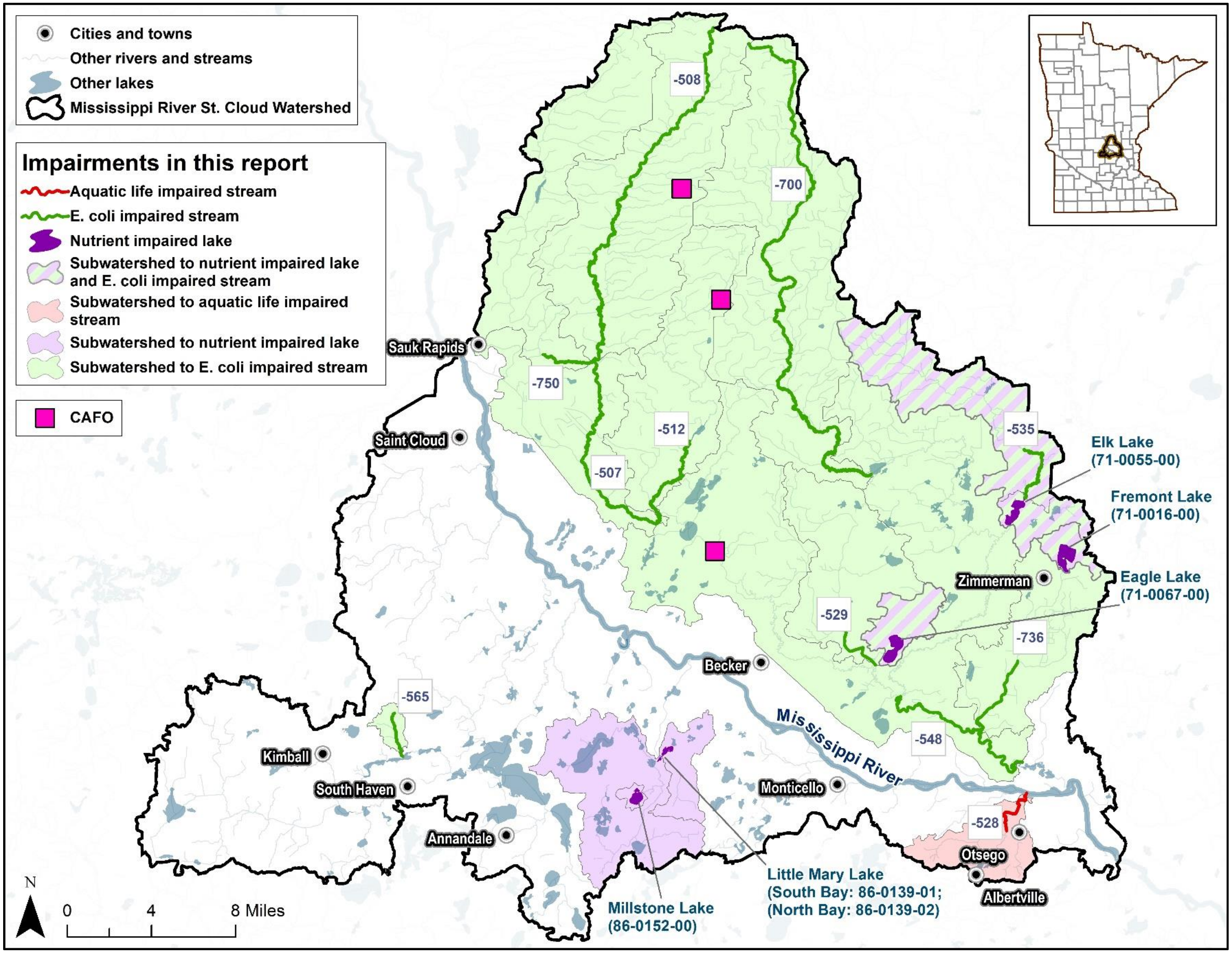
The numbers of animal units are for the entire subwatersheds draining to impaired segments. Multiple impaired subwatersheds are nested within other impaired subwatersheds; thus, the columns in this table should not be summed.

a. Beef cattle–calf, beef cattle–cow & calf pair, beef cattle–feeder/heifer, beef cattle–slaughter/stock, bison buffalo, dairy cattle–calf, dairy cattle–heifer, dairy cattle–<1000 lb, dairy cattle >1000 lb

b. Chicken–broiler <5 lb, chicken–broiler >5 lb, chicken – layers >5 lb, ducks–dry manure, fowl, mink, turkeys >5 lb, and turkeys <5 lb

c. Elk, goats, goats–small, llamas, sheep, and lambs.

Figure 15. CAFOs in the MRSC impairment subwatersheds.



Land application of wastewater

Land application of wastewater from certain permitted facilities may contain bacteria that could migrate to surface water bodies via overland flow and runoff following precipitation events.

In the subwatersheds with streams impaired by bacteria, most of the land application sites are only authorized to apply dewatering wastewater generated from facilities covered under Minnesota's general NPDES permit for nonmetallic mining (MNG490000). Nonmetallic mining dewatering is a wastewater that consists of uncontaminated groundwater and stormwater and is not a source of bacteria. A few land application sites are permitted for land application of non-biosolids sludge from industrial facilities under the MNG960000 Industrial By-product general permit, and non-biosolids sludge is not a source of bacteria.

Land application of biosolids was not assumed to contribute to *E. coli* and was not further evaluated as an *E. coli* source because of regulations associated with biosolid land application. Information about land application of biosolids is available in Minn. R. ch. 7041.

3.6.1.2 Nonpermitted sources

Nonpermitted source categories within the subwatersheds for this TMDL include non-NPDES/SDS-permitted animal feedlots, pasture, nonpermitted wastewater, wildlife, domestic pets, natural background sources, and naturalized *E. coli*.

The Elk River Watershed TMDL (MPCA 2012) identified the following three sources of *E. coli* contamination related to cropland and pastureland use that were especially important during periods of heavy precipitation: land application of manure to cropland, grazing at pastures, and nonpermitted feedlots and livestock facilities.

Non-NPDES/SDS permitted animal feedlots and manure application

Feedlots under 1,000 AUs and those that are not federally defined as CAFOs do not operate with permits. In Minnesota, feedlots with greater than 50 AUs, or greater than 10 AUs in shoreland areas, are required to register with the county feedlot officer if the county is delegated, or with the MPCA if the county is nondelegated. Facilities with fewer AUs are not required to register. Shoreland is defined by Minn. R. 7020.0300 as land within 1,000 feet from the normal high water mark of a lake, pond, or flowage, and land within 300 feet of a river or stream.

Manure that is generated on feedlots is usually stockpiled on site, on crop fields or stored in liquid manure storage areas on site until field and weather conditions and the crop rotation allow for applying the manure as fertilizer. While there are multiple benefits to using animal manure for fertilizer, manure can be delivered to surface waters from failure of manure containment, runoff from the feedlot itself, or runoff from nearby fields where the manure is applied. The timing of manure spreading, as well as the application rate and method, affects the likelihood of pollutant loading to nearby water bodies. The spreading of manure on frozen soil in the late winter is likely to result in surface runoff with precipitation and snowmelt runoff events. Deferring manure application until snow has melted and soils have thawed decreases overland runoff associated with large precipitation events. Injecting or incorporating manure is a preferred best management practice (BMP) to reduce the runoff of waste and associated pollutants. Incorporating manure into the soil reduces the risk of surface runoff associated with large precipitation events.

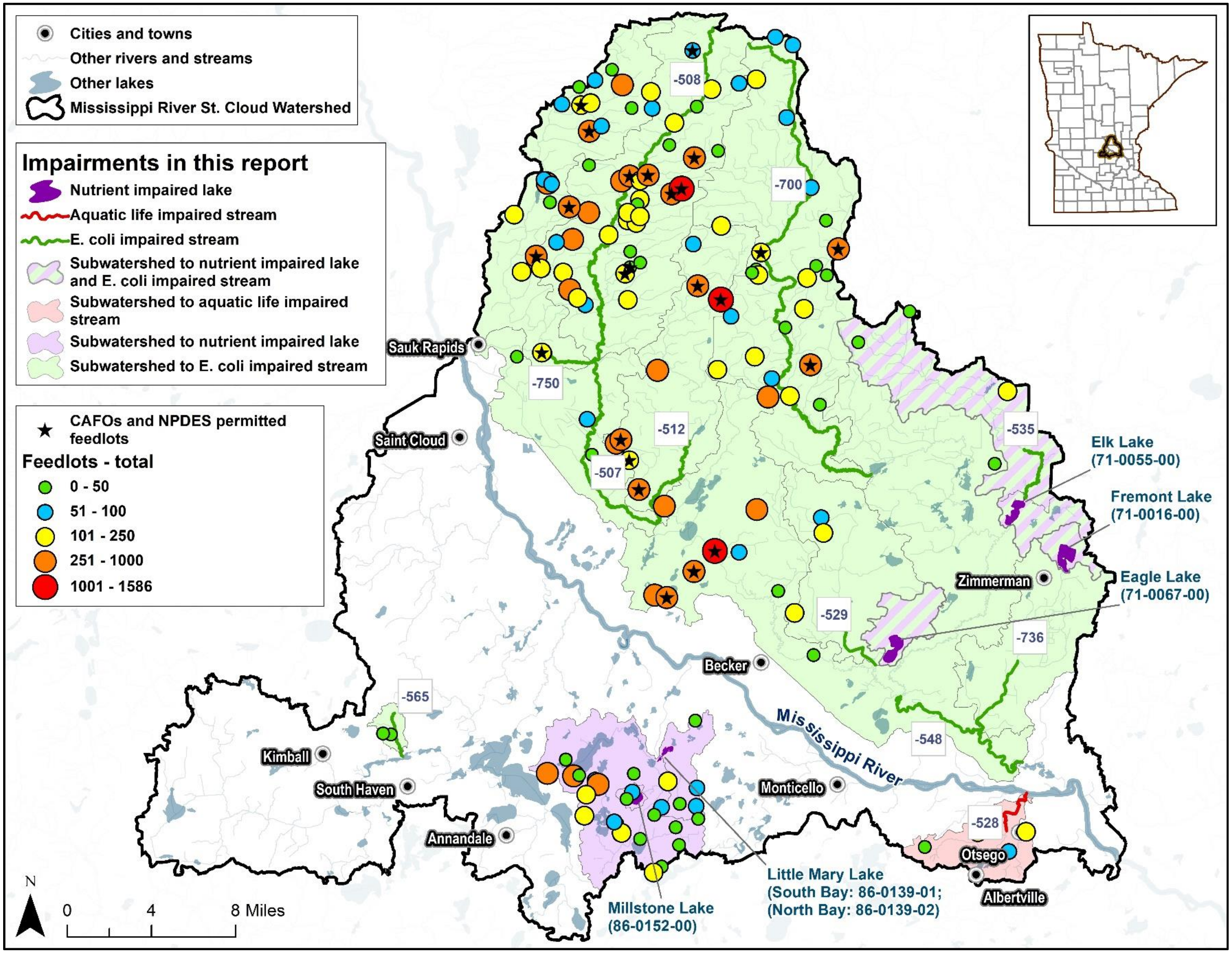
Facilities that obtain an interim or construction short form feedlot permit, in addition to feedlots with an operating permit (NPDES or SDS; see Section 3.6.1.1), are required to develop and maintain a manure management plan.

While a full accounting of the fate and transport of manure was not conducted for this project, a large portion of it is ultimately applied to the land surface and, therefore, this source is of possible concern. Minn. R. 7020.2225 contains several requirements for land application of manure; however, there are no explicit requirements for *E. coli* treatment prior to land application.

All non-CAFOs are inspected in delegated counties by the county feedlot officer on a routine basis in accordance with the delegated county's Delegation Agreement and Work Plan, which is prepared with and approved by MPCA every other year. Non-CAFOs in nondelegated counties are inspected by MPCA on an as-needed or complaint-driven basis. Meeker, Stearns, and Wright counties are delegated, while Benton, Mille Lacs, and Sherburne counties are nondelegated. In the nondelegated counties, MPCA inspected livestock operations during the period of 2004 – 2022 for the subwatersheds draining to the Elk River (12 inspections), Mayhew Creek (10 inspections), Rice Creek 8 inspections), and St. Francis River (2 inspections). The MPCA found only one operation (in the Elk River Subwatershed) to be noncompliant which is being handled through MPCA enforcement and permitting.

Registered feedlots in the drainage areas to impaired waters of the MRSCW are mapped in Figure 16.

Figure 16. Feedlots in the MRSC impairment subwatersheds.



Nine of the 10 subwatersheds draining to *E. coli*-impaired streams contained non-NPDES/SDS-permitted livestock operations (Table 17); no such operations are in the Tibbets Brook (-736) subwatershed. This analysis does not consider fate and transport of *E. coli.*

Table 17. Numbers of animals in non-NPDES/SDS-permitted operations in *E. coli* impairment subwatersheds.

Impaired Water body Name	Impaired Water body AUID	Bovine [a]	Swine	Horses, mini horses, and ponies	Poultry [b]	Goat and sheep [c]
Battle Brook	07010203-535	346	10	–	–	–
Elk River	07010203-508	3,171	875	17	95,030	–
	07010203-507	5,265	1,425	38	189,674	–
	07010203-548	11,752	1,435	46	298,485	32
Mayhew Creek	07010203-750	2,039	550	21	73,644	–
Rice Creek	07010203-512	1,236	–	3	–	–
Snake River	07010203-529	450	–	–	–	–
St. Francis River	07010203-700	1,626	–	–	108,800	32
Tibbets Brook	07010203-736	–	–	–	–	–
Unnamed creek (Fairhaven Creek)	07010203-565	–	–	–	–	150

The numbers of animals are for the entire subwatersheds draining to impaired segments. Multiple impaired subwatersheds are nested within other impaired subwatersheds; thus, the columns in this table should not be summed.

a. Beef cattle–calf, beef cattle–cow & calf pair, beef cattle–feeder/heifer, beef cattle–slaughter/stock, bison buffalo, dairy cattle–calf, dairy cattle–heifer, dairy cattle–<1000 lb, dairy cattle >1000 lb.

b. Chicken–broiler <5 lb, chicken–broiler >5 lb, chicken – layers >5 lb, ducks–dry manure, fowl, mink, turkeys >5 lb, and turkeys <5 lb.

c. Elk, goats, goats–small, llamas, sheep, and lambs.

Pasture

Pasture ranges from 4% to 20% of the land use in the *E. coli* TMDL subwatersheds. Livestock grazing operations in pastures can be a source of *E. coli* to impaired streams because runoff can transport the waste deposited by livestock on the pasture to nearby streams. Additionally, streams flow through some pastures; in these areas' livestock can deposit waste directly into streams.

The *Mississippi River–St. Cloud SID Update Report* (MPCA 2022c) identified multiple locations throughout the MRSCW where cattle had direct access to streams, for watering, stream-crossing, or to use as a corridor for movement. In these cases, waste can be directly deposited into streams. Specifically, MPCA (2022c) identified several locations where cattle have access to an unnamed stream tributary to Rice Creek (-512) and identified sludge (cattle manure) as a dominant substrate in the unnamed stream; Rice Creek is impaired for its aquatic recreation use due to elevated *E. coli* levels.

Many hobby farms with small pastures are located throughout the MRSCW. Hobby farms are very small operations and often have too few livestock to be registered or permitted. Sherburne SWCD commissioned a study of hobby farms in Sherburne County that identified about 700 hobby farms.[2]

Stearns SWCD has identified pastures where cattle have access to Johnson Creek (locally known as Meyer Creek; AUID -539) and will work with landowners to address the issue. The target area is in the city of St. Augusta, south of the city of St. Cloud. Johnson Creek has an approved *E. coli* TMDL but the biological impairments are not yet addressed by a TMDL.

At the turn of the millennium, Benton SWCD completed a county-wide inventory of riparian pasture. Benton SWCD partnered with the Elk River Watershed Association to promote Conservation Reserve Program (CRP) buffer strips and partnered with the Fish and Wildlife Service for riparian livestock exclusion fencing. About 1,000 acres of riparian buffer and over 10 miles of fencing were installed. Adoption rates were high in the St. Francis River Watershed.

Nonpermitted wastewater

Subsurface sewage treatment systems

Adequate wastewater treatment is vital to protecting the health, safety, and environment in Minnesota. Approximately 30% of Minnesotans rely on SSTSs. SSTSs that fail to treat wastewater adequately threaten groundwater used for drinking water and surface water used for recreation. Inadequate treatment of wastewater/sewage, which contains bacteria, viruses, parasites, nutrients, and chemicals, can result in contamination of drinking water sources. Additionally, straight-pipe wastewater "systems," which route raw wastewater to the ground or nearby waters, can directly impact lakes, streams, and wetlands.

SSTSs can fail for a variety of reasons, including excessive water use, poor design, physical damage, and lack of maintenance. Common limitations that contribute to failure include seasonal high water-table, fine-grained soils, bedrock, and fragipan (i.e., altered subsurface soil layer that restricts water flow and root penetration). Septic systems can fail hydraulically through surface breakouts or hydrogeologically from inadequate soil filtration. Failure potentially results in higher levels of pollutant loading to nearby surface waters.

Analysis of SSTS data for parcels adjacent to impaired waters in Sherburne County (provided by the Sherburne County Planning and Zoning Department) indicate that most inspections do not result in violations, and that many violations were due to a lack of inspection, where SSTS were found to be in compliance after the inspection occurred.

Rates of compliance and of imminent threat to public health or safety (ITPHS) for the six counties of the MRSCW are presented in Table 18. Most of the stream *E. coli* TMDL subwatersheds are in Sherburne, Stearns, and Wright counties.

[2] Dan Cibulka, Senior Water Resources Specialist, Sherburne SWCD, electronic communication, September 28, 2023.

Table 18. SSTS compliance and ITPH rates by county (2017–2021).

County	Compliant (%)	ITPH (%)
Benton	77%–75%	5%
Meeker	83%–88%	2%–5%
Mille Lacs	55%–65%	7%
Sherburne	93%–97%	1%–4%
Stearns	88%–90%	2%–3%
Wright	81%–84%	1%

Other potential sources of wastewater sources of *E. coli in* the watershed may include straight pipe discharges, earthen pit outhouses, and land application of septage. Straight pipe systems are unpermitted and illegal sewage disposal systems that transport raw or partially treated sewage directly to a lake, stream, drainage system, or the ground surface. Straight pipe systems are required to be addressed 10 months after discovery (Minn. Stat. § 15.55, subd. 11). Outhouses, or privies, are legal disposal systems and are regulated under Minn. R. 7080.2150, subp. 2F and Minn. R. 7080.2280. Septage disposal is regulated under Minn. R. 7041 and Minn. R. 7080 as well as in local and federal regulations.

Areas and communities with SSTS concerns

To ensure that effective sewage treatment occurs across the state, the MPCA regularly conducts surveys of local governmental units to identify areas in the state that may be areas of concern; these areas are defined as five or more homes within a half mile of each other that have inadequate sewage treatment. These areas are generally unincorporated communities, may not have an organized structure, may consist of families with limited financial resources, and many times do not qualify for the same financial assistance as large, incorporated communities.

As of 2022, there were 54 communities in the subwatersheds draining to impairments identified as areas and communities with SSTS concerns. Concerns with SSTSs were identified in all but one of the *E. coli* impaired subwatersheds. The communities may have been listed because they were known to be noncompliant (i.e., ITPHS that backs up into the house or surface discharges inadequately treated wastewater, or a treatment system that is failing to protect groundwater and has a leaky tank or not enough soil separation under the SSTS before reaching saturated soil conditions) or due to an unknown status of SSTS compliance and were listed because of poor soils in the area, small lot size, or are older systems that may be out of compliance.

At the time of this TMDL report, there are no known efforts of extending sanitary sewers to any of the SSTS concern areas in Sherburne or Stearns counties. However, in Benton County, the city of Foley is in the process of connecting to the sanitary sewer system and wastewater treatment plant in the city of St. Cloud. To the south of the city of Foley, the unincorporated community of Duelm, in St. George Township of Benton County, is seeking grant funding for replacing its community septic system.

Wildlife

In the rural portions of the watershed there are deer, waterfowl, and other animals, with greater numbers in conservation and remnant natural areas, wetlands and lakes, and river and stream corridors. In the 13-county central region of Minnesota, deer observations during the 2022 August road survey were 40.0 deer per 100 miles, which is down from 2021 (46.7 deer per 100 miles), 1.5 times the 2012 through 2021 average (25.7 deer per 100 miles), and 4 times the long-term average (9.9 deer per 100 miles; DNR 2022a). Deer densities in the Deer Permit Areas[3] within the subwatersheds draining to *E. coli* impaired streams in the MRSCW ranged from 16 to 36 deer per square mile in 2016 through 2021 (DNR 2021). Deer densities in the MRSCW generally increased each year from 2016 (16 to 19 deer per square mile) to 2021 (31 to 36 deer per square mile).

There may also be some instances of large geese or other waterfowl populations for some stream reaches. In urban areas wildlife may provide a more significant portion of *E. coli* loads. Recent studies in Minneapolis using microbial markers show that birds are a primary source of the *E. coli* entering stormwater conveyances (Burns & McDonnell Engineering Company, Inc. 2017).

The *Mississippi River–St. Cloud SID Report* (MPCA 2022c) identified many beaver dams along the Snake River (-529) and identified beaver in an unnamed stream tributary to Rice Creek (-512); both the Snake River and Rice Creek are impaired for their aquatic recreation uses. Beavers directly deposit waste into waterways and can contribute to elevated in-stream *E. coli* levels. No additional information on localized wildlife communities near *E. coli* impaired waters was identified by stakeholders.

Domestic pets

When pet waste is not disposed of properly, it can be picked up by runoff and washed into nearby water bodies. Dogs are considered the primary source of *E. coli* from domestic pets. Because cats generally bury their waste, *E. coli* from cats typically does not reach surface water bodies through runoff. Waste from pets can be a source of concern in subwatersheds with a higher density of developed area. Compared to rural areas, developed areas have higher densities of pets and a higher delivery of waste to surface waters due to connected impervious surfaces.

Natural background sources

"Natural background" is defined in both Minnesota statute and rule. The Clean Water Legacy Act (Minn. Stat. § 114D.15, subd. 10) defines natural background as "characteristics of the water body resulting from the multiplicity of factors in nature, including climate and ecosystem dynamics, that affect the

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[3] Based upon GIS analysis *Minnesota Deer Permit Areas* (DNR 2022c), the MRSCW is within 11 Deer Permit Areas. The nine *E. coli* stream impairments north of the Mississippi River are within Deer Permit Areas #221, #222, #223, and #224. The MRSCW is mostly within Deer Management Units #14 and #15.

physical, chemical, or biological conditions in a water body, but does not include measurable and distinguishable pollution that is attributable to human activity or influence." Minn. R. 7050.0150, subp. 4 states, "'Natural causes' means the multiplicity of factors that determine the physical, chemical, or biological conditions that would exist in a water body in the absence of measurable impacts from human activity or influence."

Natural background sources are inputs that would be expected under natural, undisturbed conditions. Natural background sources can include inputs from wildlife, including mammals and birds. However, for each impairment, natural background levels are implicitly incorporated in the water quality standards used by the MPCA to determine/assess impairment, and therefore natural background is accounted for and addressed through the MPCA's water body assessment process. Natural background conditions were evaluated within the source assessment portion of this study. These source assessment exercises indicate that natural background inputs are generally low compared to livestock, wastewater treatment facilities, failing SSTSs, and other anthropogenic sources**.**

Based on the MPCA's water body assessment process and the TMDL source assessment exercises, there is no evidence at this time to suggest that natural background sources are a major driver of any of the impairments and/or affect the water bodies' ability to meet state water quality standards.

Naturalized *E. coli*

The adaptation and evolution of naturalized *E*. *coli* that survival and reproduction in the environment make naturalized *E. coli* physically and genetically distinct from *E*. *coli* that cannot survive outside of a warm-blooded host. This naturalized *E. coli* may be a source of *E. coli* to the impairments.

The relationship between *E. coli* sources and *E. coli* concentrations found in streams is complex, involving precipitation and flow, temperature, sunlight and shading, livestock management practices, wildlife contributions, *E. coli* survival rates, land use practices, and other environmental factors. Research in the last 15 years has found the persistence of *E. coli* in soil, beach sand, and sediments throughout the year in the north central United States without the continuous presence of sewage or mammalian sources. This *E. coli* that persists in the environment outside of a warm-blooded host is referred to as naturalized *E. coli* (Jang et al. 2017). Naturalized *E. coli* can originate from different types of *E. coli* sources, including 1) natural background sources such as wildlife and 2) human attributed sources such as pets, livestock, and human wastewater. Therefore, whereas naturalized *E. coli* can be related to natural background sources, naturalized *E. coli* is not always from a natural background source.

An Alaskan study (Adhikari et al. 2007) found that total coliform bacteria in soil were able to survive for six months in subfreezing conditions. Two studies near Duluth, Minnesota found that *E. coli* was able to grow in agricultural field soil (Ishii et al. 2010) and temperate soils (Ishii et al. 2006). A study by Chandrasekaran et al. (2015) of ditch sediment in the Seven Mile Creek Watershed in southern Minnesota found that strains of *E. coli* had become naturalized to the water−sediment ecosystem. Survival and growth of fecal coliform has been documented in storm sewer sediment in Michigan (Marino and Gannon 1991), and *E. coli* regrowth was documented on concrete and stone habitat within an urban Minnesota watershed (Burns & McDonnell Engineering Company, Inc. 2017). This ability of

E. coli to survive and persist naturally in watercourse sediment can increase *E. coli* counts in the water column, especially after resuspension of sediment (e.g., Jamieson et al. 2005).

Although naturalized *E. coli* might exist in the watershed, there is no evidence to suggest that naturalized *E. coli* is a major driver of impairment and/or affect the water bodies' ability to meet state water quality standards.

3.6.1.3 *E. coli* source summary

The monitoring data and source assessment indicate that multiple sources are likely contributing to *E. coli* stream impairment.

Livestock is the primary source of concern in the majority of impaired subwatersheds. In the subwatersheds with developed areas, stormwater runoff has the potential to be a primary source. Areas or communities with SSTS concerns, defined as five or more homes within a half mile of each other that have inadequate sewage treatment and provided to the MPCA by local government units, may also be significant.

- Permitted wastewater: Except for the Aspen Hills WWTF, permitted facilities effluent is below permit limits. As such, the permitted facilities contribute *E. coli* to the impaired segments but are not a significant cause of impairment. Aspen Hills WWTF exceeds permit limits and contributes significant load to Tibbets Brook. As noted above, this is being addressed by the MPCA.
- Stormwater: Except for the St. Francis River (-700) and unnamed creek (Fairhaven Creek; -565), existing or future permitted MS4s are found within each subwatershed draining to a stream impaired by *E. coli*. Developed areas and areas with impervious surfaces, whether regulated as an MS4 or not, can act as a conveyance system for *E. coli* to be delivered to impaired streams.
- Livestock, pastures, and land application of manure: Pastures are located throughout the MRSCW and feedlots are located within most subwatersheds draining to a stream impaired by *E. coli*. Non-CAFO and non-NPDES/SDS-permitted feedlots are typically more of a concern than CAFOs or NPDES/SDS-permitted feedlots because non-CAFO and non-NPDES/SDS-permitted feedlots are not required to completely contain runoff. Land application of manure, regardless of the type of facility the manure originated, is also a likely source of *E. coli.*
- SSTSs: ITPHS are a small percentage of SSTSs (1% to 7%). Areas or communities with SSTS concerns are located in all but one (Mayhew Creek) subwatershed draining to a stream impaired by *E. coli*.

An evaluation of monitoring data (Section 3.5.1.1) indicated that high concentrations of *E. coli* did not typically occur on the same days at multiple locations across the subwatersheds with streams impaired by *E. coli*. This may indicate that localized sources of *E. coli* have more significance on water quality than watershed-scale sources. As such, source information presented in this section was supplemented via desktop analysis of NLCD 2019 land cover classes near and directly adjacent to impaired stream segments when determining the likely significance of each source (Table 19).

Table 19. Summary of sources in stream subwatersheds impaired by *E. coli*.

Likely significance of *E. coli* source: ● Higher; ○ Lower; ⊕ Higher but not a priority. Source not present (–).

Impaired water body name	Impaired water body AUID	Permitted wastewater	Permitted stormwater	Livestock, pasture, and land application of manure	ITPHS and areas of concern	Wildlife	Domestic pets	Natural background *E. coli*	Naturalized *E. coli*
Battle Brook	07010203-535	–	○	○	○	○	○	○	○
Elk River	07010203-508	○	○	●	○	○	○	○	○
	07010203-507	–	●	●	○	○	○	○	○
	07010203-548	○	●	●	○	○	○	○	○
Mayhew Creek	07010203-750	–	●	●	– [b]	○	○	○	○
Rice Creek	07010203-512	○	○	●	○	⊕	○	○	○
Snake River	07010203-529	–	●	○	○	⊕	○	○	○
St. Francis River	07010203-700	–	–	●	○	○	○	○	○
Tibbets Brook	07010203-736	● [a]	●	●	○	○	○	○	○
Unnamed creek (Fairhaven Creek)	07010203-565	–	-	○	○	○	○	○	○

a. The Aspen Hills WWTF effluent exceeds bacteria permit limits and DMR records indicate the facility's effluent load can be the majority of load in Tibbets Brook.

b. No areas or communities of SSTS concerns are within the subwatershed draining to the impaired segment of Mayhew Creek. ITPHS may be located in this subwatershed.

3.6.2 Total suspended solids

One stream segment is designated as impaired for its aquatic life use due to bioassessments of fish and macroinvertebrates: Unnamed creek (-528; locally known as Otsego Creek). A weight of evidence approach was used to determine the likely primary sources of TSS, with a focus on the sources that can be effectively reduced with management practices. TSS sources evaluated in this study are nonpermitted watershed runoff, permitted stormwater, permitted wastewater, and erosion (channel, streambank).

3.6.2.1 Permitted sources

Permitted source categories within the subwatershed for this TMDL include municipal and industrial wastewater, MS4 stormwater, industrial stormwater, and construction stormwater.

Municipal and industrial wastewater

Permitted wastewater in the watershed includes municipal/domestic and industrial wastewater. Both municipal/domestic and industrial wastewater dischargers must obtain NPDES/SDS permits.

Municipal/domestic wastewater is the domestic sewage and wastewater collected and treated by municipalities and other private entities prior to being discharged to surface waters. There is one facility that continuously discharges in the impaired subwatershed (Table 20).

Industrial wastewater is wastewater generated from industries, businesses, and other privately owned facilities that is collected and treated prior to being discharged to surface waters. There are no permitted industrial wastewater discharges impacting impaired subwatersheds.

The TSS concentration limits for Otsego WWTP West are a 30 mg/L monthly average and a 45 mg/L weekly average. The TSS load limits are 81.60 kilograms per day and 29,784 kilograms per year. A review of DMR data from 2012 through 2021 indicates that the facility did not exceed its TSS concentration or load limits. The monthly averages ranged from 3 to 22 mg/L and the weekly averages ranged from 4 to 31 mg/L. Loads were small fractions of the facility's permitted limits, and the Otsego WWTP West effluent is not a primary source of TSS. Additionally, the TSS in this facility's effluent is likely mostly volatile organic matter (i.e., likely not much of the effluent TSS is mineral sediment). As such, this facility is not a source of sediment (or degraded in-stream habitat) that causes the impairment.

Table 20. NPDES/SDS permitted facility in the impaired aquatic life use subwatershed.

Wastewater Facility	NPDES / SDS Permit #	Impaired Water body Name	Impaired Water body AUID
Otsego WWTP West	MN0066257	Unnamed creek (via unnamed creek)	528 (via 527)

Municipal separate storm sewer systems

Four regulated MS4s are within the subwatershed draining to the impaired Unnamed creek (-528):

- Albertville City MS4 (MS400281)
- MNDOT Outstate District MS4 (MS400180)
- Otsego City MS4 (MS400243)

- Saint Michael City MS4 (MS400246)

The specific areas that are regulated through the MS4 permit are estimated in Section 4.2.3.2 and Figure 35. Refer to Section 3.6.1.1 for general historical and regulatory information about MS4s.

Regulated MS4 area makes up approximately 86% of the impairment's subwatershed, and regulated stormwater runoff may contribute to impairment. Because the stormwater runoff from the regulated MS4s flows through a pond and wetland system before reaching the impaired reach, the extent of the impact is uncertain.

Construction stormwater

Construction stormwater is regulated through an NPDES/SDS permit. Untreated stormwater that runs off a construction site often carries sediment to surface water bodies. Because phosphorus travels adsorbed to sediment, construction sites can also be a source of phosphorus to surface waters. Phase II of the stormwater rules adopted by the EPA requires an NPDES/SDS permit for a construction activity that disturbs one acre or more of soil; a permit is needed for smaller sites if the activity is either part of a larger development or if the MPCA determines that the activity poses a risk to water resources. Coverage under the construction stormwater general permit requires sediment and erosion control measures that reduce stormwater pollution during and after construction activities (see Section 8.1.1).

Industrial stormwater

Industrial stormwater is regulated through an NPDES/SDS permit when stormwater discharges have the potential to come into contact with materials and activities associated with the industrial activity.

Intex Corp (MNR053BMP) is authorized to discharge under Minnesota's general NPDES permit for multi-sector industrial stormwater (MNR050000). About 4.5 acres of this facility is within the Unnamed creek subwatershed (-528) while the remainder of the facility is outside of the MRSCW and drains to the Crow River Subbasin (HUC 07010204).

Knife River Central Minnesota (MNG490003) is authorized to discharge "stormwater, nonspecific runoff" through surface discharge #231 from a "ready-mixed concrete operation" via Minnesota's general NPDES permit for nonmetallic mining (MNG490000). The 108.4-acre property discharges to an unnamed wetland that is about 0.6 acres.

3.6.2.2 Nonpermitted sources

Nonpermitted source categories within the subwatershed for this TMDL include pasture, erosion, and natural background sources.

Agricultural sources: pasture and cropland

About 10% of the Unnamed creek (-528) subwatershed is classified as pasture or hay in the 2019 National Land Cover Database. Visual analysis of aerial imagery did not identify any riparian pasture immediately adjacent to the impaired segment; one fenced pasture with paddocks was located within 200 feet of the Unnamed creek. Several fenced fields without row crops were identified near the Unnamed creek, which may have been horse pasture; they typically had thin, forested riparian buffers. Most agricultural land adjacent to the stream is row crop.

Channel incision and altered hydrology

Habitat quality and in-stream water quality, both of which affect biological community health, are degraded by altered flow conditions, bank erosion/failure, and sedimentation. The MPCA 2013 notes that the channel banks along Unnamed creek (-528) (Otsego Creek) is eroding due to the channel incision and suspected altered hydrology caused from upstream channelization and additional stormwater runoff volume and flow rate. This bank failure then increases the amount of sediment entering the stream.

The sediment transport and dynamic equilibrium of Unnamed creek (-528) are disturbed by flow alteration resulting from urban and agricultural development and are exacerbated by high stream channel slope. The altered hydrology and increased peak discharges, along with the extent of exposed bank material is allowing this area to experience a high degree of erosion and sedimentation (MPCA 2013). Much of the impaired segment flows through primarily agricultural land, including several segments (some straightened) with little to no riparian forest. Considerable urban land is upstream of the impaired segment.

Both crop and livestock operations can contribute to erosion. The installation of drain-tiles in crop fields results in higher and quicker flows discharged to streams; such flashy flows can increase erosion. When livestock have direct access to streams, they can degrade streambanks (e.g., hoof-shear), while overgrazing on pasture can lead to increase overland flow that contribute to flashiness in streams.

Urban development can also contribute to stream channel instability and erosion through direct modification of stream banks. Urban storm sewers, similar to agricultural drain tiles, can increase the flashiness in streams. Impervious cover can also increase in-stream flashiness because runoff cannot infiltrate into the ground.

Other factors that affect erosion include streambank slope, upland and streambank soil moisture, and characteristics of the material in upland soil and stream channel sediment.

3.6.2.3 TSS source summary

The MPCA (2013) found that fish and macroinvertebrate communities in Unnamed creek (-528) were impaired due to an excess sediment supply caused by bank failure, lack of habitat variability, and loss of connectivity/altered hydrology. Land cover in the drainage area to Unnamed creek (-528) is largely urban and agricultural (row crops). Impacts from agricultural and urban land uses have altered the natural flow conditions of Unnamed creek (-528) by increasing peak discharges to the stream. This flow alteration is exacerbated by high stream channel slope and results in stream channel erosion and increased sedimentation in the stream. The primary source of TSS to the impairment are channel and streambank erosion; TSS in cropland runoff and TSS in urban stormwater runoff are also likely sources of sediment to the stream.

3.6.3 Total phosphorus

Phosphorus is an essential nutrient for aquatic and terrestrial life and is found naturally throughout a watershed. However, there are several potential sources of phosphorus contributing excess amounts to impaired water bodies. Phosphorus sources evaluated in this study are permitted wastewater and permitted stormwater, permitted feedlots, nonpermitted watershed runoff (feedlots, pasture, stormwater), SSTSs, erosion (channel, streambank), and internal loading. BATHTUB models were developed for each of the six phosphorus-impaired lakes. A weight of evidence approach was used with available data to determine likely primary sources of phosphorus to input into the BATHTUB models.

3.6.3.1 Permitted sources

Permitted source categories within the subwatershed for this TMDL include municipal and industrial wastewater, MS4s, industrial stormwater, and construction stormwater.

Municipal and industrial wastewater

Permitted wastewater in the watershed includes municipal/domestic and industrial wastewater. Both municipal/domestic and industrial wastewater dischargers must obtain NPDES/SDS permits.

Municipal/domestic wastewater is the domestic sewage and wastewater collected and treated by municipalities and other private entities prior to being discharged to surface waters. Six municipal wastewater treatment plants are within two impaired lakes subwatersheds; however, none of these facilities are authorized to discharge to surface water and none are covered by NPDES/SDS permits.

Industrial wastewater is wastewater generated from industries, businesses, and other privately owned facilities that is collected and treated prior to being discharged to surface waters. A single industrial operation is authorized to discharge industrial stormwater to surface waters: a construction sand and gravel mining operation at Knife River Central Minnesota (MNG490003, SD 216) is authorized to discharge dewatering effluent which consists of uncontaminated groundwater and stormwater from the Stay Pit via SD 216 under Minnesota's Nonmetallic Mining and Associated Activities (MNG490000) General NPDES/SDS Permit. This outfall is estimated to discharge 20 million gallons per year (Ron Klinker, Environmental & Land Development Manager for Knife River Central Minnesota, personal communication, May 19, 2022).

Municipal separate storm sewer systems

Only one currently regulated MS4 is within one of the subwatersheds that drain to the six impaired lakes. The Big Lake Township MS4 (MS400234) is within the subwatershed draining to Eagle Lake (71-0067-00). The specific area that is regulated through the MS4 permit is estimated in Section 4.3.4.2 and Figure 38.

Four additional communities in Sherburne County are currently unregulated MS4s, but MPCA anticipates that the MS4s will become regulated soon. Portions of these communities are within the three impaired lake subwatersheds (Table 21).

Refer to Section 3.6.1.1 for general historical and regulatory information about MS4s.

Table 21. Regulated MS4s in impaired aquatic recreation use subwatersheds.
Note: Impaired lake subwatersheds and MS4s are sorted alphabetically top to bottom and left to right, respectively.

Impaired lake subwatershed	**Baldwin Township** *	**Becker Township** *	**Big Lake Township** (MS400234)	**Livonia Township** *	**Zimmerman City** *
Eagle Lake (71-0067-00)	–	X	X	–	–
Elk Lake (71-0055-00)	X	–	–	–	–
Fremont Lake (71-0016-00)	X	–	–	X	X
Little Mary Lake–North Bay (86-0139-02)	–	–	–	–	–
Little Mary Lake–South Bay (86-0139-01)	–	–	–	–	–
Millstone Lake (86-0152-00)	–	–	–	–	–

*These communities are not currently regulated but are expected to come under MS4s permit coverage in the near future.

Construction stormwater

Construction stormwater is regulated through an NPDES/SDS permit. Untreated stormwater that runs off of a construction site often carries sediment to surface water bodies. Because phosphorus travels adsorbed to sediment, construction sites can also be a source of phosphorus to surface waters. Phase II of the stormwater rules adopted by the EPA requires an NPDES/SDS permit for a construction activity that disturbs one acre or more of soil; a permit is needed for smaller sites if the activity is either part of a larger development or if the MPCA determines that the activity poses a risk to water resources. Coverage under the construction stormwater general permit requires sediment and erosion control measures that reduce stormwater pollution during and after construction activities (see Section 8.1.1).

Industrial stormwater

Industrial stormwater is regulated through an NPDES/SDS permit when stormwater discharges have the potential to come into contact with materials and activities associated with the industrial activity.

Four facilities within impaired lake subwatersheds are authorized to discharge “stormwater, nonspecific” to surface waters by Minnesota’s MNG490000 Nonmetallic Mining and Associated Activities General NPDES/SDS Permit (Table 22). Within the South Bay of Little Mary Lake Subwatershed (86-139-01), Cedar Lake Engineering Inc. (MNRNE3B24) is an industrial facility with no exposure certification under Minnesota’s general NPDES/SDS permit for industrial stormwater (MNR050000); this facility does not discharge to surface waters.

Table 22. NPDES/SDS permitted industrial stormwater facilities in the impaired aquatic recreation use lake subwatersheds.

Industrial Stormwater Facility	NPDES/SDS Permit # (SD station)	Impaired Water body Name	Impaired Water body AUID
Knife River Central Minnesota	MNG490003 (SD 150)	Little Mary Lake (South Bay)	86-0139-01
	MNG490003 (SD 028)	Elk Lake	71-0055-00
Kolles Sand & Gravel Inc	MNG490241 (SD 001)	Little Mary Lake (South Bay)	86-0139-01
Hastings Sand and Gravel	MNG490592 (SD 005)	Elk Lake	71-0055-00

NPDES and SDS permitted animal feedlots

Of the 27 animal feedlots in the impaired lake subwatersheds, none are CAFOs with NPDES or SDS permits. Refer to Section 3.6.1.1 for general and regulatory information about permitted feedlots.

3.6.3.2 Nonpermitted sources

Nonpermitted sources that have the potential to contribute to excessive nutrients include non-CAFO livestock facilities and pastures, nonpermitted wastewater, crop farming, pasture runoff, watershed runoff, shoreline erosion and watershed erosion, atmospheric deposition, and internal nutrient loading.

Non-NPDES/SDS permitted animal feedlots and manure application

Feedlots under 1,000 AUs and those that are not federally defined as CAFOs do not operate with permits (Section 3.6.1.2). In Minnesota, feedlots with greater than 50 AUs, or greater than 10 AUs in shoreland areas, are required to register with the county feedlot officer if the county is delegated, or with the MPCA if the county is nondelegated. Facilities with fewer AUs are not required to register.

Of the 30 feedlots in the lake-impaired subwatersheds, 21 are registered and nine are not required to register (Table 23). As shown in Figure 17 and Figure 18, most feedlots are located in the uplands of each lake subwatershed, with the exception of a single feedlot adjacent to Millstone Lake (Figure 18).

Table 23. Feedlots in the lake impairment subwatersheds.

Lake	AUID	No. of feedlots [a]	Livestock type	No. of animals
Eagle Lake	71-0067-00	–	–	–
Elk Lake	71-0055-00	3 (1/2)	Beef cattle Swine	346 10
Fremont Lake	71-0016-00	–	–	–
Little Mary (South Bay) [b]	86-0139-01	19 (15/4)	Beef cattle Chicken Dairy cattle Duck Fowl Horses Sheep Swine Turkey	2,432 207 719 5,014 87,000 33 40 13 25
Little Mary (North Bay)	86-0139-02	7 (4/3)	Beef cattle Chicken Horses Swine	287 30 89 13
Millstone Lake [b]	86-0152-00	1 (1/0)	Dairy cattle	84

a. Total number of feedlots, with the number of registered feedlots followed by the number of nonregistered feedlots in parentheses.

b. The Millstone Lake Subwatershed is within the Little Mary Lake – South Bay Subwatershed.

Figure 17. Feedlots in the impaired lake subwatersheds in Sherburne County.

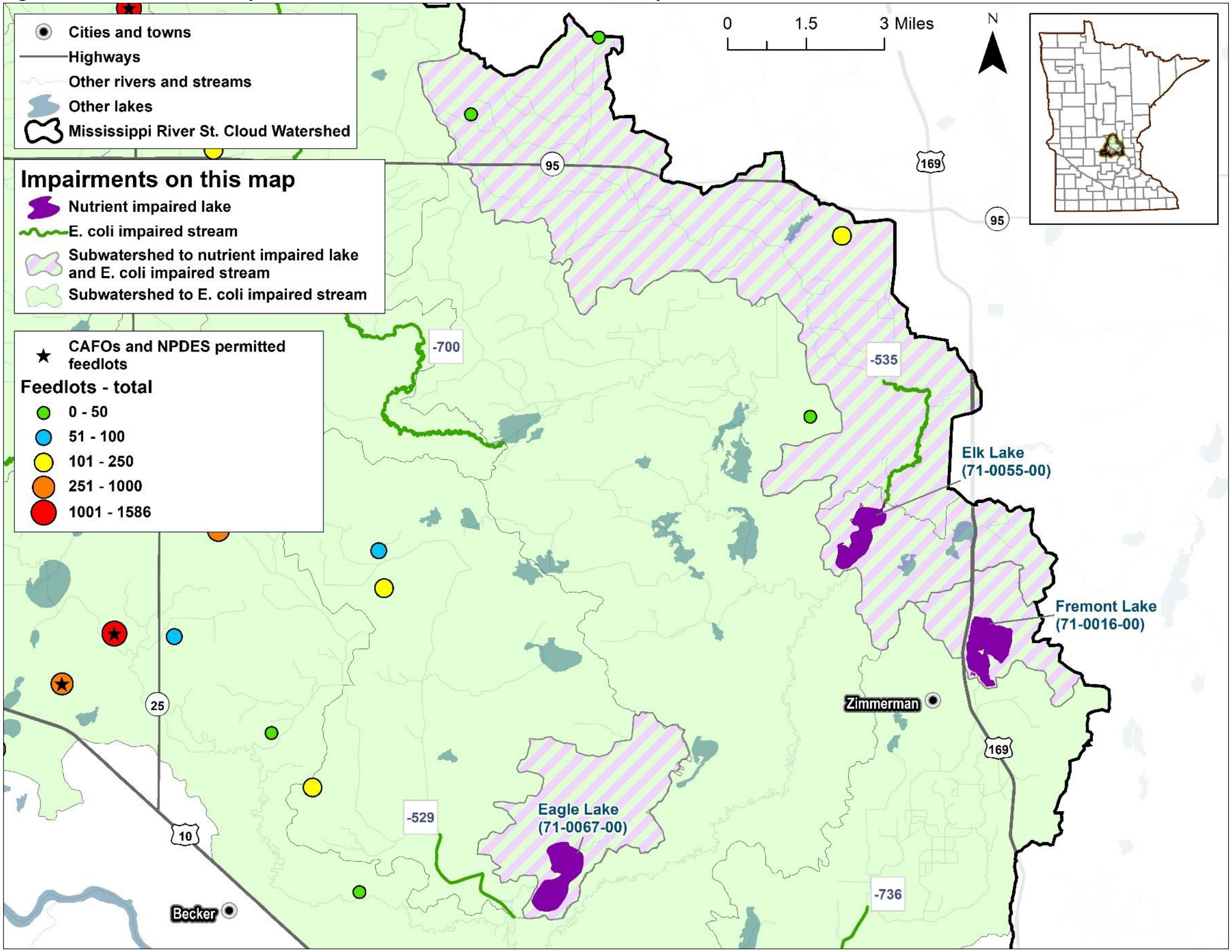
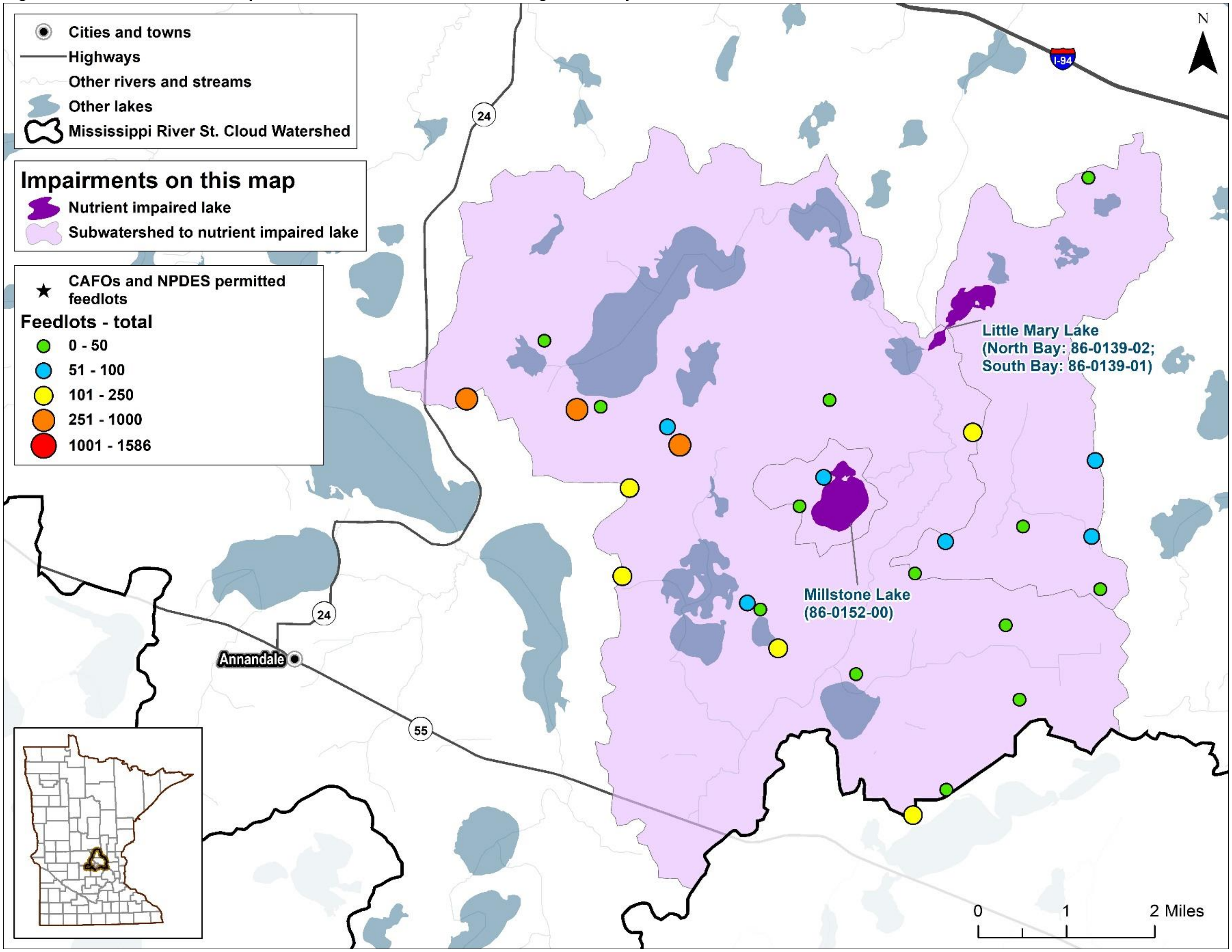


Figure 18. Feedlots in the impaired lake subwatersheds in Wright County.



Nonpermitted wastewater

Subsurface sewage treatment systems

Failing SSTSs can be a source of phosphorus. Refer back to the SSTS discussion in Section 3.6.1.2 for general information about SSTSs and SSTS failure.

Visual analysis of aerial imagery was used to identify residential properties within 1,000 feet of each impaired lake. No residential properties were identified within 1,000 feet of the three impaired lakes in Wright County. In Sherburne County, the following numbers of residential properties were identified: Eagle Lake, 245; Elk Lake, 285; and Fremont Lake[4], 227. Residential properties were assumed to be served by SSTS. Total loading is based on the number of conforming and failing SSTSs, an average of 2.32 people per household (Barr Engineering 2004), and an average value for phosphorus production per person per year (MPCA 2014).

Analysis of SSTS data for parcels adjacent to impaired waters in Sherburne County (provided by the Sherburne County Planning and Zoning Department) indicate that most inspections do not result in violations, and that many violations were due to a lack of inspection, where SSTS were found to be in compliance after the inspection occurred. Additionally, the Sherburne County Planning and Zoning Department (2019) reviewed 136 riparian lots along Eagle Lake with structures and identified the installation or upgrade dates of 121 SSTSs. Of the 136 riparian lots, 35 lots are non-homestead/seasonal properties. Forty-eight SSTSs (35%) were upgraded or inspected in 2009 to 2018.

Rates of compliance and of ITPHS for the six counties of the MRSCW are presented in Table 18 in Section 3.6.1.2. The lake subwatersheds are in Sherburne and Wright counties.

Areas and communities with SSTS concerns

Refer back to the areas and communities with SSTS concerns discussion in Section 3.6.1.2 for general information such areas and communities.

As of 2022, concerns with SSTSs were identified in three of the six lake phosphorus impaired subwatersheds, those in Sherburne County. The MPCA had not identified any areas or communities with SSTS concerns in the subwatershed draining to the three phosphorus-impaired lakes in Wright County.

Cropland

Cultivated crop operations can be a source of TP to impaired lakes because runoff and tile-flow from crop fields can rapidly transport nutrients to nearby streams and ditches that are tributary to impaired lakes. Nutrients captured by runoff and tile-flow can be derived from inorganic or organic fertilizer application, pesticide application (often nitrogen compounds), and soil erosion.

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[4] Sherburne SWCD estimated that between 65 and 75 residences (assumed to have SSTS) are within 1,000-feet of Fremont Lake (Dan Cibulka, Sherburne SWCD, Senior Water Resources Specialist, electronic communication, November 29, 2022).

A considerable portion of several of the subwatersheds draining to impaired lakes is composed of cultivated cropland (see Table 6 in Section 3.4)[5]. As simulated in BATHTUB models developed for impaired lakes, cropland is a considerable source of TP loading in several lakes (Table 24).

Table 24. Cultivated cropland areas and estimated TP loads for the six impaired lakes.
Note: Elk Lake and Little Mary (South Bay) Lake are excluded because upstream tributaries dominate the lake subwatersheds.

Lake	AUID	Cropland TP load (pound/year) [a]	Cropland TP load (%) [b]
Eagle Lake	71-0067-00	63	29%
Fremont Lake	71-0016-00	57	17%
Little Mary (North Bay)	86-0139-02	744	65%
Millstone Lake	86-0152-00	179	90%

a. Total phosphorus load (pounds/year) estimated by the HSPF model (Appendix B). Loads are rounded to the nearest integer.

b. Portion of the watershed TP loading to each lake that is from cropland. This calculation excludes internal load and other external loads (e.g., SSTS).

Pasture

Livestock grazing operations in pastures can be a source of TP to impaired lakes because runoff can transport the waste deposited by livestock on the pasture to nearby streams that are tributary to the impaired lakes. Additionally, streams flow through some pastures; in these areas' livestock can deposit waste directly into streams. Livestock access to streams can also result in erosion from hoof-shear. Shorn soil, which may contain soil-bound TP, can then be transported downstream to impaired lakes.

In Sherburne County, pasture/hay from the National Land Cover Database ranges from 12% to 26% in the subwatersheds of the three impaired lakes. Analysis of aerial imagery indicates that land use along the shores of Eagle, Elk, and Fremont lakes is predominantly residential or wetland; riparian pasture is not evident in the imagery. Pasture is evident in the subwatersheds draining to the lakes.

In Wright County, pasture/hay from the National Land Cover Database ranges from 4% to 11% in the subwatersheds of the three impaired lakes. Little Mary Lake (North and South bays) is in Lake Maria State Park; thus, there is no riparian pasture. The subwatershed draining to the North Bay has very little pasture. However, the larger subwatershed draining to South Bay does have pasture. Millstone Lake, which is in the subwatershed draining to the South Bay of Little Mary Lake, has a feedlot with pasture on its northwest shores.

Watershed Runoff

In addition to cropland and pastureland, many land covers and land uses can be sources of TP via runoff to streams and lakes. Generally, undisturbed or minimally impacted natural land covers (e.g., forest) are expected to contribute less TP loading than anthropogenic land uses (e.g., cropland, urban development).

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Developed land, forestland, grassland, and wetland were simulated in the HSPF model (Appendix B). As compared with the other lakes, these land uses and land covers contributed relatively larger TP loads in Eagle and Fremont lakes:

- *Eagle Lake*: Developed land, 9%; forest, 21%; grassland, 9%; and wetland, 7%.
- *Fremont Lake*: Developed land, 8%; forest, 9%; grassland, 8%; and wetland, 4%.

Shoreline erosion and watershed erosion (channel, streambank)

The shorelines along Sherburne County impaired lakes are typically wooded residential lots or wetlands; Fremont Lake also has shoreline roadways. Sherburne SWCD has conducted shoreline surveys at Eagle and Elk lakes. Around Eagle Lake, in 2019, Sherburne SWCD identified several shoreline properties with moderate or severe erosion. The northern and eastern shorelines of Fremont Lake, along a seasonal road, are experiencing varying levels of erosion. Attempts to revegetate steep banks were not successful due to winter ice[6].

The shorelines around Little Mary Lake (North and South bays) in Wright County are predominantly natural land covers (i.e., wetlands, woods), while Millstone Lake tends to have a thin line of lakeshore trees with adjacent agricultural fields. Visual analysis of aerial imagery did not identify any lakeshore areas with significant shoreline erosion.

The *Mississippi River–St. Cloud SID Report* (MPCA 2022c) evaluated geomorphology of specific stream channels and generally found channel and streambank erosion in waterways throughout the MRSCW. Except for Millstone Lake, with no perennial streams in its subwatershed, stream erosion could contribute sediment load, and thus particulate phosphorus, to each of the lake phosphorus impairments. Phosphorus loads from streambank erosion were not explicitly quantified.

Atmospheric Deposition

Atmospheric deposition of phosphorus to lakes is composed of wet deposition (via rain or snow) and dry deposition (via wind transport of particulates). Atmospheric deposition is controlled by local weather conditions, in addition to the original source of phosphorus (e.g., pollen, dust from mining).

The loading contributions of atmospheric deposition to the six lakes were quantified during BATHTUB modeling. The total atmospheric areal TP deposition rate was set to 0.268 kilograms per hectare per year (0.239 pounds per acre per year). The rate was applied to the surface area of each lake.

Internal Loading

Internal phosphorus loading from lake bottom sediments can be a substantial component of the phosphorus budget in lakes. The sediment phosphorus originates as an external phosphorus load that settles out of the water column to the lake bottom. Internal loading can be a result of low oxygen concentrations in the water overlying the lake sediment, curly-leaf pondweed decay, bottom-feeding fish, and wind energy in shallow depths.

[6] Dan Cibulka, Sherburne SWCD, Senior Water Resources Specialist, electronic communication, November 21, 2022.

Available information regarding these mechanisms by which phosphorus can be released back into the water column as internal loading is presented below:

- **Dissolved Oxygen**. Low oxygen concentrations (also called anoxia) in the water overlying the sediment can lead to phosphorus release. In shallow lakes such as Elk Lake, Fremont Lake, Little Mary–North Bay, Little Mary–South Bay, and Millstone Lake that undergo intermittent mixing of the water column throughout the growing season (i.e., polymixis), the released phosphorus can mix with surface waters throughout the summer and become available for algal growth. Bottom TP concentration data are not available for the Sherburne County Lakes.
  - **Eagle Lake** (2019–2022): Bottom DO concentrations were always less than top DO concentrations. At monitoring site 71-0067-00-204 in 2019 and 2020 (5 events each), from June through September, DO concentrations decreased considerably from the surface to the bottom but only occasionally dropped below 1 mg/L. Data collected by BELIA volunteers at monitoring sites 71-0067-00-203 and -204 in 2019 (19 events) and 2020 (11 events) were similar; however, DO concentrations from June through September at depths greater than 12 to 14 feet often dropped below 1 mg/L.
  - **Elk Lake** (2019): DO profile data indicate that DO concentrations from top to bottom decrease considerably during certain sample events in the summer (July 17, August 13, September 17), while concentrations decrease marginally during other sample events in the summer (June 12, July 29, and September 3).
  - **Fremont Lake** (2019–2020): Top and bottom DO concentrations in this very shallow lake collected by the Sherburne County Lake Assessment Program typically varied by 0.1 mg/L, with a few pairs of samples varying by 0.5 to 1.3 mg/L. DO profile data collected in the Clean Water Legacy Surface Water Monitoring program in 2019 indicated that DO concentrations were stable across depth in May through September.
  - **Little Mary Lake–North Bay** (2022): From late June through August, bottom DO concentrations were less than 1 mg/L. DO concentrations were stable across depth in late September and October. Top and bottom TP concentrations were similar in late May, early June, and August through October. Top concentrations were about 20 µg/L smaller than bottom concentrations in late June through July.
  - **Little Mary Lake–South Bay** (2022): Between June and August, bottom DO concentrations were less than 1 mg/L. DO was either stable or decreased a little (but not to less than 1 mg/L) in September and October. Top and bottom TP concentrations were similar in about half of samples, and top concentrations were considerably smaller than bottom concentrations in the other half of samples. No temporal pattern was evident.
  - **Millstone Lake** (2022): In late May, late June, and late August, bottom DO concentrations were less than 1 mg/L. DO concentrations were stable or decreased a little across depth in late across the rest of the samples. Top and bottom TP concentrations were similar, except in mid-July (difference of 18 µg/L) and early August (difference of 27 µg/L) when the top concentrations were less than the bottom concentrations.

- **Aquatic Vegetation**. Curly-leaf pondweed (*Potamogeton crispus*), which can reach nuisance levels in shallow lakes, decays in the early summer and releases phosphorus to the water column. A couple of watermilfoils are similar to curly-leaf pondweed. Surveys for the presence and dominance of curly-leaf pondweed or watermilfoils were conducted for five lakes.
    - **Eagle Lake**: WSB (2020) identified two reports that discussed aquatic vegetation. The *Big Eagle Lake Improvement Association Lake Management Plan–2008* indicated that Eurasian watermilfoil was present in 2009. A draft report from AIS Consulting indicated that curly-leaf pondweed was present in early spring in 2015 and 2018 and dominated other plant species in 2018. WSB (2020) found that a 2002 DNR aquatic vegetation survey was conducted but the results were not published.
    - **Fremont Lake**: Freshwater Scientific Services conducted a curly-leaf pondweed survey on May 31, 2023, that identified curly-leaf pondweed throughout the southern portion of Fremont Lake (Johnson 2023). DNR Ecological Services Division conducted an aquatic vegetation survey in 2002. DNR (2002, p. 4) concluded that "Fremont Lake has a rather diverse native aquatic plant community, considering the large population of curly leaf." Curly-leaf pondweed and Canada waterweed (*Elodea canadensis*) were the most frequently observed plants. The 2002 study also cited a DNR study from 1957 that identified abundant curly-leaf pondweed.
    - **Little Mary Lake–North Bay and South Bay**: The Wright SWCD conducted a curly-leaf pondweed survey on June 22, 2022. No curly-leaf pondweed was observed at 51 of 52 locations in the North Bay and 30 of 31 locations in the South Bay. Low abundance of curly leaf pondweed was observed at two locations. Northern watermilfoil (*Myriophyllum sibiricum*) was observed in high abundance in both bays, and the water was observed to be green.
    - **Millstone Lake**: The Wright SWCD conducted a curly-leaf pondweed survey on June 22, 2022. The following abundances of curly-leaf pondweed were observed at 69 locations: none (19%), low (29%), medium (23%), and high (29%). Higher abundances were observed in the middle of the lake and lower abundances were observed closer to the eastern shoreline. The water was observed to be green.
- **Fish**. Bottom-feeding fish such as carp and black bullhead forage in lake sediments. This physical disturbance can release phosphorus into the water column. Additionally, such fish species can up-root submergent and emergent vegetation that can contribute to higher algae levels in a lake.
    - Fisheries data available on the DNR's Lake Finder website indicate that common carp and black bullhead are present in Eagle Lake, Elk Lake, and Fremont Lake. Black bullhead, but not common carp, are present in Millstone Lake. Fisheries data are not available for the north and south bays of Little Mary Lake.
    - Sherburne SWCD has observed common carp in Fremont Lake and Elk Lake.

- An integrated pest management plan utilizing an adaptive management approach was developed for Eagle Lake (Havranek and Newman 2022). WSB estimated carp abundance to be 172 lb/acre in 2019 and 109 lb/acre in 2021. Using a target of 89 lb/acre, Havranek and Newman (2022) found an overabundance of carp in Eagle Lake. The plan includes installation of barriers and an outlet trap to reduce carp movement and reduce recruitment, and the plan proposes various methods of trapping to reduce adult carp population.
- Carp Solutions LLC (2024) conducted carp surveys on Fremont Lake and estimate a total population of 38,619 carp with a biomass density of 744.8 kilograms per hectare. Boat electrofishing surveys were conducted on August 14, August 23, and September 21, 2023. Carp Solutions LLC recommended an integrated pest management strategy that included monitoring spawning, installation of barriers, and box-netting.

- **Wind**. Wind energy in shallow depths can mix the water column and disturb bottom sediments, which leads to phosphorus release.
- Other sources of physical disturbance, such as motorized boating in shallow areas, can disturb bottom sediments and lead to phosphorus release.

The lake response models inherently include a recycled (i.e., internal) phosphorus load that is typical of lakes in the model development data set (see Section 4.3 and Appendix B.2 for the lake modeling approach). Because an average amount of recycled phosphorus is inherent in the lake models, the full recycled phosphorus load cannot be explicitly quantified. In some cases, recycled phosphorus loading to a lake is greater than the recycled phosphorus load that is inherent in the model. In these cases, an additional phosphorus load can be added to the lake phosphorus budget to calibrate the lake response model. This approach was used to estimate recycled phosphorus loads in Elk Lake, Millstone Lake, and Little Mary–North Bay. A portion of this load that was attributed to internal load could be from watershed or septic system loads that were not quantified with the available data.

An additional phosphorus load was not needed to calibrate the Eagle Lake or Fremont Lake models, and internal load was not quantified in these two lakes. However, because internal load is inherent in the BATHTUB model, the model assumes that an average amount of internal load is present, whether or not the load is explicitly quantified.

Although not explicitly quantified, internal loads from upstream lakes, ponds, and wetlands can also contribute phosphorus loads to the impaired lakes. There are several smaller lakes in the Elk Lake, Little Mary Lake–North Bay, and Little Mary–South Bay subwatersheds, including Diann Lake (upstream of Elk Lake) and Silver Lake (upstream of Little Mary–South Bay). Also, there are multiple smaller lakes in these subwatersheds; limited water quality data are available on most of these lakes.

3.6.3.3 Phosphorus source summary

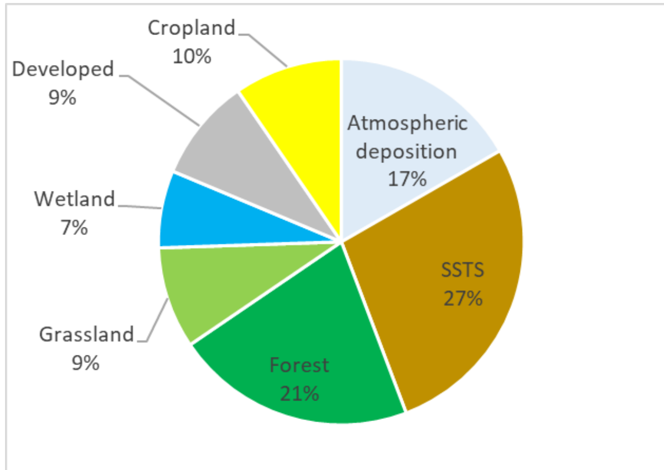
The sources of TP load to each impaired lake are summarized in the following subsections. Generally, SSTS and cropland contribute the largest external TP loads in direct drainage to the impaired lakes. TP loading to lakes with large subwatersheds is dominated by upstream tributary subwatersheds (e.g., Battle Brook for Elk Lake).

Eagle Lake

Eagle Lake, locally known as Big Eagle Lake, is in the headwaters of an unnamed ditch that is tributary to Tibbets Brook. The southwest portion of the Uncas Dunes State Nature Area, in the Sand Dunes State Forest, drains to Eagle Lake.

The TMDL BATHTUB model results indicate that SSTS (181 lb/yr, 27%), forest (140 lb/yr, 21%), and atmospheric deposition (110 lb/yr, 17%) are the largest sources of TP to Eagle Lake (Figure 19). The other significant watershed runoff sources, besides forest, are cropland (63 lb/yr, 10%), developed land (60 lb/yr, 9%), grassland (59 lb/yr, 9%), and wetland (45 lb/yr, 7%). The watershed runoff includes the MS4 for Big Lake Township (MS400234).

Figure 19. Sources of TP load to Eagle Lake.



In *Big Eagle Lake Water Quality Assessment and Load Source Assessment* ("Assessment Report," WSB (2020) also developed a BATHTUB lake model for Eagle Lake. The primary differences between the TMDL model and the Assessment Report model are the following:

- The TMDL model assumes an implicit amount of internal load, whereas the Assessment Report explicitly quantified 2019 internal loads, which consisted of load estimates due to anoxic sediment release and carp. Although the TMDL model does not quantify internal loading, internal loading to the lake impacts lake water quality, and the evaluation of internal load in the Assessment Report can be used to guide management actions.
- The TMDL model used the HSPF watershed model to estimate long term (2008 through 2015) average annual watershed loads to Eagle Lake, whereas the Assessment Report used the models P8 (Program for Predicting Polluting Particle Passage Thru Pits, Puddles, and Ponds) and FLUX to estimate 2019 loads to Eagle Lake. Because the time period over which loads were averaged differed between the two models, the watershed load estimates are not directly comparable.
- To estimate SSTS loads, MPCA used a visual analysis of aerial imagery and a 1,000-foot buffer to identify 245 residential properties that are assumed to have SSTS. The Assessment Report assumed 136 SSTS are adjacent to the lake. The TMDL report assumed a larger percent of parcels have year-round (vs. seasonal) residences. These differences in approach yielded larger loads from SSTS in the TMDL report.

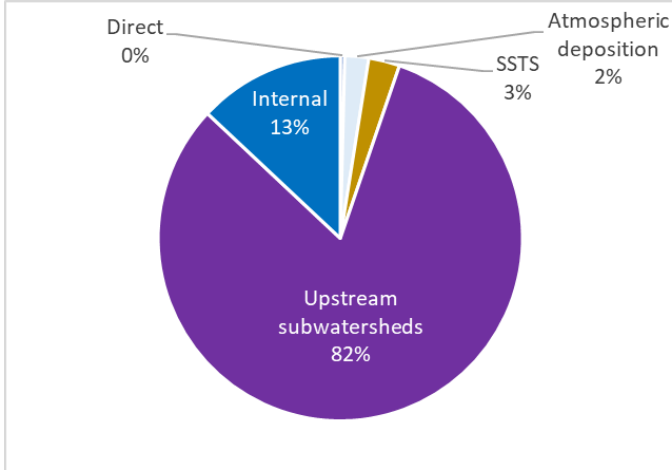
Elk Lake

Elk Lake is a flow-through lake along lower Battle Brook. The entire Battle Brook HUC-12 Subwatershed (HUC 07010203-04-05) drains through Elk Lake. Downstream of Elk Lake, Battle Brook flows a couple stream miles until its confluence with the St. Francis River.

Most of the subwatershed draining to Elk Lake flows through Battle Brook (-535). The subwatershed-to-lake area ratio for Elk Lake is 72:1.

Sherburne SWCD describes Diann Lake (71-0046-00) as a small seepage lake with low water levels[7]. Further investigation may be necessary to determine if appreciable flow drains from Diann Lake to Elk Lake.

Figure 20. Source of TP load to Elk Lake



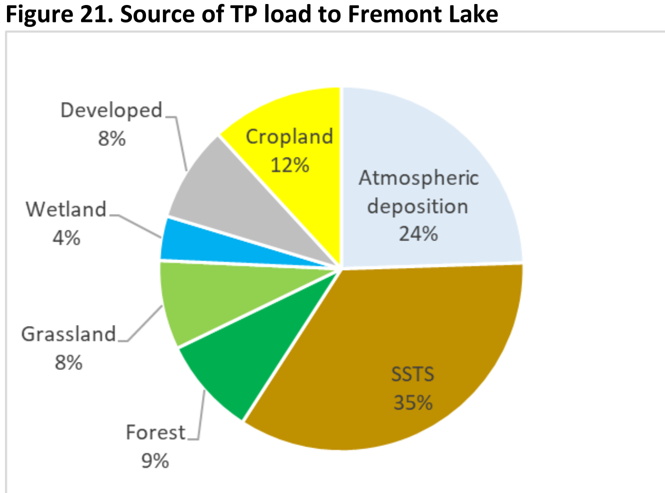
As expected, BATHTUB results indicate that upstream subwatersheds, which is primarily made up of the *E. coli* impaired Battle Creek subwatershed, are the dominant source of TP loading (3,321 lb/yr, 82%) to Elk Lake (Figure 20). TP loading from direct drainage (16 lb/yr, <1%) is negligible. Battle Brook, an upstream tributary, contributes the largest TP load (2,944 lb/yr, 72%). Other large TP sources include internal loading (529 lb/yr, 13%) and Diann Lake (377 lb/yr, 9%). SSTS (112 lb/yr, 3%) and atmospheric deposition (86 lb/yr, 2%) contribute relatively small TP loads.

While no regulated MS4s are currently in the direct drainage to Elk Lake, MPCA anticipates that Baldwin Township will become a regulated MS4 in the future. Its existing loads are represented as watershed runoff in the BATHTUB model and as “Direct” in Figure 20.

Fremont Lake

BATHTUB results indicate that SSTS (167 lb/yr 35%)[8], atmospheric deposition (118 lb/yr; 24%), and cropland (57 lb/yr; 12%) are the largest sources of TP to Fremont Lake (Figure 21). Developed land, forest, grassland, and wetlands contributions are nearly 30% of the annual TP load (individually, 19 to 42 lb/yr; 4% to 9%).

Figure 21. Source of TP load to Fremont Lake



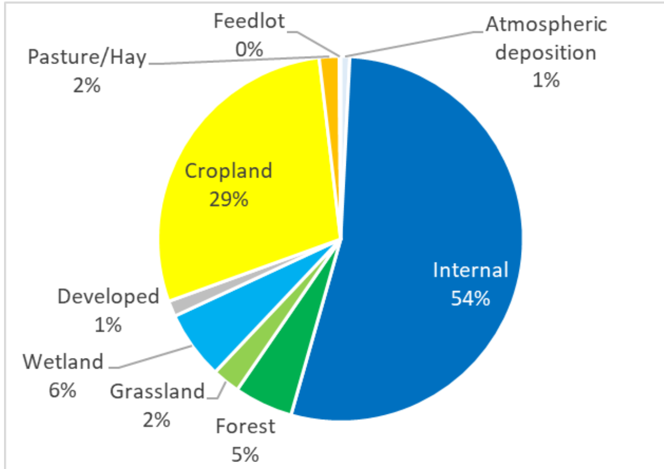
While no regulated MS4s are currently in the Fremont Lake Subwatershed, MPCA anticipates that Baldwin Township, Livonia Township, and Zimmerman City will

[7] Results from an analysis in 2021 by Sherburne SWCD question whether Diann Lake drains to Elk Lake (Dan Cibulka, Sherburne SWCD, Senior Water Resources Specialist, electronic communication, November 29, 2022).
[8] Sherburne SWCD estimated a smaller number of residences with SSTS near Fremont Lake than Tetra Tech estimated. The BATHTUB model likely overestimates TP loading from SSTS.

become regulated MS4s in the future. Their existing loads are represented as watershed runoff (e.g., developed land, forest land) in the BATHTUB model and Figure 21.

Little Mary Lake

Figure 22. Sources of TP load to North Bay.



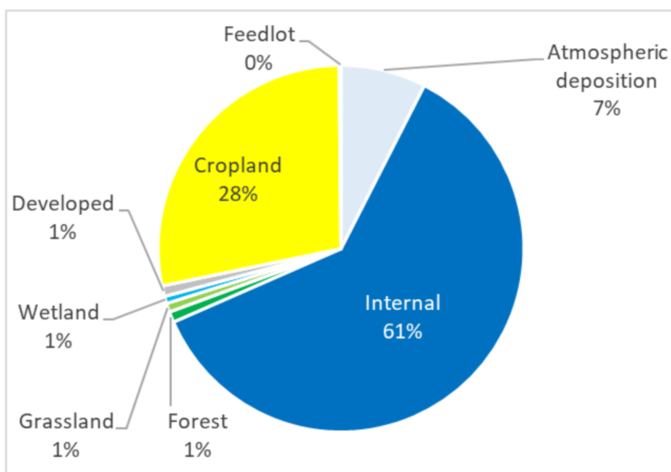
Little Mary Lake is composed of two bays: North Bay and South Bay. Much of the subwatershed draining to the North Bay is within the Lake Maria State Park. South Bay is a flow-through lake along Silver Creek. The subwatershed draining to South Bay is much larger than the subwatershed draining through North Bay. The subwatershed draining to South Bay includes several impaired lakes (e.g., Millstone Lake).

BATHTUB results indicate that internal loading (1,392 lb/season, 54%) and cropland (379 lb/season, 29%) are the largest sources of TP to North Bay (Figure 22). Atmospheric deposition, developed land, feedlots, forest, grassland, pasture/hay, and wetlands contributions are relatively small (2 to 80 lb/season; <1% to 6%).

The Silver Creek Subwatershed, upstream of South Bay, is the dominant source of TP loading to South Bay (4,212 lb/season, 99%). TP loading from direct drainage (19 lb/season, <1%) and atmospheric deposition (4 lb/season, <1%) is negligible.

Millstone Lake

Figure 23. Sources of TP load to Millstone Lake.



Millstone Lake is a small lake in Wright County, with a small direct drainage subwatershed that is dominated by agriculture.

BATHTUB results indicate that internal loading (388 lb/yr, 61%), cropland (179 lb/yr, 28%) and atmospheric deposition (48 lb/yr; 7%) are the largest sources of TP to Millstone Lake (Figure 23). Developed land, feedlots, forest, grassland, and wetlands contributions are relatively small (1 to 6 lb/yr; <1% to 1%).

4.0 TMDL development

A water body's TMDL represents the loading capacity, or the amount of pollutant that a water body can assimilate while still meeting water quality standards. The loading capacity is divided up and allocated to the water body's pollutant sources. The allocations include WLAs for NPDES-permitted sources, LAs for nonpermitted sources (including natural background), and an MOS, which is implicitly or explicitly defined. The sum of the allocations and MOS cannot exceed the loading capacity, or TMDL.

4.1 *E. coli*

4.1.1 Loading capacity methodology

Assimilative loading capacities for the streams were developed using LDCs. See Section 3.5 for a description of LDC development. Simulated daily average flow from 1995 through 2015 from HSPF modeling (Tetra Tech 2019) were used to develop the LDCs, which provide assimilative loading capacities. Both seasonal variation and critical conditions are accounted for in the stream TMDLs through the application of LDCs. For any given flow in the LDC, the loading capacity is determined by selecting the point on the LDC that corresponds to the flow exceedance (along the x-axis). Loads calculated from water quality monitoring data are also plotted on the LDCs, based on the concentration of the sample multiplied by the simulated flow on the day that the sample was taken. Each load calculated from a water quality sample that plots above the LDC represents a sample with a pollutant concentration higher than the water quality standard used to the develop the LDC, whereas those that plot below the LDC are less than the water quality standard used to develop the LDC. LDCs were developed for each impaired reach (Section 4.1.8).

The LDC method is based on an analysis that encompasses the cumulative frequency of historical flow data over a specified period. Because this method uses a long-term record of daily flow volumes, virtually the full spectrum of allowable loading capacities is represented by the resulting curve. In the TMDL equation tables of this report, only five points on the entire loading capacity curve are depicted (the midpoints of the designated flow zones). However, the entire curve represents the TMDL and is what the EPA ultimately approves.

4.1.2 Load allocation methodology

The LA is allocated to existing or future nonpermitted pollutant sources. For the *E. coli* stream TMDLs, the LA is the remainder of the loading capacity after the WLAs and MOS are allocated.

Natural background conditions were also evaluated, where possible, within the modeling and source assessment portion of this study (Section 3.6.1.2; e.g., contributions from wildlife, like beaver). For *E. coli*, natural background sources are implicitly included in the LA portion of the TMDL tables, and reductions should focus on the major human attributed sources identified in the source assessment.

4.1.3 Wasteload allocation methodology

The WLA is allocated to existing or future NPDES/SDS-permitted pollutant sources. *E. coli* WLAs are provided for municipal WWTPs and permitted MS4 communities. Since construction and industrial stormwater are not considered to be significant sources of pathogens, WLAs are not provided. Because

NPDES/SDS-permitted feedlots are required to completely contain runoff (except for basin overflows that are caused by extreme climatic events), they are not allowed to discharge *E. coli* to surface waters and WLAs are not provided; this is equivalent to a WLA of zero.

If a permittee that is assigned a WLA in this report has previously been assigned one or more WLAs for the same pollutant for another TMDL, the applicable permit(s) and/or associated planning documents will need to address the most restrictive WLA.

4.1.3.1 Municipal and industrial wastewater

The *E. coli* WLAs for municipal wastewater are based on the *E. coli* geometric mean standard of 126 organisms per 100 mL and the average wet weather design flow for continuous dischargers and the 6-inch per day draw down for the controlled discharges (Table 25). Two of the WWTPs that receive *E. coli* WLAs have controlled discharges: Foley WWTP and Gilman WWTP. There are no required changes to the permit.

All five of the facilities discharge to class 2 waters and are required to disinfect from April 1 through October 31, which is the same time period that the class 2 stream *E. coli* standard applies. It is assumed that if a facility meets the fecal coliform limit of 200 organisms per 100 mL it is also meeting the *E. coli* WLA.

The total daily loading capacity in the low or very low flow zones for some reaches is less than the calculated WWTF allowable load. This is an artifact of using design flows for allocation setting and results in these permitted sources appearing to use all (or more than) the available loading capacity. In reality, actual treatment facility flow can never exceed stream flow as it is a component of stream flow. To account for these unique situations, the WLAs and LAs in these flow zones where needed are expressed as an equation rather than an absolute number:

Allocation = flow contribution from a given source x 126 org *E. coli*/100 mL

This amounts to assigning a concentration-based limit to these sources for the lower flow zones. By definition rainfall, and thus runoff, is very limited if not absent during low flow. Thus, runoff sources would need little to no allocation for these flow zones. All wastewater WLAs are listed in the TMDL tables in Section 4.1.8 and in Table 25.

Table 25. Individual *E. coli* wastewater wasteload allocations.

Facility name	Permit number	Surface discharge station	Design flow [a] (mgd)	Impaired water body AUID (07010203)	Pollutant	Permit limit (#/100 mL fecal coliform)	Wasteload allocation (B #/day *E. coli*)	Existing permit consistent with WLA assumptions
Aspen Hills WWTF	MN0066028	001	0.02	-736 [b]	*E. coli*	200	0.095	Y
Becker WWTP–Municipal	MN0025666	001	2.15	-548	*E. coli*	200	10.254	Y
Foley WWTP – Birch Pond	MN0023451	001	0.815	-512 [b]	*E. coli*	200	3.885	Y
Foley WWTP – Golf Pond	MN0023451	002	2.038	-512 [b]	*E. coli*	200	9.720	Y
Gilman WWTP	MNG585021	002	0.391	-508 [b]	*E. coli*	200	1.865	Y
Zimmerman WWTP	MN0042331	002	0.452	-736 [b]	*E. coli*	200	2.156	Y

B #/day *E. coli* = billion counts of *E. coli* per day; mgd = million gallons per day; #/100 mL fecal coliform = counts of fecal coliform per 100 milliliters.

a. Flow used to calculate the WLA.

b. Each of these impaired streams is within the subwatershed draining to the impaired Elk River (-548).

4.1.3.2 Municipal separate storm sewer systems

Stormwater runoff regulated by the MS4 general permit must be included in the WLA portion of a TMDL. The EPA recommends that WLAs be broken down as much as possible in the TMDL, as information allows. This facilitates implementation planning and load reduction goals for the MS4 entities. See the pollutant source summary in Section 3.6 for more information on permitted MS4s.

The WLA area for each MS4, except for road MS4s, was approximated using the jurisdictional boundary within the impairment subwatershed of the township, city, correctional facility, or university. Permitted areas for the road MS4s (see next paragraph) were excluded from the areas for the townships, cities, and nontraditional MS4s.

Legislation passed in 2019, and subsequently amended in 2021, changed the regulated area for certain MS4s, including Minden, Sauk Rapids, and Watab townships. In order to accommodate future changes to regulated area per this legislation, WLAs were developed for all of the municipalities in the study area using entire jurisdictional areas within impaired subwatersheds, instead of only currently regulated areas.

MS4 regulation for permitted road authorities apply to roads within the 2010 Urban Area, determined by the U.S. Census Bureau. The WLA areas for counties' and MNDOT road MS4s were approximated using MNDOT road centerlines and aerial imagery with rights-of-way estimated using aerial imagery. The average rights-of-way widths were applied as buffers to the centerlines. The buffers were clipped to the appropriate jurisdiction and the 2010 Census Urbanized Area.

WLA areas for each MS4 are shown in Table 26 and Figure 16.

The estimated area of each current or future permitted MS4 within the subwatershed draining to an impairment was divided by the total area of the subwatershed to represent the percent coverage of each MS4 within the subwatershed draining to an impairment. The WLAs for MS4s were calculated as the percent coverage of each MS4 multiplied by the loading capacity minus the MOS.

Table 26. Permitted MS4s and estimated regulated areas for *E. coli* TMDLs.

MS4 name and permit number	Estimated MS4 area (ac)	Impaired water body	Impaired water body AUID
Baldwin Township *	5,491.7	Battle Brook	535
	9,480.8	Elk River	548
	320.6	Tibbets Brook	736
Becker Township *	28,176.0	Elk River	548
	13,707.8	Snake River	529
Benton County (MS400067)	46.5	Elk River	507
	46.5	Elk River	548
	7.4	Mayhew Creek	750
Big Lake City (MS400249)	3,559.3	Elk River	548
Big Lake Township (MS400234)	17,462.3	Elk River	548
	514.4	Snake River	529
	4,464.7	Tibbets Brook	736
Elk River City (MS400089)	5,510.4	Elk River	548

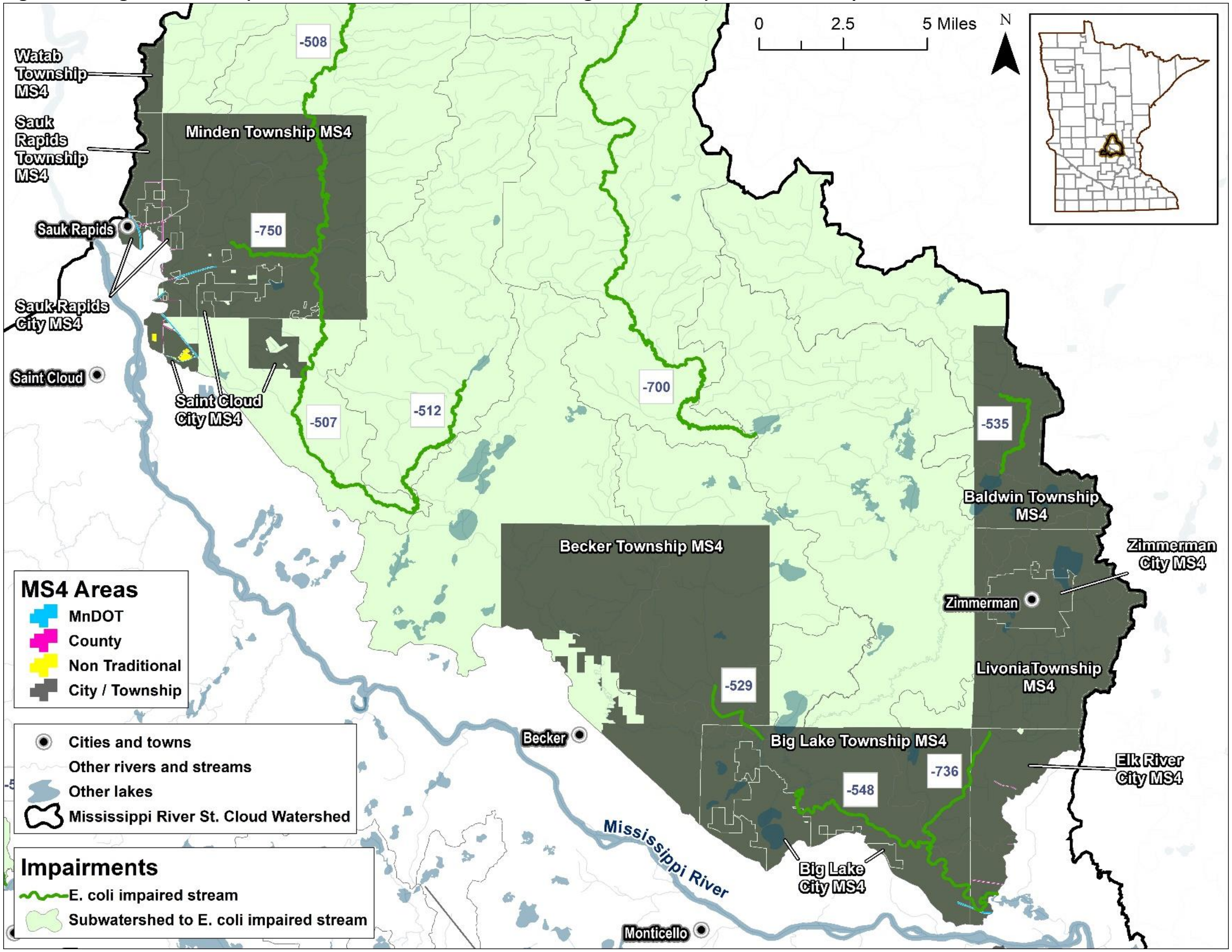
MS4 name and permit number	Estimated MS4 area (ac)	Impaired water body	Impaired water body AUID
	4,177.3	Tibbets Brook	736
Livonia Township *	13,195.1	Elk River	548
	11,555.2	Tibbets Brook	736
Minden Township (MS400147)	21,398.8	Elk River	507
	7,949.0	Elk River	508
	21,587.8	Elk River	548
	7,091.6	Mayhew Creek	750
	189.0	Rice Creek	512
Minnesota Correctional–St. Cloud (MS400179)	49.1	Elk River	507
	49.1	Elk River	548
MNDOT Outstate District (MS400180)	102.9	Elk River	507
	127.7	Elk River	548
	5.5	Mayhew Creek	750
Sauk Rapids City (MS400118)	1,331.2	Elk River	507
	1,331.2	Elk River	548
	525.3	Mayhew Creek	750
Sauk Rapids Township (MS400153)	1,676.1	Elk River	507
	1,676.1	Elk River	548
	1,409.6	Mayhew Creek	750
Sherburne County (MS400155)	12.4	Elk River	507
	26.9	Elk River	548
	4.4	Tibbets Brook	736
St. Cloud City (MS400052)**	3,502.7	Elk River	507
	3,502.7	Elk River	548
	4.1	Mayhew Creek	750
St. Cloud State University (MS400197)	16.6	Elk River	507
	16.6	Elk River	548
Watab Township (MS400161)	910.1	Elk River	507
	910.1	Elk River	548
	910.1	Mayhew Creek	750
Zimmerman City *	2,445.8	Tibbets Brook	736
	2,506.3	Elk River	548

ac = acres; AUID = assessment unit identifier.

*These communities are not currently regulated but are expected to come under MS4 permit coverage in the near future.

**The city of St. Cloud submitted updated drainage information during the public notice period indicating a small portion of the -507 and -548 watersheds within St. Cloud's jurisdiction discharges to the Mississippi River. The table above does not reflect that submission.

Figure 24. Regulated MS4s (and communities that will become regulated MS4s) in the *E. coli* impairment subwatersheds.



4.1.3.3 Construction stormwater

WLAs for regulated construction stormwater (MNR100001) are not developed in Minnesota because *E. coli* is not a typical pollutant from construction sites.

4.1.3.4 Industrial stormwater

Industrial stormwater receives a WLA only if the pollutant is part of benchmark monitoring for an industrial site in the watershed of an impaired water body. There are no fecal bacteria or *E. coli* benchmarks associated with the industrial stormwater general permit (MNR050000) or nonmetallic mining operations general permit (MNG490000), and therefore industrial stormwater *E. coli* WLAs were not assigned.

4.1.3.5 NPDES/SDS permitted animal feeding operations

WLAs are not assigned to CAFOs, including CAFOs with NPDES or SDS permits, and CAFOs not requiring permits; this is equivalent to a WLA of zero. Although the NPDES and SDS permits allow discharge of manure and manure contaminated runoff due to a precipitation event greater than or equal to a 25-year, 24-hour precipitation event, the permits prohibit discharges that cause or contribute to nonattainment of water quality standards.

All other non-CAFO feedlots and the land application of all manure are accounted for in the LA for nonpermitted sources.

4.1.4 Margin of safety

The MOS accounts for uncertainty concerning the relationship between water quality and allocated loads. The MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e., expressed in the TMDL as a load set aside).

An explicit MOS of 10% was included in the TMDLs to account for uncertainty that the pollutant allocations would attain the water quality targets. The use of an explicit MOS accounts for environmental variability in pollutant loading, variability in water quality monitoring data, calibration and validation processes of modeling efforts, uncertainty in modeling outputs, conservative assumptions made during the modeling efforts, and limitations associated with the drainage area-ratio method used to extrapolate flow data. The MRSC HSPF model was calibrated and validated using seven stream flow gaging stations (Tetra Tech 2019). One gage is on the main stem Mississippi River near St. Cloud, and the remaining sites gage tributary stream flows. Calibration results indicate that the HSPF model is a valid representation of hydrologic and water quality conditions in the watershed. Flow data used to develop the stream TMDLs are derived from HSPF-simulated daily flow data. Flow model performance on tributaries to the Mississippi River was fair due to extensive surface-to-groundwater interactions in the Anoka Sand Plain (Tetra Tech 2019). Agricultural irrigation wells in the Mississippi River alluvium were excluded from the recalibrated model because they could not be accurately represented in the model; these wells further complicate surface-to-groundwater interactions and the water balance. The explicit MOS addresses uncertainty with development of the flow duration curve from HSPF modeling.

4.1.5 Seasonal variation and critical conditions

The application of LDCs in the *E. coli* TMDLs addresses seasonal variation and critical conditions. LDCs evaluate pollutant loading across all flow regimes including high flow, which is when pollutant loading from watershed runoff is typically the greatest, and low flow, which is when loading from direct sources to the stream typically has the most impact. Because flow varies seasonally, LDCs address seasonality through their application across all flow conditions in the impaired water body.

Seasonal variation and critical conditions are also addressed by the water quality standards. *E. coli* standards for aquatic recreation apply from April through October. This time period is when aquatic recreation is more likely to occur in Minnesota waters and when high *E. coli* concentrations generally occur.

4.1.6 Baseline year

The monitoring data used to calculate the percent reductions are from 2012 through 2021; except for Unnamed creek (-565; Fairhaven Creek) that is 2013 through 2022. Because projects undertaken recently may take a few years to influence water quality, the baseline year for crediting load reductions for a given water body is 2016, the midpoint of the time period; for Unnamed creek (-565; Fairhaven Creek) the baseline year is 2017. Any activities implemented during or after the baseline year that led to a reduction in pollutant loads to the water bodies may be considered as progress towards meeting a WLA or LA. If a BMP was implemented during or just prior to the baseline year, the MPCA may consider evidence presented by the MS4 permit holder to demonstrate that the BMP should be considered as progress towards meeting a WLA. BMPs present on the landscape during the model simulation time period are implicitly accounted for in the model.

4.1.7 Percent reduction

The estimated percent reductions provide a rough approximation of the overall reduction needed for the water body to meet the TMDL. The percent reduction is a means to capture the level of effort needed to reduce *E. coli* concentrations in the watershed. The percent reductions should not be construed to mean that each of the separate sources listed in the TMDL table needs to be reduced by that amount.

The estimated percent reduction needed to meet each TMDL was calculated by comparing the highest observed (monitored) monthly geometric mean from the months that the standard applies to the geometric mean standard (monitored – standard/monitored). Monthly geometric means were used to estimate percent reduction only if they are based on five or more samples.

4.1.8 TMDL summary

This section provides the water quality summary tables, LDCs, and TMDLs for streams impaired for their aquatic recreation use. See Section 3.5.1 for an explanation of the data analyses.

E. coli load reductions are needed to address multiple source types (see Section 3.6.1: Stream *E. coli* source summary).

The impairments are listed ordered from upstream to downstream. The maximum recordable value for *E. coli* concentration depends on the extent of sample dilution and is often 2,420 org/100 mL.

Concentrations that are noted as 2,420 org/100 mL are likely higher, and the magnitude of the exceedances is not known.

Loads in the *E. coli* TMDL tables are rounded to two significant digits, except in the case of values greater than 100, which are rounded to the nearest whole number. Percent reductions are rounded to the nearest whole number.

4.1.8.1 Elk River (AUID 07010203-507)

Table 27. Annual summary of *E. coli* data at the Elk River (AUID 07010203-507; June–August).

Month	Sample count	Geometric mean (org/100 mL)	Minimum (org/100 mL)	Maximum (org/100 mL)	No. of individual sample exceedances	Percent of individual sample exceedances
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	0	–	–	–	–	–
2015	0	–	–	–	–	–
2016	0	–	–	–	–	–
2017	0	–	–	–	–	–
2018	0	–	–	–	–	–
2019	9	168	52	529	0	0%
2020	6	215	79	1,274	1	17%
2021	0	–	–	–	–	–

Table 28. Monthly summary of *E. coli* data at the Elk River (AUID 07010203-507; 2019–2020).
Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded, or the individual standard of 1,260 org/100 mL was exceeded in greater than 10% of the samples. Standard applies only to months April–October.

Month	Sample count	Geometric mean (org/100 mL)	Minimum (org/100 mL)	Maximum (org/100 mL)	No. of individual sample exceedances	Percent of individual sample exceedances
April	0	–	–	–	–	–
May	0	–	–	–	–	–
June	5	170	79	461	0	0%
July	5	171	52	529	0	0%
August	5	519	97	1,274	1	20%
September	0	–	–	–	–	–
October	0	–	–	–	–	–

Figure 25. *E. coli* load duration curve, Elk River (AUID 07010203-507).

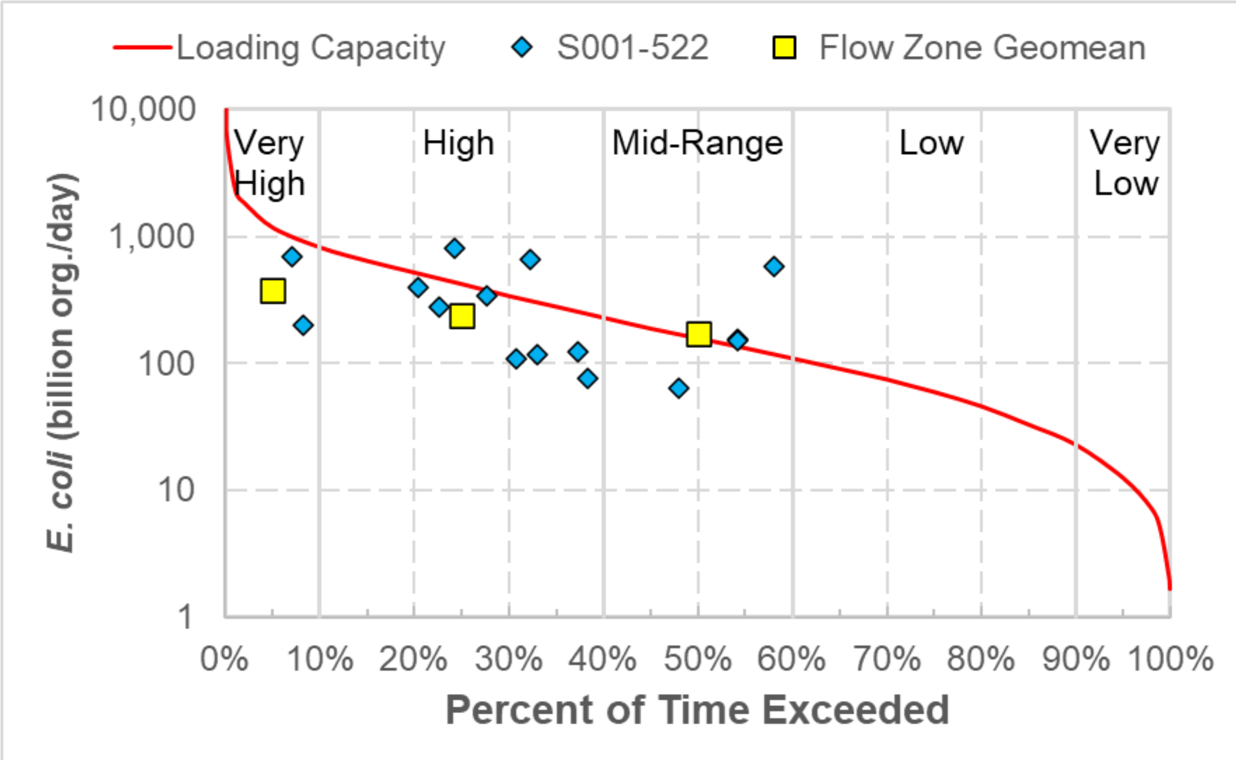


Table 29. *E. coli* TMDL summary, Elk River (AUID 07010203-507).

- 303(d) listing year or proposed year: 2012
- Baseline year: 2016
- Use class: 2Bg
- Numeric standard used to calculate TMDL: 126 organisms per 100 milliliters
- Standard applicable: April–October

TMDL Parameter		Flow Zones				
		Very high	**High**	**Mid-range**	**Low**	**Very low**
Sources		***E. coli* load (billion organisms per day)**				
Wasteload	Gilman WWTP (MNG585021)	1.9	1.9	1.9	1.9	1.9
	Saint Cloud City MS4 (MS400052)	34	12	4.5	1.7	0.31
	Benton County MS4 (MS400067)	0.45	0.16	0.060	0.022	0.0042
	Sauk Rapids City MS4 (MS400118)	13	4.6	1.7	0.63	0.12
	Minden Township MS4 (MS400147)	206	74	27	10	1.9
	Sauk Rapids Township MS4 (MS400153)	16	5.8	2.2	0.79	0.15
	Sherburne County MS4 (MS400155)	0.12	0.043	0.016	0.0059	0.0011
	Watab Township MS4 (MS400161)	8.8	3.1	1.2	0.43	0.081
	Minnesota Correctional–St. Cloud MS4 (MS400179)	0.47	0.17	0.063	0.023	0.0044
	MNDOT Outstate District MS4 (MS400180)	1.0	0.36	0.13	0.049	0.0092
	St. Cloud University MS4 (MS400197)	0.16	0.057	0.021	0.0078	0.0015
	Total WLA	**282**	**102**	**39**	**16**	**4.5**
Load	**Total LA**	**778**	**280**	**104**	**38**	**7.2**
MOS		**118**	**43**	**16**	**6.0**	**1.3**
Total load		**1,178**	**425**	**159**	**60**	**13**
Maximum monthly geomean (org/100 mL)		**219**				
Overall estimated percent reduction		**42%**				

4.1.8.2 Elk River (AUID 07010203-508)

Table 30. Annual summary of *E. coli* data at the Elk River (AUID 07010203-508; June–August).

Month	Sample count	Geometric mean (org/100 mL)	Minimum (org/100 mL)	Maximum (org/100 mL)	No. of individual sample exceedances	Percent of individual sample exceedances
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	0	–	–	–	–	–
2015	0	–	–	–	–	–
2016	0	–	–	–	–	–
2017	0	–	–	–	–	–
2018	0	–	–	–	–	–
2019	9	777	63	17,329	3	33%
2020	5	95	20	336	0	0%
2021	0	–	–	–	–	–

Table 31. Monthly summary of *E. coli* data at the Elk River (AUID 07010203-508; 2019–2020).
Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded, or the individual standard of 1,260 org/100 mL was exceeded in greater than 10% of the samples. Standard applies only to months April–October.

Month	Sample count	Geometric mean (org/100 mL)	Minimum (org/100 mL)	Maximum (org/100 mL)	No. of individual sample exceedances	Percent of individual sample exceedances
April	0	–	–	–	–	–
May	0	–	–	–	–	–
June	5	232	20	6,488	1	20%
July	6	397	63	8,984	1	17%
August	3	671	109	17,329	1	33%
September	0	–	–	–	–	–
October	0	–	–	–	–	–

Figure 26. ***E. coli*** **load duration curve, Elk River (AUID 07010203-508).**

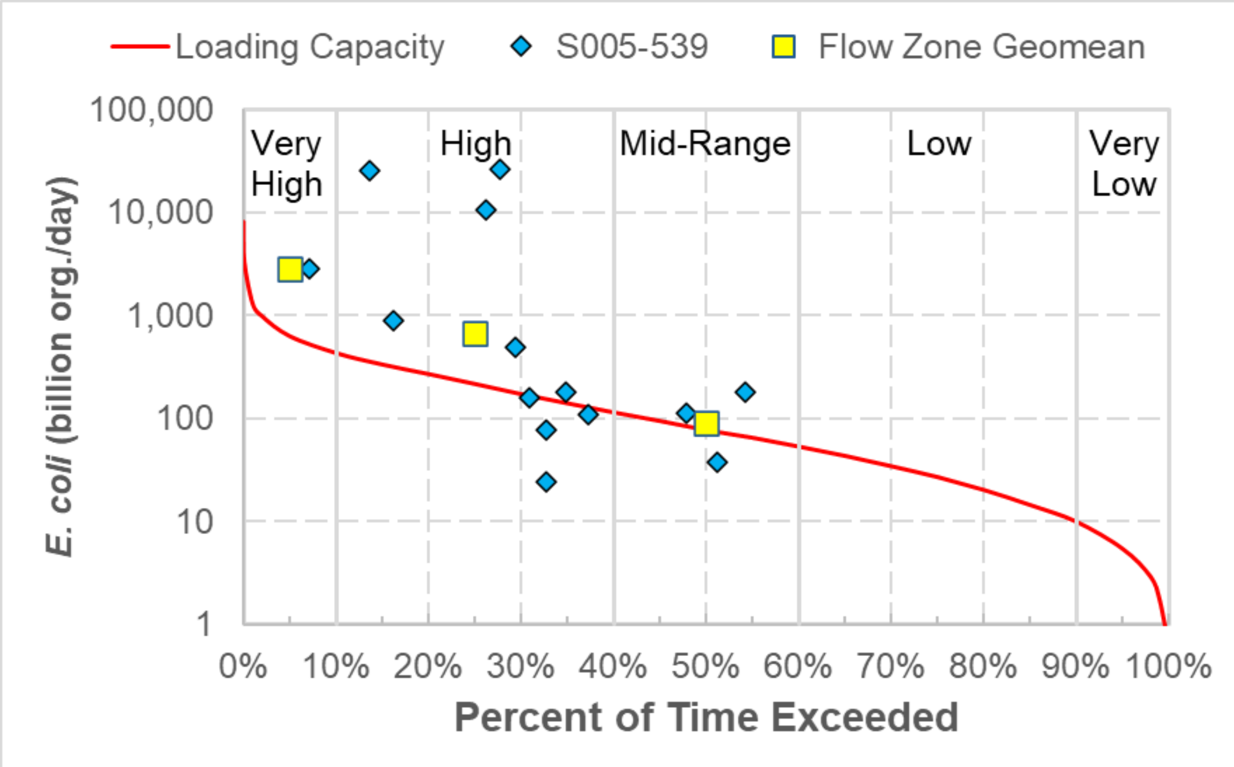


Table 32. ***E. coli*** **TMDL summary, Elk River (AUID 07010203-508).**

- 303(d) listing year or proposed year: 2012
- Baseline year: 2016
- Use class: 2Bg
- Numeric standard used to calculate TMDL: 126 organisms per 100 milliliters
- Standard applicable: April–October

TMDL Parameter		**Flow Zones**				
		Very high	**High**	**Mid-range**	**Low**	**Very low**
Sources		***E. coli*** **load (billion organisms per day)**				
Wasteload	Gilman WWTP (MNG585021)	1.9	1.9	1.9	1.9	1.9
	Minden Township MS4 (MS400147)	83	29	10.0	3.3	0.45
	Total WLA	**85**	**31**	**12**	**5.2**	**2.4**
Load	**Total LA**	**477**	**163**	**57**	**19**	**2.5**
	MOS	**63**	**22**	**8**	**2.7**	**0.55**
	Total load	**625**	**216**	**77**	**27**	**5.4**
Maximum monthly geomean (org/100 mL)		**671**				
Overall estimated percent reduction		**81%**				

4.1.8.3 Mayhew Creek (AUID 07010203-750)

Table 33. Annual summary of *E. coli* data at Mayhew Creek (AUID 07010203-750; June–August).

Month	Sample count	Geometric mean (org/100 mL)	Minimum (org/100 mL)	Maximum (org/100 mL)	No. of individual sample exceedances	Percent of individual sample exceedances
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	0	–	–	–	–	–
2015	0	–	–	–	–	–
2016	0	–	–	–	–	–
2017	0	–	–	–	–	–
2018	0	–	–	–	–	–
2019	9	1,764	173	24,196	5	55%
2020	6	578	144	2,187	1	17%
2021	0	–	–	–	–	–

Table 34. Monthly summary of *E. coli* data at Mayhew Creek (AUID 07010203-750; 2019–2020).
Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded, or the individual standard of 1,260 org/100 mL was exceeded in greater than 10% of the samples. Standard applies only to months April–October.

Month	Sample count	Geometric mean (org/100 mL)	Minimum (org/100 mL)	Maximum (org/100 mL)	No. of individual sample exceedances	Percent of individual sample exceedances
April	0	–	–	–	–	–
May	0	–	–	–	–	–
June	5	756	144	24,196	1	20%
July	5	1,345	285	8,664	2	40%
August	5	1,416	581	3,076	3	60%
September	0	–	–	–	–	–
October	0	–	–	–	–	–

Figure 27. *E. coli* load duration curve, Mayhew Creek (AUID 07010203-750).

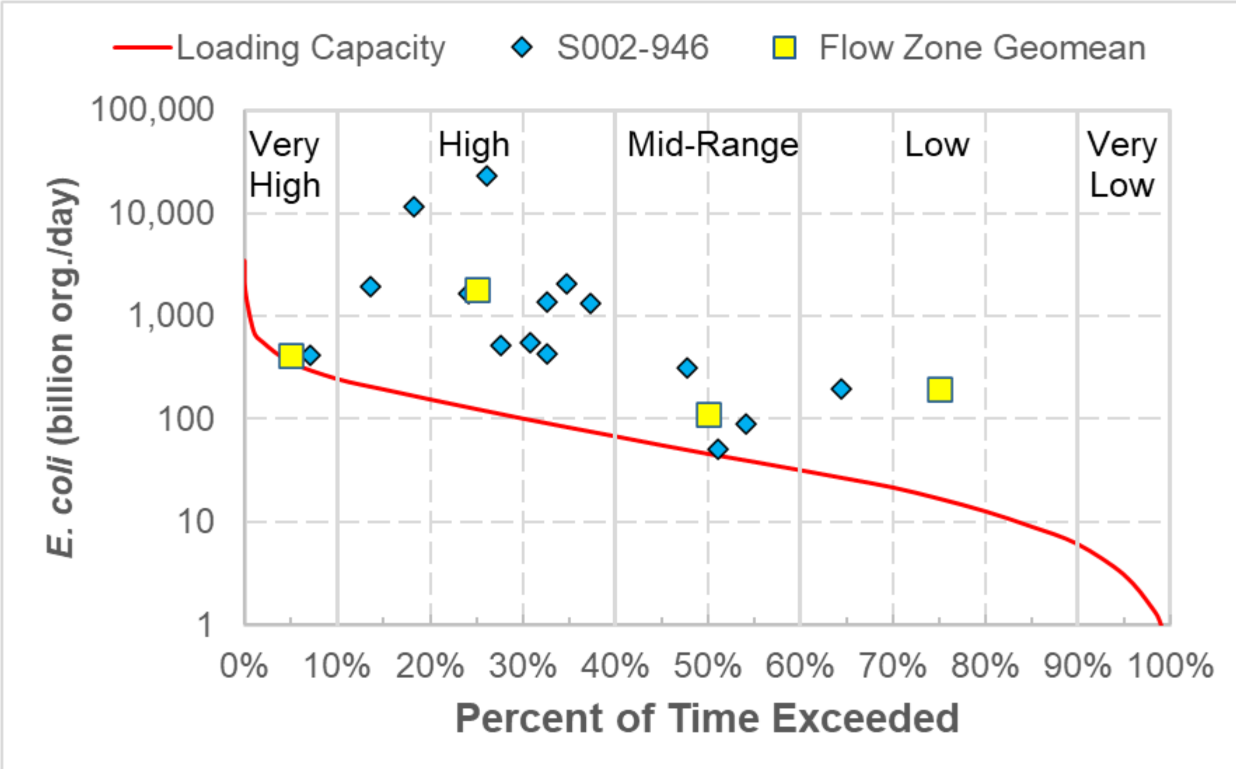


Table 35. *E. coli* TMDL summary, Mayhew Creek (AUID 07010203-750).

- 303(d) listing year or proposed year: 2012
- Baseline year: 2016
- Use class: 2Bg
- Numeric standard used to calculate TMDL: 126 organisms per 100 milliliters
- Standard applicable: April–October

TMDL Parameter		Flow Zones				
		Very high	**High**	**Mid-range**	**Low**	**Very low**
Sources		***E. coli* load (billion organisms per day)**				
Wasteload	Saint Cloud City MS4 (MS400052)	0.039	0.014	0.0051	0.0019	0.00034
	Benton County MS4 (MS400067)	0.072	0.025	0.0093	0.0034	0.00063
	Sauk Rapids City MS4 (MS400118)	5.1	1.8	0.66	0.24	0.045
	Minden Township MS4 (MS400147)	69	24	8.9	3.3	0.60
	Sauk Rapids Township MS4 (MS400153)	14	4.8	1.8	0.66	0.12
	Watab Township MS4 (MS400161)	8.8	3.1	1.1	0.42	0.077
	MNDOT Outstate District MS4 (MS400180)	0.054	0.019	0.0069	0.0026	0.00047
	Total WLA	**97**	**34**	**12**	**4.6**	**0.84**
Load	**Total LA**	**222**	**78**	**29**	**11**	**1.9**
MOS		**36**	**13**	**4.6**	**1.7**	**0.31**
Total load		**355**	**125**	**46**	**17**	**3.1**
Maximum monthly geomean (org/100 mL)		**1,416**				
Overall estimated percent reduction		**91%**				

4.1.8.4 Rice Creek (AUID 07010203-512)

Table 36. Annual summary of *E. coli* data at Rice Creek (AUID 07010203-512; June–September).

Month	Sample count	Geometric mean (org/100 mL)	Minimum (org/100 mL)	Maximum (org/100 mL)	No. of individual sample exceedances	Percent of individual sample exceedances
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	0	–	–	–	–	–
2015	0	–	–	–	–	–
2016	0	–	–	–	–	–
2017	0	–	–	–	–	–
2018	0	–	–	–	–	–
2019	9	133	31	323	0	0%
2020	7	353	132	1,317	1	14%
2021	0	–	–	–	–	–

Table 37. Monthly summary of *E. coli* data at Rice Creek (AUID 07010203-512; 2019–2020).
Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded, or the individual standard of 1,260 org/100 mL was exceeded in greater than 10% of the samples. Standard applies only to months April–October.

Month	Sample count	Geometric mean (org/100 mL)	Minimum (org/100 mL)	Maximum (org/100 mL)	No. of individual sample exceedances	Percent of individual sample exceedances
April	0	–	–	–	–	–
May	0	–	–	–	–	–
June	5	182	75	301	0	0%
July	5	174	31	554	0	0%
August	5	251	110	1,317	1	20%
September	1	288 [a]	288	288	0	0%
October	0	–	–	–	–	–

a. Not enough samples to assess compliance with the monthly geometric mean standard.

Figure 28. *E. coli* load duration curve, Rice Creek (AUID 07010203-512).

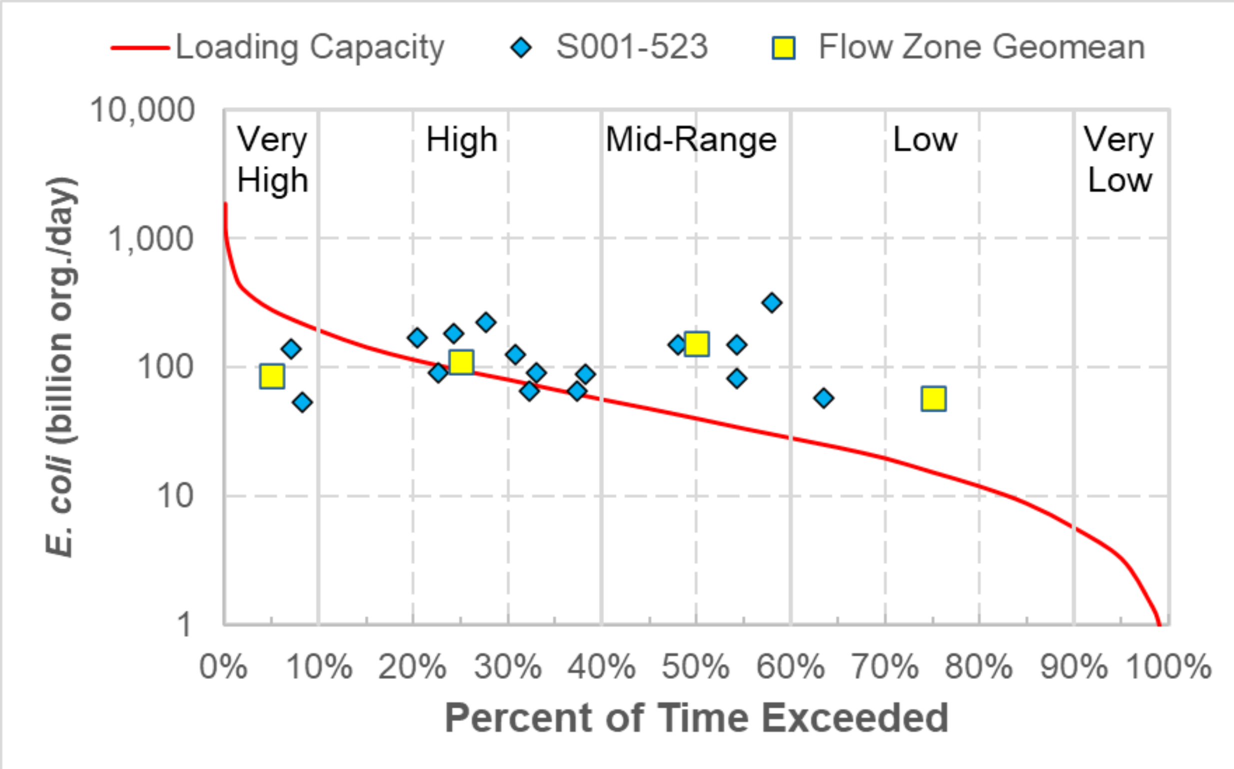


Table 38. *E. coli* TMDL summary, Rice Creek (AUID 07010203-512).

- 303(d) listing year or proposed year: 2012
- Baseline year: 2016
- Use class: 2Bg
- Numeric standard used to calculate TMDL: 126 organisms per 100 milliliters
- Standard applicable: April-October

TMDL Parameter		Flow Zones				
		Very high	**High**	**Mid-range**	**Low**	**Very low**
Sources		***E. coli* load (billion organisms per day)**				
Wasteload	Foley WWTP (MN0023451)	14	14	14	– [a]	– [a]
	Minden Township MS4 (MS400147)	1.5	0.46	0.14	– [a]	– [a]
	Total WLA	**16**	**14**	**14**	**– [a]**	**– [a]**
Load	**Total LA**	**233**	**71**	**22**	**– [a]**	**– [a]**
MOS		**28**	**9.4**	**4.0**	**1.5**	**0.32**
Total load		**277**	**95**	**40**	**15**	**3.2**
Maximum monthly geomean (org/100 mL)		**288**				
Overall estimated percent reduction		**56%**				

a. The permitted wastewater design flows exceed the stream flow in the indicated flow zones. The allocations are expressed as an equation rather than an absolute number: allocation = (flow contribution from a given source) x (126 org. per 100 mL) x conversion factors. See Section 4.1.3 for more detail.

4.1.8.5 Snake River (AUID 07010203-529)

Table 39. Annual summary of *E. coli* data at the Snake River (AUID 07010203-529; June–August).

Month	Sample count	Geometric mean (org/100 mL)	Minimum (org/100 mL)	Maximum (org/100 mL)	No. of individual sample exceedances	Percent of individual sample exceedances
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	0	–	–	–	–	–
2015	0	–	–	–	–	–
2016	0	–	–	–	–	–
2017	0	–	–	–	–	–
2018	0	–	–	–	–	–
2019	9	216	75	488	0	0%
2020	7	556	146	2,987	2	28%
2021	0	–	–	–	–	–

Table 40. Monthly summary of *E. coli* data at the Snake River (AUID 07010203-529; 2019–2020).
Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded, or the individual standard of 1,260 org/100 mL was exceeded in greater than 10% of the samples. Standard applies only to months April–October.

Month	Sample count	Geometric mean (org/100 mL)	Minimum (org/100 mL)	Maximum (org/100 mL)	No. of individual sample exceedances	Percent of individual sample exceedances
April	0	–	–	–	–	–
May	0	–	–	–	–	–
June	5	257	75	624	0	0%
July	5	302	134	1,725	1	20%
August	5	454	146	2,987	1	20%
September	0	–	–	–	–	–
October	0	–	–	–	–	–

Figure 29. *E. coli* load duration curve, Snake River (AUID 07010203-529).

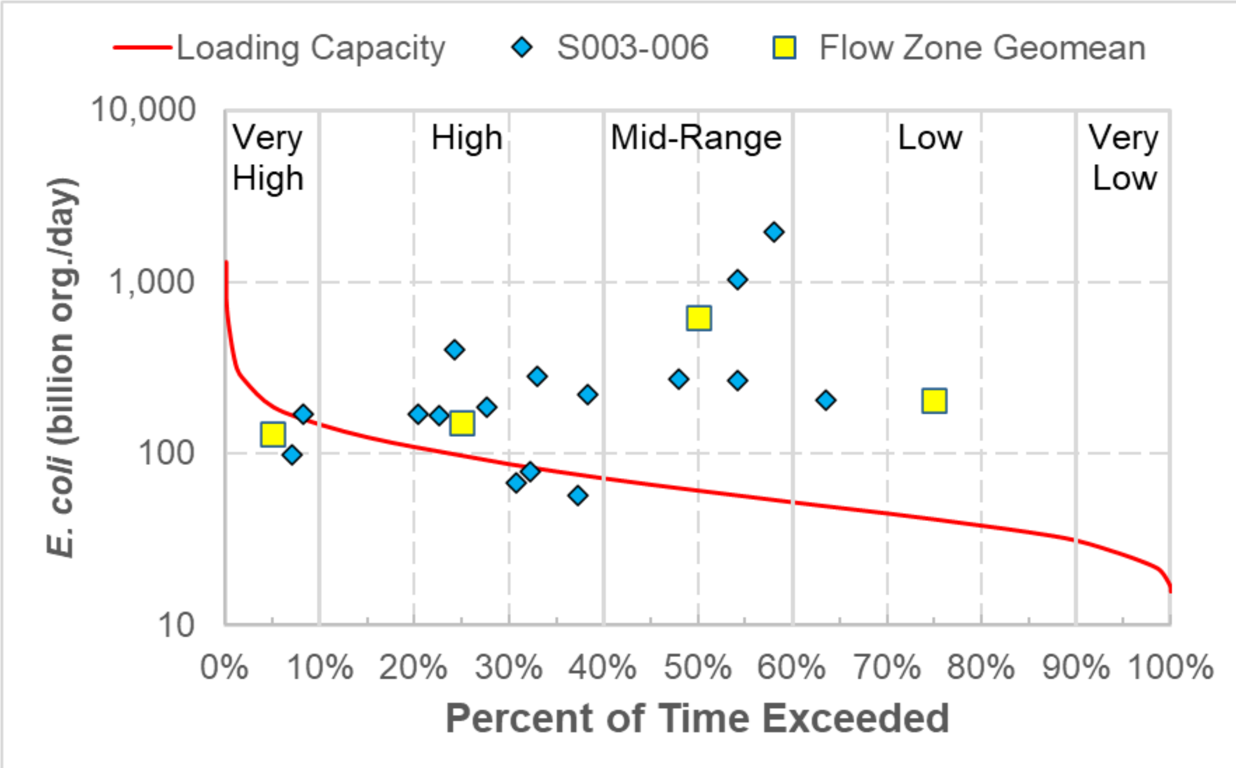


Table 41. *E. coli* TMDL summary, Snake River (AUID 07010203-529).

- 303(d) listing year or proposed year: 2012
- Baseline year: 2016
- Use class: 1B, 2Ag
- Numeric standard used to calculate TMDL: 126 organisms per 100 milliliters
- Standard applicable: April–October

TMDL Parameter		Flow Zones				
		Very high	**High**	**Mid-range**	**Low**	**Very low**
Sources		***E. coli* load (billion organisms per day)**				
Wasteload	Big Lake Township MS4 (MS400234)	3.0	1.6	0.99	0.67	0.42
	Becker Township MS4 [a]	81	42	26	18	11
	Total WLA	**84**	**44**	**27**	**19**	**11**
Load	**Total LA**	**84**	**43**	**28**	**18**	**12**
MOS		**19**	**10**	**6.1**	**4.1**	**2.6**
Total load		**187**	**97**	**61**	**41**	**26**
Maximum monthly geomean (org/100 mL)		**454**				
Overall estimated percent reduction		**72%**				

*This community is not currently regulated but is expected to come under MS4s permit coverage in the near future.

4.1.8.6 Battle Brook (AUID 07010203-535)

Table 42. Annual summary of *E. coli* data at Battle Brook (AUID 07010203-535; June–September).

Month	Sample count	Geometric mean (org/100 mL)	Minimum (org/100 mL)	Maximum (org/100 mL)	No. of individual sample exceedances	Percent of individual sample exceedances
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	0	–	–	–	–	–
2015	0	–	–	–	–	–
2016	0	–	–	–	–	–
2017	0	–	–	–	–	–
2018	0	–	–	–	–	–
2019	9	165	52	359	0	0%
2020	7	195	52	771	0	0%
2021	0	–	–	–	–	–

Table 43. Monthly summary of *E. coli* data at Battle Brook (AUID 07010203-535; 2019–2020).
Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded, or the individual standard of 1,260 org/100 mL was exceeded in greater than 10% of the samples. Standard applies only to months April–October.

Month	Sample count	Geometric mean (org/100 mL)	Minimum (org/100 mL)	Maximum (org/100 mL)	No. of individual sample exceedances	Percent of individual sample exceedances
April	0	–	–	–	–	–
May	0	–	–	–	–	–
June	5	94	52	210	0	0%
July	5	211	120	771	0	0%
August	5	284	135	727	0	0%
September	1	173 [a]	173	173	0	0%
October	0	–	–	–	–	–

a. Not enough samples to assess compliance with the monthly geometric mean standard.

Figure 30. *E. coli* load duration curve, Battle Brook (AUID 07010203-535).

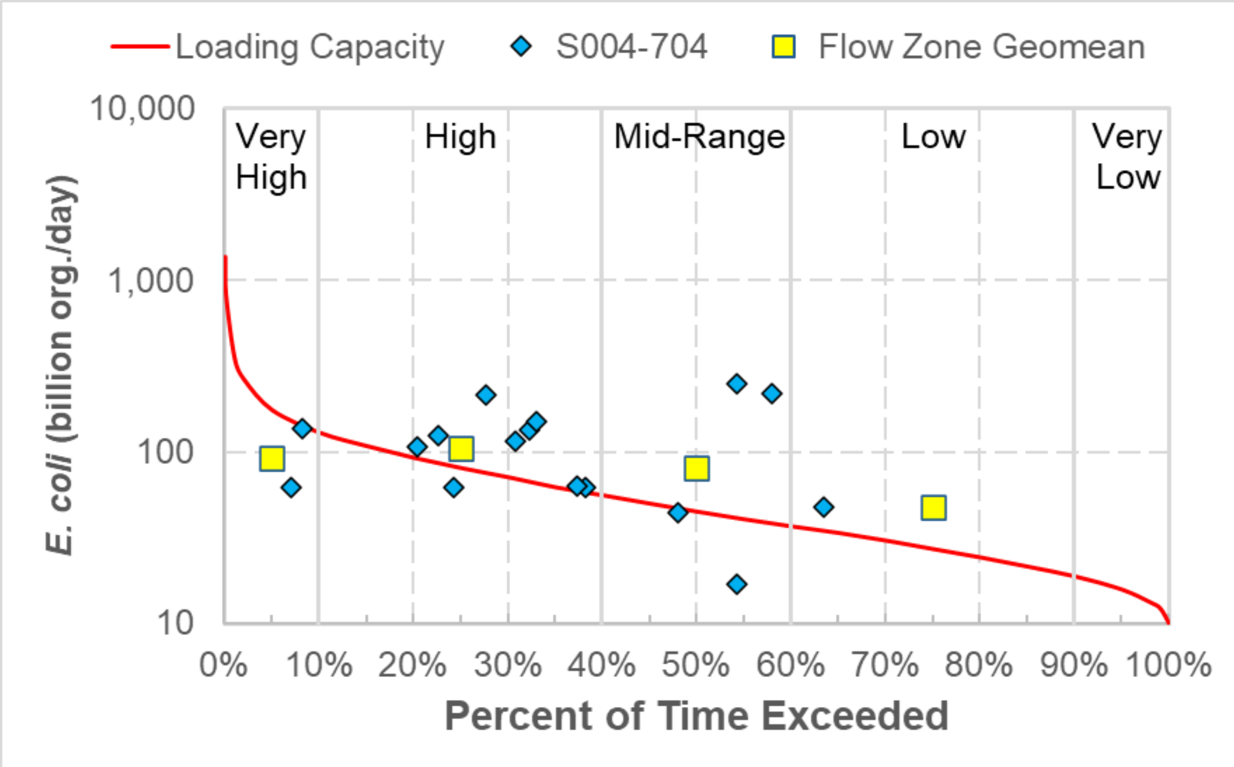


Table 44. *E. coli* TMDL summary, Battle Brook (AUID 07010203-535).

- 303(d) listing year or proposed year: 2012
- Baseline year: 2016
- Use class: 2Bg
- Numeric standard used to calculate TMDL: 126 organisms per 100 milliliters
- Standard applicable: April–October

TMDL Parameter		Flow Zones				
		Very high	**High**	**Mid-range**	**Low**	**Very low**
Sources		***E. coli* load (billion organisms per day)**				
Wasteload	Baldwin Township MS4 [a]	41	19	10	6.3	3.7
	Total WLA	**41**	**19**	**10**	**6.3**	**3.7**
Load	**Total LA**	**116**	**53**	**31**	**18**	**11**
MOS		**18**	**8**	**4.5**	**2.7**	**1.6**
Total load		**175**	**80**	**46**	**27**	**16**
Maximum monthly geomean (org/100 mL)		**284**				
Overall estimated percent reduction		**56%**				

*This community is not currently regulated but is expected to come under MS4s permit coverage in the near future.

4.1.8.7 Elk River (AUID 07010203-548)

Table 45. Annual summary of *E. coli* data at the Elk River (AUID 07010203-548; June–September).

Month	Sample count	Geometric mean (org/100 mL)	Minimum (org/100 mL)	Maximum (org/100 mL)	No. of individual sample exceedances	Percent of individual sample exceedances
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	0	–	–	–	–	–
2015	0	–	–	–	–	–
2016	0	–	–	–	–	–
2017	0	–	–	–	–	–
2018	0	–	–	–	–	–
2019	9	71	30	259	0	0%
2020	7	106	24	1,012	0	0%
2021	0	–	–	–	–	–

Table 46. Monthly summary of *E. coli* data at the Elk River (AUID 07010203-548; 2019–2020).
Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded, or the individual standard of 1,260 org/100 mL was exceeded in greater than 10% of the samples. Standard applies only to months April–October.

Month	Sample count	Geometric mean (org/100 mL)	Minimum (org/100 mL)	Maximum (org/100 mL)	No. of individual sample exceedances	Percent of individual sample exceedances
April	0	–	–	–	–	–
May	0	–	–	–	–	–
June	5	51	24	166	0	0%
July	5	93	41	1,012	0	0%
August	5	115	63	259	0	0%
September	1	146 [a]	146	146	0	0%
October	0	–	–	–	–	–

a. Not enough samples to assess compliance with the monthly geometric mean standard.

Figure 31. *E. coli* load duration curve, Elk River (AUID 07010203-548).

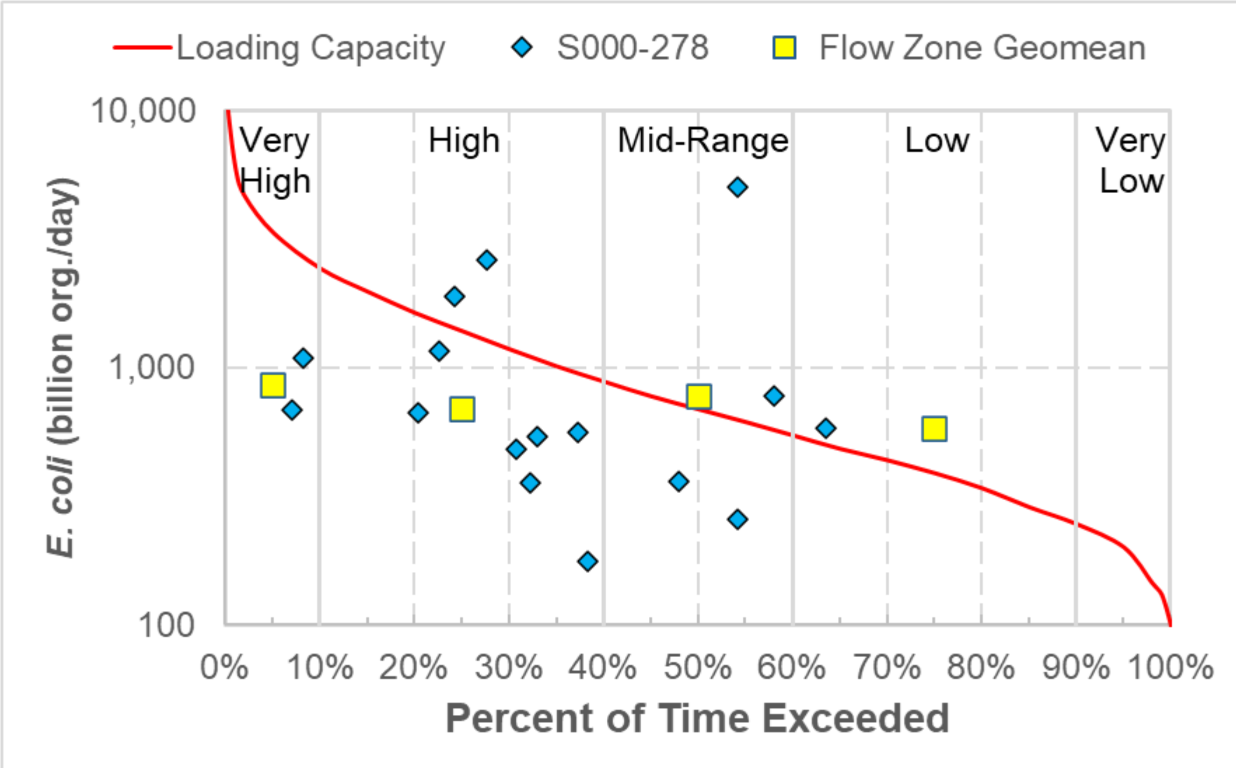


Table 47. *E. coli* TMDL summary, Elk River (AUID 07010203-548).

- 303(d) listing year or proposed year: 2012
- Baseline year: 2016
- Use class: 2Bg
- Numeric standard used to calculate TMDL: 126 organisms per 100 milliliters
- Standard applicable: April–October

TMDL Parameter		Flow Zones				
		Very high	**High**	**Mid-range**	**Low**	**Very low**
Sources		***E. coli* load (billion organisms per day)**				
Wasteload	Aspen Hills WWTF (MN0066028)	0.095	0.095	0.095	0.095	0.095
	Becker WWTP (MN0025666)	10	10	10	10	10
	Foley WWTP (MN0023451)	14	14	14	14	14
	Gilman WWTP (MNG585021)	1.9	1.9	1.9	1.9	1.9
	Zimmerman WWTP (MN0042331)	2.2	2.2	2.2	2.2	2.2
	Saint Cloud City MS4 (MS400052)	27	11	4.9	3.0	1.4
	Benton County MS4 (MS400067)	0.36	0.15	0.065	0.039	0.019
	Elk River City MS4 (MS400089)	43	18	7.7	4.6	2.2

TMDL Parameter		Flow Zones				
		Very high	High	Mid-range	Low	Very low
Sources		*E. coli* load (billion organisms per day)				
	Sauk Rapids City MS4 (MS400118)	10	4.3	1.9	1.1	0.53
	Minden Township (MS400147)	169	69	30	18	8.6
	Sauk Rapids Township MS4 (MS400153)	13	5.4	2.4	1.4	0.67
	Sherburne County MS4 (MS400155)	0.21	0.086	0.038	0.023	0.011
	Watab Township MS4 (MS400161)	7.1	2.9	1.3	0.77	0.36
	Minnesota Correctional–St. Cloud (MS400179)	0.38	0.16	0.069	0.041	0.020
	MNDOT Outstate District MS4 (MS400180)	1.0	0.41	0.18	0.11	0.051
	St. Cloud University (MS400197)	0.13	0.053	0.023	0.014	0.0066
	Big Lake Township MS4 (MS400234)	136	56	25	15	7.0
	Big Lake City MS4 (MS400249)	28	11	5.0	3.0	1.4
	Baldwin Township MS4 [a]	74	30	13	8.0	3.8
	Becker Township MS4 [a]	220	90	40	24	11
	Livonia Township MS4 [a]	103	42	19	11	5.3
	Zimmerman City MS4 [a]	20	8.0	3.5	2.1	1.0
	Total WLA	**880**	**377**	**182**	**120**	**72**
Load	**Total LA**	**2,139**	**875**	**440**	**231**	**109**
	MOS	**336**	**139**	**69**	**39**	**20**
	Total load	**3,355**	**1,391**	**691**	**390**	**201**
Maximum monthly geomean (org/100 mL)		**146**				
Overall estimated percent reduction		**14%**				

*These communities are not currently regulated but are expected to come under MS4s permit coverage in the near future.

4.1.8.8 Unnamed Creek (Fairhaven Creek) (AUID 07010203-565)

Table 48. Annual summary of *E. coli* data at Unnamed Creek (Fairhaven Creek) (AUID 07010203-565; April–October).

Month	Sample count	Geometric mean (org/100 mL)	Minimum (org/100 mL)	Maximum (org/100 mL)	No. of individual sample exceedances	Percent of individual sample exceedances
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	0	–	–	–	–	–
2015	0	–	–	–	–	–
2016	0	–	–	–	–	–
2017	0	–	–	–	–	–
2018	0	–	–	–	–	–
2019	0	–	–	–	–	–
2020	0	–	–	–	–	–
2021	0	–	–	–	–	–
2022	10	476	46	3,654	1	10%

Table 49. Monthly summary of *E. coli* data at Unnamed Creek (Fairhaven Creek) (AUID 07010203-565; 2022). Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded, or the individual standard of 1,260 org/100 mL was exceeded in greater than 10% of the samples. Standard applies only to months April–October.

Month	Sample count	Geometric mean (org/100 mL)	Minimum (org/100 mL)	Maximum (org/100 mL)	No. of individual sample exceedances	Percent of individual sample exceedances
April	0	–	–	–	–	–
May	0	–	–	–	–	–
June	2	141 [a]	46	435	0	0%
July	2	932 [a]	722	1,203	0	0%
August	3	395 [a]	211	1,014	0	0%
September	3	825 [a]	295	3,654	1	33%
October	0	–	–	–	–	–

a. Not enough samples to assess compliance with the monthly geometric mean standard.

Figure 32. *E. coli* load duration curve, Unnamed creek (Fairhaven Creek) (AUID 07010203-565).

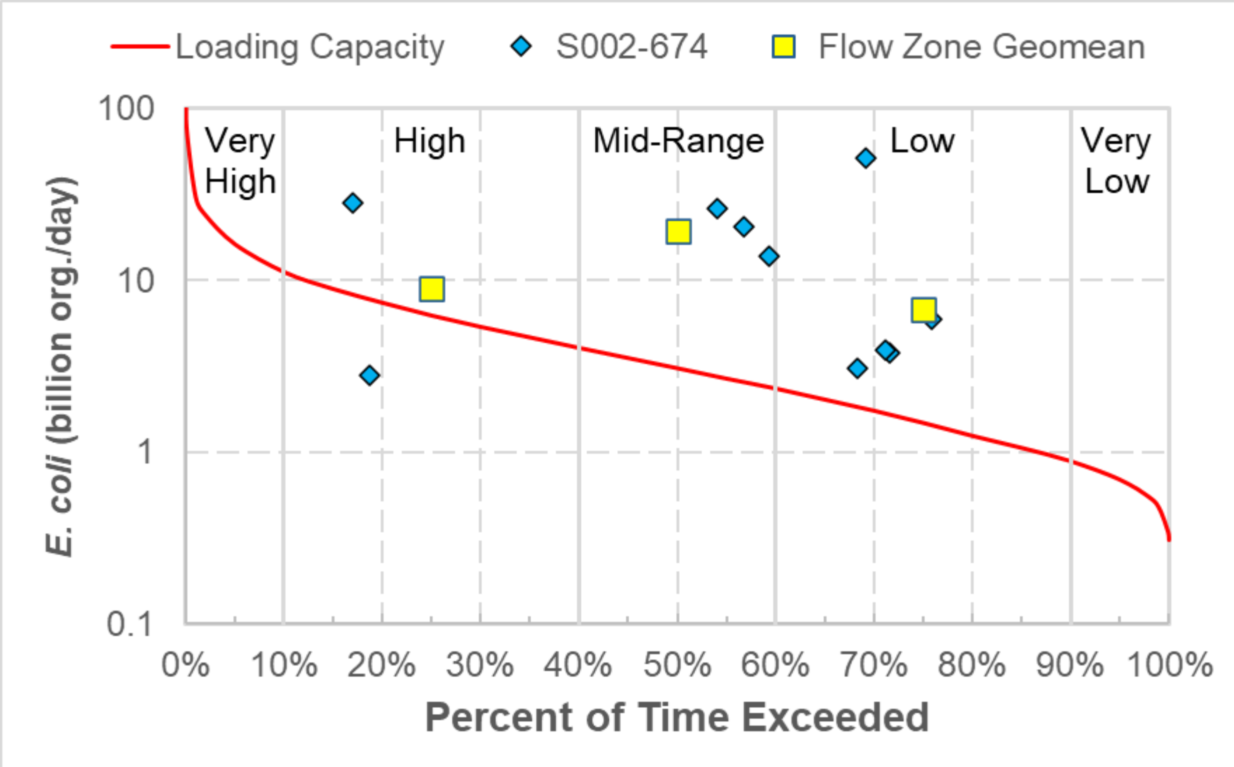


Table 50. *E. coli* TMDL summary, Unnamed creek (Fairhaven Creek) (AUID 07010203-565).

- 303(d) listing year or proposed year: 2012
- Baseline year: 2017
- Use class: 1B, 2Ag
- Numeric standard used to calculate TMDL: 126 organisms per 100 milliliters
- Standard applicable: April–October

TMDL Parameter		Flow Zones				
		Very high	**High**	**Mid-range**	**Low**	**Very low**
Sources		***E. coli* load (billion organisms per day)**				
Load	**Total LA**	**14**	**5.6**	**2.8**	**1.3**	**0.62**
	MOS	**1.6**	**0.62**	**0.31**	**0.15**	**0.069**
	Total load	**16**	**6.2**	**3.1**	**1.5**	**0.69**
Maximum monthly geomean (org/100 mL)		**932**				
Overall estimated percent reduction		**86%**				

4.1.8.9 St. Francis River (AUID 07010203-700)

Table 51. Annual summary of *E. coli* data at the St. Francis River (AUID 07010203-700; June–September).

Month	Sample count	Geometric mean (org/100 mL)	Minimum (org/100 mL)	Maximum (org/100 mL)	No. of individual sample exceedances	Percent of individual sample exceedances
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	0	–	–	–	–	–
2015	0	–	–	–	–	–
2016	0	–	–	–	–	–
2017	0	–	–	–	–	–
2018	0	–	–	–	–	–
2019	9	266	20	2,098	1	11%
2020	7	208	41	1,187	0	0%
2021	0	–	–	–	–	–

Table 52. Monthly summary of *E. coli* data at the St. Francis River (AUID 07010203-700; 2019–2020).
Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded, or the individual standard of 1,260 org/100 mL was exceeded in greater than 10% of the samples. Standard applies only to months April–October.

Month	Sample count	Geometric mean (org/100 mL)	Minimum (org/100 mL)	Maximum (org/100 mL)	No. of individual sample exceedances	Percent of individual sample exceedances
April	0	–	–	–	–	–
May	0	–	–	–	–	–
June	5	98	20	722	0	0%
July	5	275	108	882	0	0%
August	5	497	110	2,098	1	20%
September	1	259 [a]	259	259	0	0%
October	0	–	–	–	–	–

a. Not enough samples to assess compliance with the monthly geometric mean standard.

Figure 33. *E. coli* load duration curve, St. Francis River (AUID 07010203-700).

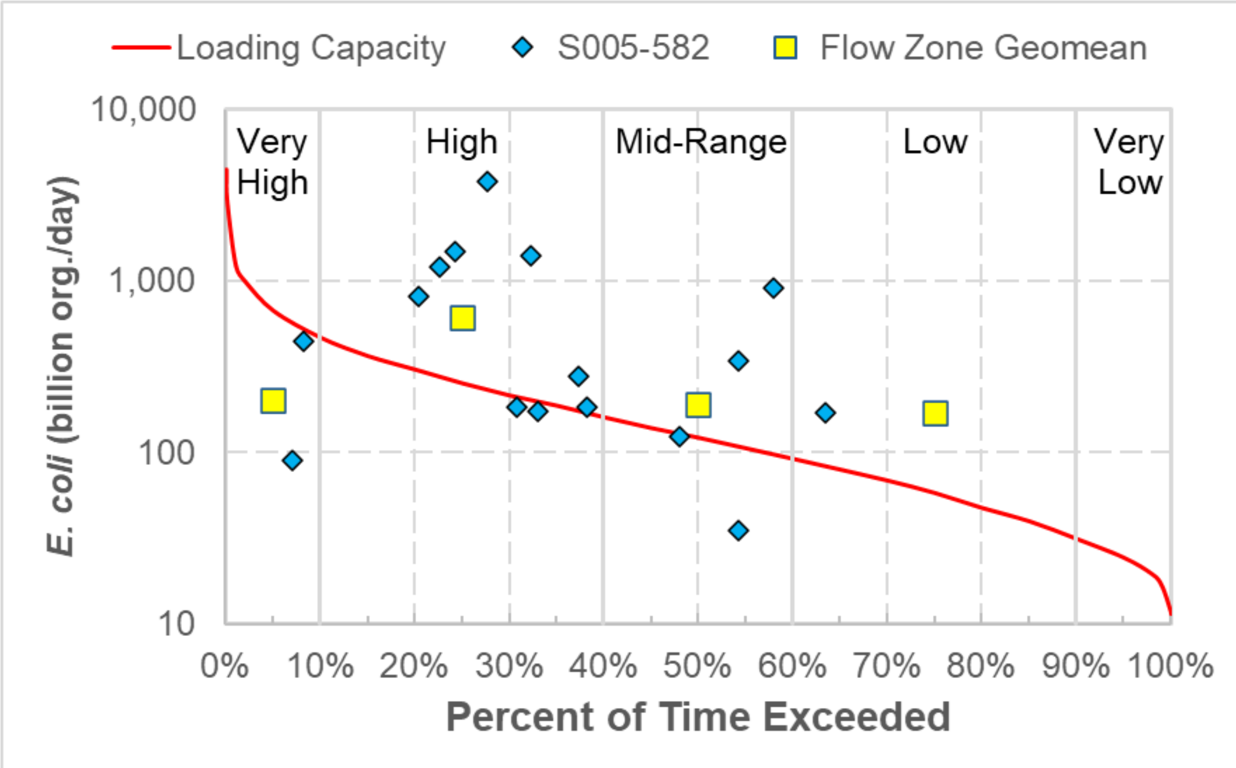


Table 53. *E. coli* TMDL summary, St. Francis River (AUID 07010203-700).

- 303(d) listing year or proposed year: 2012
- Baseline year: 2016
- Use class: 2Bg
- Numeric standard used to calculate TMDL: 126 organisms per 100 milliliters
- Standard applicable: April–October

TMDL Parameter		Flow Zones				
		Very high	**High**	**Mid-range**	**Low**	**Very low**
Sources		***E. coli* load (billion organisms per day)**				
Load	**Total LA**	**603**	**229**	**110**	**52**	**22**
	MOS	**67**	**25**	**12.2**	**5.8**	**2.4**
	Total load	**670**	**254**	**122**	**58**	**24**
Maximum monthly geomean (org/100 mL)		**497**				
Overall estimated percent reduction		**75%**				

4.1.8.10 Tibbets Brook (AUID 07010203-736)

Table 54. Annual summary of *E. coli* data at Tibbets Brook (AUID 07010203-736; June–September).

Month	Sample count	Geometric mean (org/100 mL)	Minimum (org/100 mL)	Maximum (org/100 mL)	No. of individual sample exceedances	Percent of individual sample exceedances
2012	0	–	–	–	–	–
2013	0	–	–	–	–	–
2014	0	–	–	–	–	–
2015	0	–	–	–	–	–
2016	0	–	–	–	–	–
2017	0	–	–	–	–	–
2018	0	–	–	–	–	–
2019	8	119	31	272	0	0%
2020	7	262	110	1,124	0	0%
2021	0	–	–	–	–	–

Table 55. Monthly summary of *E. coli* data at Tibbets Brook (AUID 07010203-736; 2019–2020).
Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded, or the individual standard of 1,260 org/100 mL was exceeded in greater than 10% of the samples. Standard applies only to months April–October.

Month	Sample count	Geometric mean (org/100 mL)	Minimum (org/100 mL)	Maximum (org/100 mL)	No. of individual sample exceedances	Percent of individual sample exceedances
April	0	–	–	–	–	–
May	0	–	–	–	–	–
June	4	144	31	327	0	0%
July	5	159	120	265	0	0%
August	5	233	97	1,124	0	0%
September	1	110 [a]	110	110	0	0%
October	0	–	–	–	–	–

a. Not enough samples to assess compliance with the monthly geometric mean standard.

Figure 34. *E. coli* load duration curve, Tibbets Brook (AUID 07010203-736).

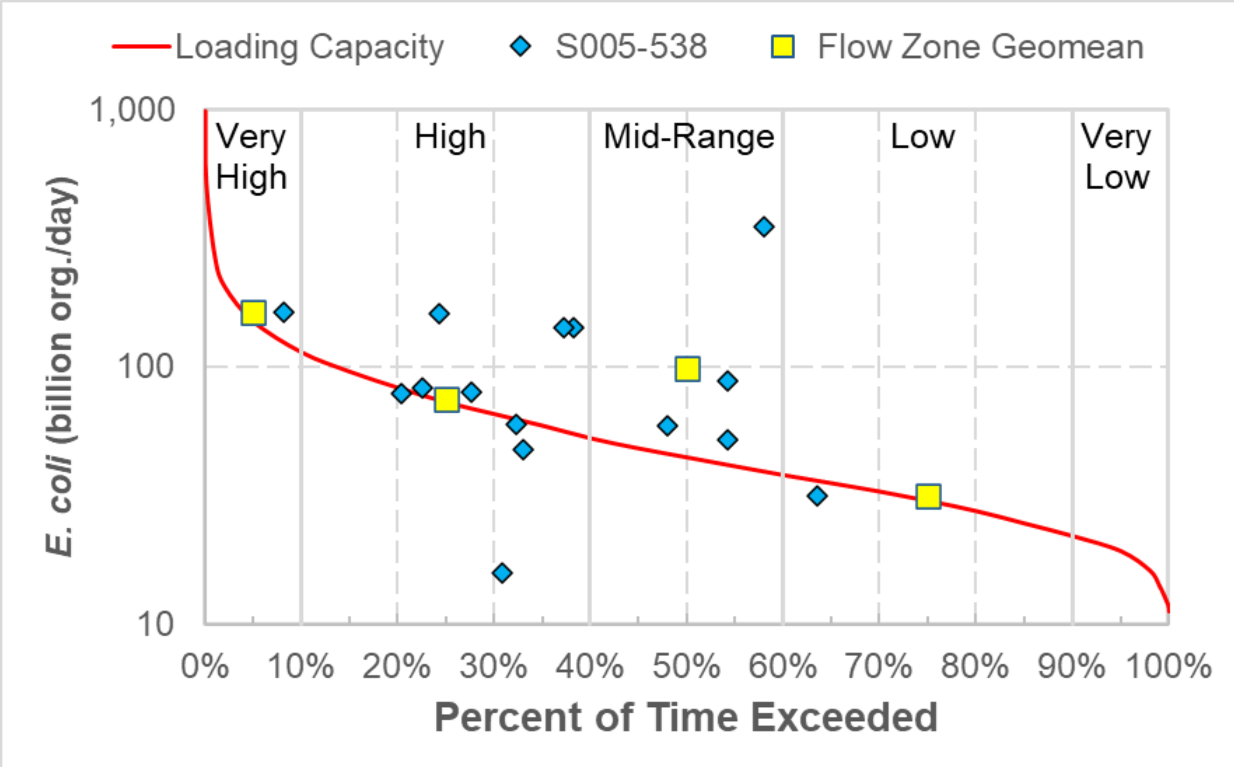


Table 56. *E. coli* TMDL summary, Tibbets Brook (AUID 07010203-736).

- 303(d) listing year or proposed year: 2012
- Baseline year: 2016
- Use class: 2Bg
- Numeric standard used to calculate TMDL: 126 organisms per 100 milliliters
- Standard applicable: April–October

TMDL Parameter		Flow Zones				
		Very high	**High**	**Mid-range**	**Low**	**Very low**
Sources		***E. coli* load (billion organisms per day)**				
Wasteload	Aspen Hills WWTF (MN0066028)	0.095	0.095	0.095	0.095	0.095
	Zimmerman WWTP (MN0042331)	2.2	2.2	2.2	2.2	2.2
	Elk River City MS4 (MS400089)	23	11	6.6	4.3	2.6
	Sherburne County MS4 (MS400155)	0.024	0.011	0.0069	0.0045	0.0027
	Big Lake Township MS4 (MS400234)	24	12	7.0	4.6	2.7
	Baldwin Township MS4 [a]	1.8	0.84	0.51	0.33	0.20
	Livonia Township MS4 [a]	63	30	18	12	7.1
	Zimmerman City MS4 [a]	13	6.4	3.9	2.5	1.5
	Total WLA	**127**	**63**	**38**	**26**	**16**
Load	**Total LA**	**8.0**	**2.7**	**2.5**	**1.0**	**1.1**
	MOS	**15**	**7.3**	**4.5**	**3.0**	**1.9**
	Total load	**150**	**73**	**45**	**30**	**19**
Maximum monthly geomean (org/100 mL)		**233**				
Overall estimated percent reduction		**46%**				

a. These communities are not currently regulated but are expected to come under MS4s permit coverage in the near future.

4.2 Total Suspended Solids

4.2.1 Loading capacity methodology

Assimilative loading capacities for the stream were developed using an LDC. See Section 3.5 for a description of LDC development. Simulated daily average flow from 1995 through 2015 from HSPF modeling (Tetra Tech 2019) was used to develop the LDC. Both seasonal variation and critical conditions are accounted for in the TSS TMDL through the application of the LDC. For any given flow in the LDC, the loading capacity is determined by selecting the point on the LDC that corresponds to the flow exceedance (along the x-axis).

The LDC method is based on an analysis that encompasses the cumulative frequency of historical flow data over a specified period. Because this method uses a long-term record of daily flow volumes, virtually the full spectrum of allowable loading capacities is represented by the resulting curve. In the TMDL equation tables of this report, only five points on the entire loading capacity curve are depicted (the midpoints of the designated flow zones). However, the entire curve represents the TMDL and is what the EPA ultimately approves.

4.2.2 Load allocation methodology

The LA is allocated to existing or future nonpermitted pollutant sources. For the TSS stream TMDL, the LA is the remainder of the loading capacity after the WLAs and MOS are allocated.

Natural background conditions were also evaluated, where possible, within the modeling and source assessment portion of this study (Section 3.6.2; e.g., erosion). For TSS, natural background sources are implicitly included in the LA portion of the TMDL tables, and reductions should focus on the major human attributed sources identified in the source assessment.

4.2.3 Wasteload allocation methodology

The WLA is allocated to existing or future NPDES/SDS-permitted pollutant sources. TSS WLAs are provided for municipal WWTPs, permitted MS4 communities, construction stormwater, and industrial stormwater.

If a permittee that is assigned a WLA in this report has previously been assigned one or more WLAs for the same pollutant for another TMDL, the applicable permit(s) and/or associated planning documents will need to address the most restrictive WLA.

4.2.3.1 Municipal and industrial wastewater

The TSS WLA for municipal wastewater is based on the TSS permit limit of 30 mg/L and the average wet weather design flow for the facility (Table 57). There are no required changes to the permit.

All wastewater WLAs are listed in the TMDL tables in Section 4.2.8 and in Table 57.

Table 57. Individual TSS wastewater wasteload allocations.

Facility name	Permit number	Surface discharge station	Design flow [a] (mgd)	Impaired water body AUID (07010203)	Pollutant	Permit limit (mg/L)	WLA (lb/d)	Existing permit consistent with WLA assumptions
Otsego WWTP West	MN0066257	001	0.72 [b]	-528	TSS	30	180	Y

a. Flow used to calculate the WLA.

b. Permit issued 11/7/2022 authorizes a facility expansion to 1.75 mgd. In the case of a facility expansion, the 180 lb/day WLA will still be valid because the permit's calendar month average TSS limit will remain 81.6 kg/day after the expansion.

4.2.3.2 Municipal separate storm sewer systems

Stormwater runoff regulated by the MS4 general permit must be included in the WLA portion of a TMDL. Refer to Section 4.1.3.2 for a general discussion of how WLA areas were determined. Discussion to this specific subwatershed is below. Table 58 and Figure 35 present the areas used for WLA development for the MS4s in the TSS TMDL.

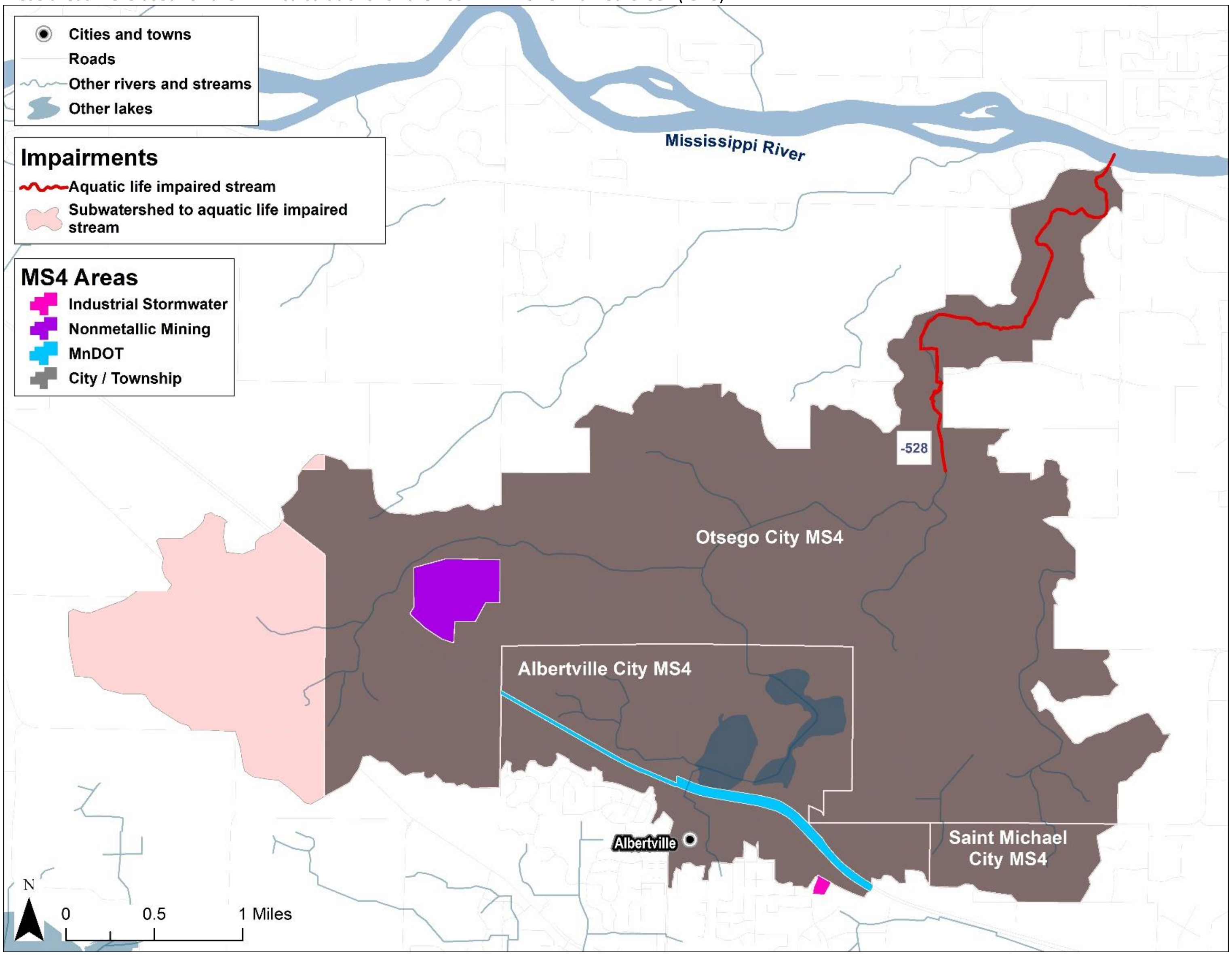
The cities of Albertville and Otsego provided sewershed shapefiles that were used in the delineation of the unnamed creek (-528) subwatershed, the delineation of the cities regulated areas, and the calculation of WLA areas. The MNDOT WLA area (54.7 acres) and the property covered by General NPDES/SDS Permit MNR050000 for Industrial Stormwater (4.5 acres) were subtracted from the Albertville WLA area, and the area for a property covered by the NPDES/SDS General Permit MNG490000 for Nonmetallic Mining and Associated Activities (108.4 acres) was subtracted from the Otsego WLA area.

Table 58. Permitted MS4s and estimated regulated area for the Unnamed creek (-528) TSS TMDL.

These areas were used for the WLA calculations for the TSS TMDL for Unnamed creek (-528)

MS4 name and permit number	Estimated WLA area (acres)
Albertville City (MS400281)	1,326.4
MNDOT Outstate District (MS400180)	54.7
Otsego City (MS400243)	4,882.7
Saint Michael City (MS400246)	248.0

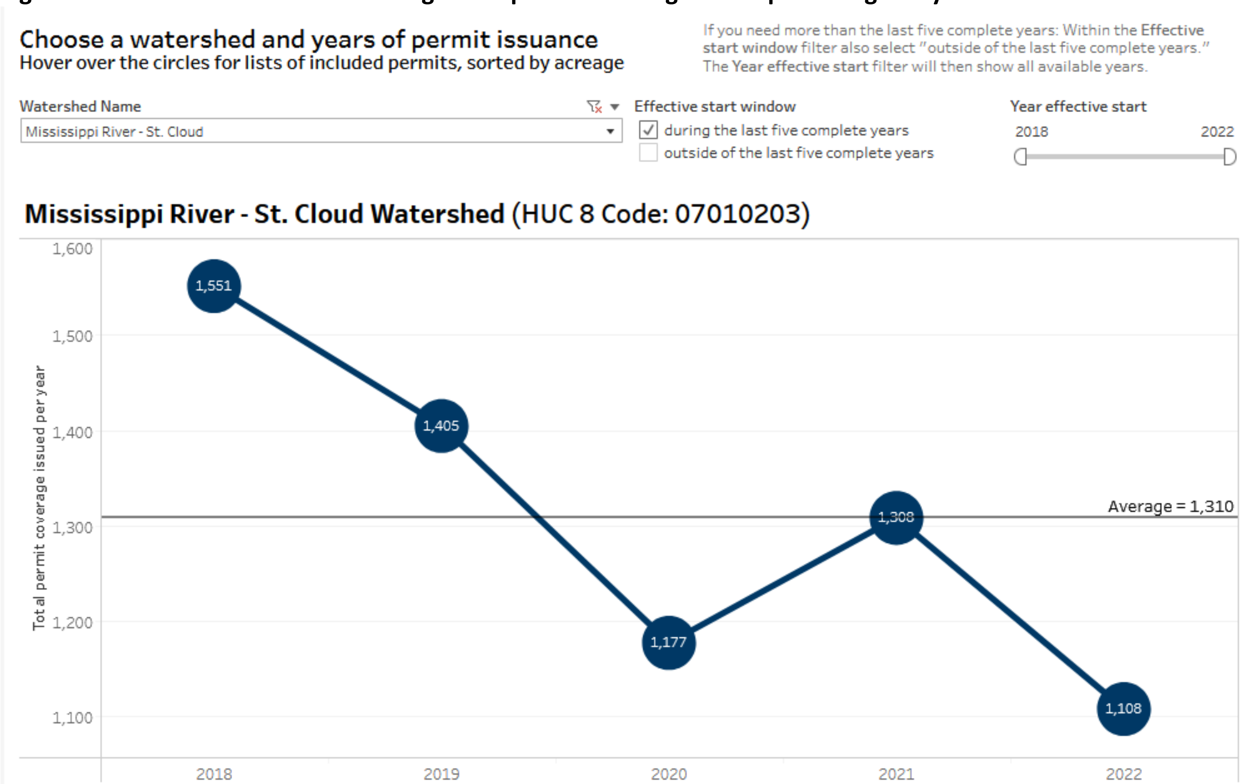
Figure 35. Regulated stormwater in the Unnamed creek (-528; locally Otsego Creek) subwatershed.
These areas were used for the WLA calculations for the TSS TMDL for Unnamed Creek (-528).



4.2.3.3 Construction stormwater

Construction stormwater is permitted through the Construction Stormwater General Permit MNR100001, and a single categorical TSS WLA for construction stormwater is assigned. For the TSS TMDL, the construction stormwater WLA was calculated as 0.2% multiplied by the loading capacity (i.e., TMDL) less the MOS and wastewater WLAs. The percent of the MRSCW under new construction permit coverage ranged from 0.15% to 0.22% between 2018 and 2022, with a downward trend (Figure 36). The 5-year annual average is 0.18%, so the selection of 0.2% should be a conservative assumption, even with considerable growth along the I-94 corridor. It is assumed that loads from permitted construction stormwater sites that operate in compliance with their permits are meeting the WLA.

Figure 36. Percent of the MRSC under general permit coverage in the preceding five years.



Percent of watershed under permit coverage for the selected time period

Avg. annual total permit issuance for watershed (acres)	Total watershed acreage	
1,310	717,376	0.18%

4.2.3.4 Industrial stormwater

Industrial stormwater is permitted through the General NPDES/SDS Permit MNR050000 for Industrial Stormwater Multi-Sector and through NPDES/SDS General Permit MNG490000 for Nonmetallic Mining and Associated Activities. A single categorical TSS WLA for industrial stormwater is provided. Industrial stormwater permittees are required to sample their stormwater for parameters that closely match the potential contribution of pollutants for their industry sector or subsector. For example, recycling facilities and auto salvage yards are required to sample for TSS, metals, and other pollutants likely present at these types of facilities. It is assumed that loads from permitted industrial stormwater sites that operate in compliance with the permit are meeting the WLA.

Permitted areas for each operation covered by the Industrial Stormwater Multi-Sector General Permit were provided by MPCA. Permitted areas for the operations covered by the MNG490000 Nonmetallic Mining and Associated Activities General Permit were estimated using aerial imagery. The total area for operations covered by either General Permit is 112.9 acres, which is about 1.5% of the area of the subwatershed draining to the impaired stream segment.

The WLA was calculated using an area ratio (total area of industrial permittees divided by TMDL subwatershed area) multiplied by the quantity of the loading capacity less the MOS and WLAs for nonstormwater permittees.

4.2.4 Margin of safety

The MOS accounts for uncertainty concerning the relationship between water quality and allocated loads. The MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e., expressed in the TMDL as a load set aside).

An explicit MOS of 10% was included in the TMDLs to account for uncertainty that the pollutant allocations would attain the water quality targets. The use of an explicit MOS accounts for environmental variability in pollutant loading, variability in water quality monitoring data, calibration and validation processes of modeling efforts, uncertainty in modeling outputs, conservative assumptions made during the modeling efforts, and limitations associated with the drainage area-ratio method used to extrapolate flow data. This MOS is considered to be sufficient given the robust datasets used and quality of modeling. The MRSC HSPF model was calibrated and validated using seven stream flow gaging stations (Tetra Tech 2019). One gage is on the main stem Mississippi River near St. Cloud, and the remaining sites gage tributary stream flows. Calibration results indicate that the HSPF model is a valid representation of hydrologic and water quality conditions in the watershed. Flow data used to develop the stream TMDL are derived from HSPF-simulated daily flow data.

4.2.5 Seasonal variation and critical conditions

The application of LDCs in the TSS TMDLs addresses seasonal variation and critical conditions. LDCs evaluate pollutant loading across all flow regimes including high flow, which is when pollutant loading from watershed runoff is typically the greatest, and low flow, which is when loading from direct sources to the stream typically has the most impact. Because flow varies seasonally, LDCs address seasonality through their application across all flow conditions in the impaired water body.

Seasonal variation and critical conditions are also addressed by the water quality standards. TSS standards for aquatic life apply from April through September.

4.2.6 Baseline year

The monitoring data point used to calculate the percent reductions is from 2019, which is the baseline year for crediting load reductions. Any activities implemented during or after the baseline year that led to a reduction in pollutant loads to the water bodies may be considered as progress towards meeting a WLA or LA. If a BMP was implemented during or just prior to the baseline year, the MPCA may consider evidence presented by the MS4 permit holder to demonstrate that the BMP should be considered as progress towards meeting a WLA. BMPs present on the landscape during the model simulation time period are implicitly accounted for in the model.

4.2.7 Percent reduction

The estimated percent reduction provides a rough approximation of the overall reduction needed for the water body to meet the TMDL. The percent reduction is a means to capture the level of effort needed to reduce TSS loads in the watershed.

The estimated percent reduction needed to meet the TMDL was calculated by comparing the observed (monitored) concentration from August 2019 to the 30 mg/L standard, for a 10% reduction.

4.2.8 TMDL summary

This section provides the LDC and TMDL for Unnamed creek (-528; locally known as Otsego Creek) that is impaired for its aquatic life use. See Section 3.5.1 for an explanation of the data analyses.

TSS load reductions are needed to address multiple source types (see Section 3.6.2: Stream TSS source summary).

Loads in the TSS TMDL table are rounded to two significant digits, except in the case of values greater than 100, which are rounded to the nearest whole number. The percent reduction is rounded to the nearest whole number.

Figure 37. TSS load duration curve, Unnamed creek (AUID 07010203-528).

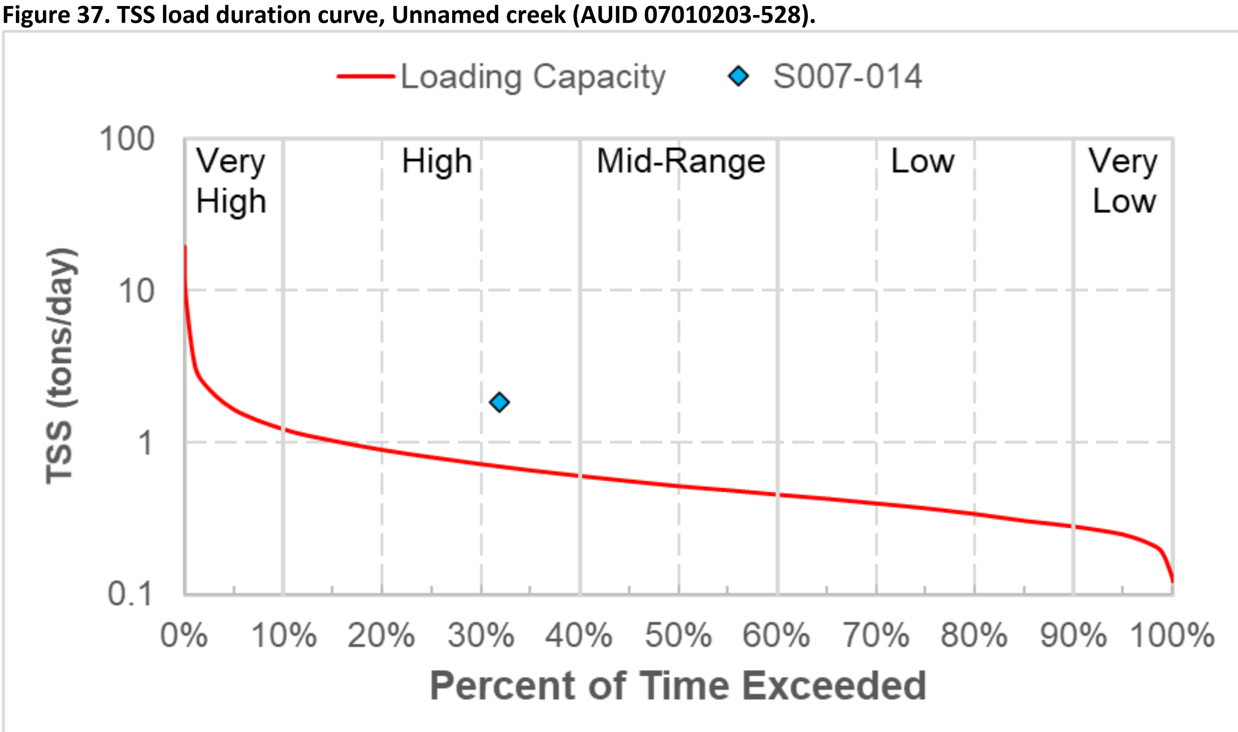


Table 59. TSS TMDL summary, Unnamed creek (AUID 07010203-528).

- 303(d) listing year or proposed year: 2012
- Baseline year: 2019
- Use class: 2Bg
- Numeric standard used to calculate TMDL: 30 mg/L TSS
- Standard applicable: April–September

TMDL Parameter		Flow Zones				
		Very high	High	Mid-range	Low	Very low
Sources		TSS load (pounds per day)				
Wasteload	Otsego WWTP West (MN006257)	180	180	180	180	180
	MNDOT Outstate District MS4 (MS400180) [a]	20	9.1	5.4	3.5	1.9
	Otsego City MS4 (MS400243) [a]	1,804	814	485	314	172
	Saint Michael City MS4 (MS400246) [a]	92	41	25	16	8.7
	Albertville City MS4 (MS400281) [a]	490	221	132	85	47
	Industrial stormwater	42	19	11	7.9	4.0
	Construction stormwater	5.6	2.5	1.5	0.97	0.53
	Total WLA	**2,634**	**1,287**	**840**	**607**	**414**
Load	**Total LA**	**331**	**150**	**88**	**57**	**31**
MOS		**329**	**160**	**103**	**74**	**50**
Total load		**3,294**	**1,597**	**1,031**	**738**	**495**
Maximum observed (mg/L)		**33.2**				
Overall estimated percent reduction		**10%**				

[a] To evaluate compliance with the TSS TMDL WLA, MS4 permittees should use the 10% reduction target from their baseline loads in 2019 (Section 8.1.3.2).

4.3 Total Phosphorus

Allowable pollutant loads in lakes were determined using the lake response model BATHTUB. BATHTUB is a steady state model that predicts eutrophication response in lakes based on empirical formulas developed for nutrient balance calculations and algal response (Walker 1987). The model was developed by the U.S. Army Corps of Engineers and has been used extensively in Minnesota and across the Midwest for lake nutrient TMDLs. The BATHTUB model requires nutrient loading inputs from the upstream watershed and atmospheric deposition (Section 3.6.3), lake morphometric data (Table 5) and estimated mixed depth. Annual precipitation and watershed runoff volumes and loads were derived from the HSPF model (Tetra Tech 2019; see Section 3.6.3 for a brief description of the model and Appendix B for discussion of model development and calibration).

The lake eutrophication standards apply June through September, and the lake TMDL analysis is based on either annual (January through December) or seasonal (April through October) loads; the Little Mary Lake model is based on seasonal loads and the remaining models are based on annual loads.

4.3.1 Loading capacity and TMDL scenario methodology

The BATHTUB models were calibrated to the long-term average phosphorus concentration, consisting of all data from 2012 through 2022 (Section 3.5.2).

After the models were calibrated, the TMDL scenarios for all lakes except for Fremont Lake were developed by reducing phosphorus load inputs until the lake TP standard was met. For Fremont Lake, recent data show that the lake meets standards. To ensure that lake water quality is maintained, the Fremont Lake TMDL is based on a 5% reduction in phosphorus loads to the lake, which corresponds to a lake target of 44 µg/L TP, compared to the average existing concentration of 46 µg/L and the water quality standard of 60 µg/L.

The TMDL scenarios were modeled according to the following:

- Boundary conditions for upstream impaired lakes (i.e., Silver Lake and Little Mary–North loads to Little Mary–South; Diann Lake load to Elk Lake): based on upstream lake meeting phosphorus standards (see Section 4.3.2).
- SSTS (Fremont, Elk, and Eagle Lakes): Based on 100% compliant SSTS for Elk and Eagle Lakes; less reduction is needed for Fremont Lake because the lake current meets water quality standards.
- Atmospheric deposition: no changes to loading.
- Internal loading (Elk, Millstone, and Little Mary–North): based on implicit amount of internal load in BATHTUB for Elk, a 66% reduction for Little Mary–North, and an 87% reduction for Millstone Lake.
- Watershed runoff: Loads were reduced from 2% to 78%. Reductions are higher in the TMDL tables than in the lake models to accommodate the additional reductions needed to account for the explicit MOS. Percent reductions for MS4-permitted and nonpermitted watershed runoff are the same within a TMDL table. Load reductions are not required from permitted construction or industrial stormwater.
- Wastewater: The WLA for the one wastewater discharger is consistent with the existing permit (see Section 4.3.4).

The total load to the lake in each TMDL scenario represents the loading capacity, the total load reduction needed is the sum of the individual load reductions needed, and the overall percent reduction needed to meet the TMDL was calculated as total load reduction needed divided by the existing load.

The estimated percent reductions provide a rough approximation of the overall reduction needed for the water body to meet the TMDL. The percent reductions should not be construed to mean that each of the separate sources listed in the TMDL table needs to be reduced by that amount. Within each lake TMDL table, an estimated percent reduction by source is provided (Table 63, Table 65, Table 67, Table 69, Table 71, and Table 73). The complete model inputs and outputs are presented in Appendix B.

4.3.2 Boundary conditions

Boundary conditions are used to set aside load for a geographic area in a TMDL watershed without establishing LAs or WLAs for that area.

Boundary conditions are used in the Little Mary South Bay TMDL to account for the allocated loads from upstream impaired lakes with approved phosphorus TMDLs or TMDLs developed in this report: Silver Lake (MPCA 2015) and Little Mary North Bay (TMDL in this report). Because allocations are established for the upstream water body, they do not need to be defined again in additional TMDLs unless there is a need for further pollutant reductions. The boundary condition existing loads were calculated as the simulated flow from the upstream lake outlet multiplied by the average phosphorus concentration (Section B.1.2.4.3 in Appendix B). The boundary condition TMDL loads were calculated as the same volume multiplied by the lake phosphorus water quality standard (Section B.3.3 in Appendix B).

A boundary condition is used in the Elk Lake TMDL to account for loads from Diann Lake. The TMDL target for the boundary condition was calculated as the simulated flow in the lake outlet multiplied by the phosphorus water quality criterion for shallow lakes (60 µg/L). Diann Lake has an aquatic recreation impairment due to high nutrients and does not yet have a TMDL (Table 78). When the TMDL is developed, MS4 WLAs will be assigned to existing and/or future MS4s. If Diann Lake is found to meet the lake eutrophication standards and is delisted before a TMDL is developed, the boundary condition established in this Elk Lake TMDL will remain as is. If Diann Lake is removed from the impaired waters list for other reasons, the Elk Lake TMDL will need to be revised to assign WLAs and/or LAs for the Diann Lake Watershed.

4.3.3 Load allocation methodology

The LA is allocated to existing or future nonpermitted pollutant sources (e.g., unregulated watershed runoff, septic systems, internal loading, and natural background). Where sufficient data are available, sources within the LA are provided individually in the TMDL tables for guidance in implementation planning; the individual loading goals for the nonpermitted sources may change through the adaptive implementation process.

The LAs are based on each lake's TMDL scenario (Section 4.3.1).

4.3.4 Wasteload allocation methodology

The WLA is allocated to existing or future NPDES-permitted pollutant sources. If a permittee that is assigned a WLA in this report has previously been assigned one or more WLAs for the same pollutant for another TMDL, the applicable permit(s) and/or associated planning documents will need to address the most restrictive WLA.

4.3.4.1 Municipal and industrial wastewater

The only municipal or industrial wastewater discharger in the impaired lakes subwatersheds is Knife River Central Minnesota (MNG490003), which is authorized to discharge dewatering effluent through surface discharge station #216. A WLA was developed for this discharge for the Elk Lake TMDL based on the existing permit and available dewatering effluent data (Table 60 and Section 4.3.9.2).

Municipal and industrial wastewater facilities that discharge to groundwater are not assigned WLAs because they do not discharge to surface waters.

Table 60. TP industrial wastewater wasteload allocation.

Facility name	Permit number	Surface discharge station	Design flow [a]	Impaired water body AUID	Pollutant	Target (mg/L)[b]	WLA (lb/y)	Existing permit consistent with WLA assumptions
Knife River Central Minnesota	MNG490003	216	20	71-0055-00	TP	0.059	9.8	TBD [c]

a. Flow used to calculate the WLA, million gallons per year.

b. This target is calculated from the single available dewatering effluent concentration of 0.047 mg/L TP, increased by 25% to account for uncertainty.

c. TBD (to be determined): The discharge does not currently have a phosphorus permit limit; upon permit reissuance, a water quality based effluent limit (WQBEL) will be developed if the discharge is found to have a reasonable potential to cause or contribute to excursions above the water quality standards.

4.3.4.2 Municipal separate storm sewer systems

Stormwater runoff regulated by the MS4 general permit must be included in the WLA portion of a TMDL. Refer to Section 4.1.3.2 for a discussion of how permitted areas were determined.

Areas used to develop WLAs for each current or possible future regulated MS4 are shown in Figure 38 and Table 61.

The jurisdictional area of each current or possible future regulated MS4 within an impairment subwatershed was divided by the total area of the subwatershed to represent the percent coverage of each MS4 within the impairment subwatershed. The WLAs for current or future permitted MS4s were calculated as the percent coverage of each current or future permitted MS4 area multiplied by the loading capacity minus the MOS, boundary condition (where applicable), and wastewater WLA (Elk Lake).

Figure 38. Regulated MS4s in the subwatersheds for three phosphorus-impaired lakes in Sherburne County.
Baldwin Township, Becker Township, Livonia Township, and Zimmerman City are not currently regulated but are expected to come under MS4 permit coverage in the near future.

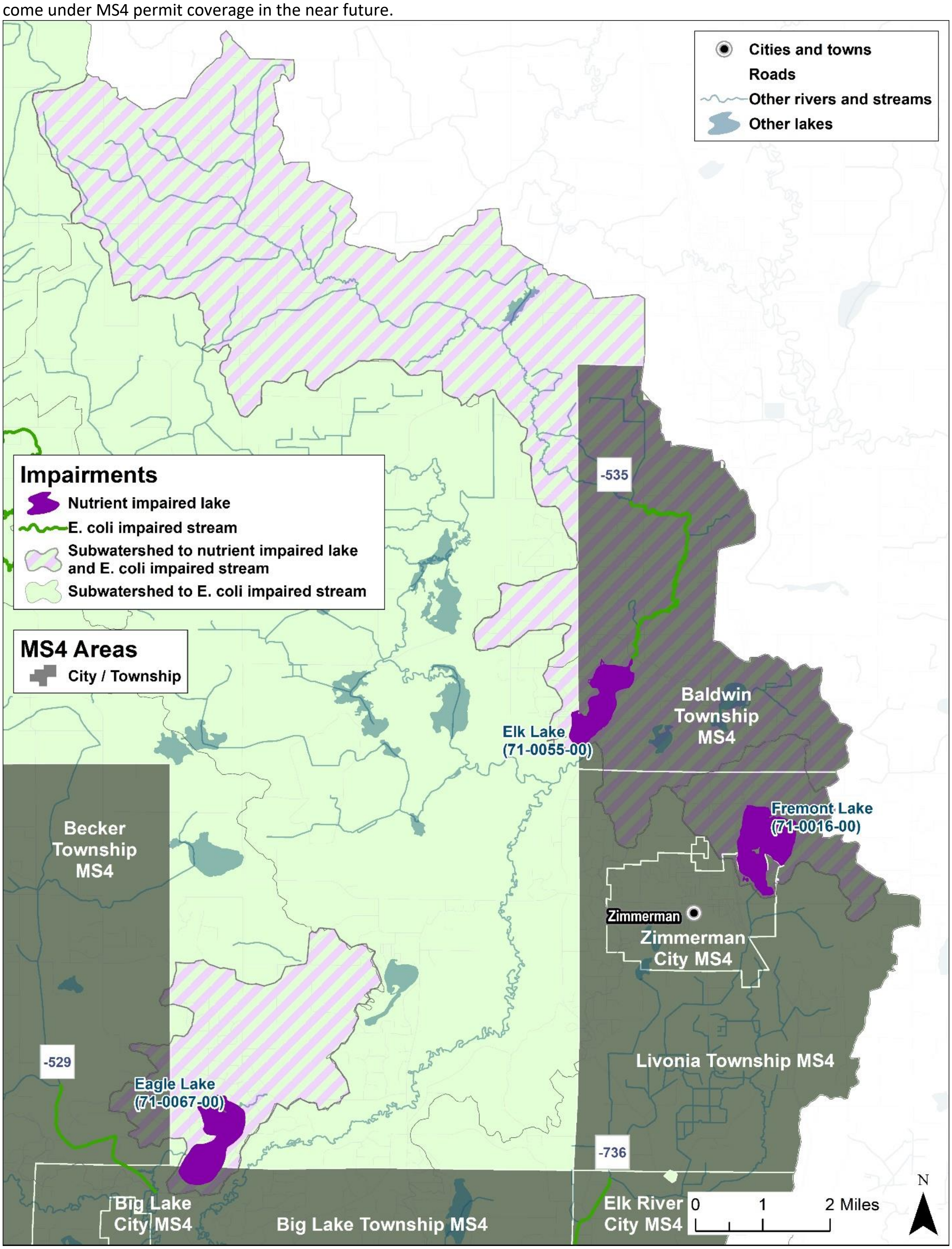


Table 61. Permitted MS4s and estimated regulated areas for lake TMDLs.

MS4 name and permit number	MS4 area (ac)	Impaired water body	Impaired water body AUID
Baldwin Township *	6,587.0	Elk Lake	71-0055-00
	315.8	Fremont Lake	71-0016-00
Becker Township *	560.0	Eagle Lake	17-0067-00
Big Lake Township (MS400234)	216.4	Eagle Lake	17-0067-00
Livonia Township *	2,113.8	Fremont Lake	71-0016-00
Zimmerman City *	154.5	Fremont Lake	71-0016-00

ac = acres; AUID = assessment unit identifier.

*These communities are not currently regulated but are expected to come under MS4 permit coverage in the near future.

4.3.4.3 Construction stormwater

Construction stormwater is permitted through the Construction Stormwater General Permit MNR100001, and a single categorical phosphorus WLA for construction stormwater is assigned to each of the impaired lakes. Refer to Section 4.2.3.3 for a discussion of the 5-year average annual percent area that is permitted through the construction stormwater permit. For each lake TMDL, the construction stormwater WLA was calculated as 0.2% multiplied by the loading capacity (i.e., TMDL) less the MOS and wastewater WLAs. It is assumed that loads from permitted construction stormwater sites that operate in compliance with their permits are meeting the WLA.

4.3.4.4 Industrial stormwater

Industrial stormwater is permitted through the NPDES/SDS General Permit for Industrial Stormwater Multi-Sector (MNR050000) and through the NPDES/SDS General Permit for Nonmetallic Mining and Associated Activities (MNG490000). Industrial stormwater permittees are required to sample their stormwater for parameters that closely match the potential contribution of pollutants for their industry sector or subsector. For example, recycling facilities and auto salvage yards are required to sample for TSS, metals, and other pollutants likely present at these types of facilities. It is assumed that loads from permitted industrial stormwater sites that operate in compliance with the permit are meeting the WLA.

Except for one operation in the Little Mary Lake–South Bay Subwatershed that has a no exposure certification, there are no operations covered by the Industrial Stormwater Multi-Sector General Permit (MNR050000) in the six impaired lake subwatersheds.

There are two facilities covered by the NPDES/SDS Nonmetallic Mining and Associated Activities General Permit (MNG490000) that are assigned a categorical industrial stormwater WLA in the Elk Lake TMDL:

There are two facilities covered by the Nonmetallic Mining Operations General Permit (MNG490000) that are assigned a categorical industrial stormwater WLA in the Elk Lake TMDL:

- Knife River Central Minnesota (MNG490003, SD 028): 17.8 acres, *Stay*
- Hastings Sand and Gravel (MNG490592, SD 005): 5.2 acres, *Greenbush Pit*

Although there are two industrial stormwater facilities in the Little Mary Lake–South Bay Subwatershed (Table 22), they were not assigned a WLA because both facilities are in the Silver Lake Subwatershed, which is part of the boundary condition to the Little Mary Lake–South Bay TMDL.

Permitted areas for the operations covered by the NPDES/SDS MNG490000 Nonmetallic Mining and Associated Activities General Permit were estimated using aerial imagery. The total area for operations covered by the WLA for the NPDES/SDS MNG490000 Nonmetallic Mining and Associated Activities General Permit in the Elk Lake Subwatershed is 23 acres. The WLA for Elk Lake was calculated using an area ratio (total area of industrial stormwater permittee divided by TMDL subwatershed area) multiplied by the quantity of the loading capacity less the MOS and wastewater WLA.

4.3.5 Margin of safety

The MOS accounts for uncertainty concerning the relationship between water quality and allocated loads. The MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e., expressed in the TMDL as a load set aside).

An explicit MOS of 10% was included in nearly all of the lake TMDLs to account for uncertainty that the pollutant allocations will attain water quality targets. The use of an explicit MOS accounts for environmental variability in pollutant loading, variability in water quality monitoring data, calibration and validation processes of modeling efforts, uncertainty in modeling outputs, conservative assumptions made during the modeling efforts, and limitations associated with the drainage area-ratio method used to extrapolate flow data. This MOS is considered to be sufficient given the robust datasets used and quality of modeling, as described below.

An explicit MOS was not allocated for Fremont Lake and Little Mary Lake–South Bay. Although on the impaired waters list, Fremont Lake currently meets the water quality standard, and the TMDL is based on a 5% reduction in loading to the lake to ensure that existing concentrations are maintained. This reduction to Fremont Lake, which is higher quality than water quality standards (existing lake concentration is 46 µg/L compared to the standard of 60 µg/L) serves as an implicit MOS; an explicit MOS is not assigned.

The Little Mary South Bay does not include an explicit MOS because it is primarily controlled by inputs from upstream impaired lakes with TMDLs for which explicit MOS are already assigned Silver Lake and Little Mary North Bay inputs represent greater than 99% of the TP load to the South Bay. Including an additional explicit MOS for the small direct drainage area to the South Bay would be overly conservative.

The HSPF model was also used to estimate watershed phosphorus loading to the impaired lakes; refer to Section 4.1.4 for a discussion of HSPF model calibration and validation. The MRSC HSPF model was calibrated and validated using six stream flow gaging stations (Tetra Tech 2019). One gage is on the main stem Mississippi River at Royalton, and the remaining sites gage tributary stream flows. Calibration results indicate that the HSPF model is a valid representation of hydrologic and water quality conditions in the watershed. The BATHTUB models used to develop the lake TMDLs show generally good agreement between the observed lake water quality and the water quality predicted by the lake response models (see Appendix B for details). The watershed loading models and lake response models reasonably reflect the watershed and lake conditions.

4.3.6 Seasonal variation and critical conditions

Seasonal variations are addressed in lake TMDLs by assessing conditions during the summer growing season, which is when the water quality standards apply (e.g., June 1 through September 30). The frequency and severity of nuisance algal growth in Minnesota lakes is typically highest during the growing season. The nutrient standards set by the MPCA—which are a growing season concentration average, rather than an individual sample (e.g., daily) concentration value—were set with this concept in mind. Additionally, by setting the TMDL to meet targets established for the most critical period (e.g., summer), the TMDL will inherently be protective of water quality during all other seasons.

Seasonal variation and critical conditions are also addressed by the water quality standards. The eutrophication standards for lakes apply from June through September. This time period is when aquatic recreation is more likely to occur in Minnesota waters and when high phosphorus concentrations generally occur.

4.3.7 Baseline year

The modeled loads used to calculate the percent reductions are from 2012 through 2022. However, except for Secchi data, all the data for the three lakes in Sherburne County were collected in 2019 and 2020 and all of the data for the three lakes in Wright County were collected in 2022. Because projects undertaken recently may take a few years to influence water quality, the baseline year for crediting load reductions for a given water body is 2016, the midpoint of the modeling time period. Any activities implemented during or after the baseline year that led to a reduction in pollutant loads to the water bodies may be considered as progress towards meeting a WLA or LA. If a BMP was implemented during or just prior to the baseline year, the MPCA may consider evidence presented by the MS4 permit holder to demonstrate that the BMP should be considered as progress towards meeting a WLA. BMPs present on the landscape during the model simulation time period are implicitly accounted for in the model.

4.3.8 Percent reduction

The estimated percent reduction provides a rough approximation of the overall reduction needed for the water body to meet the TMDL. The percent reduction is a means to capture the level of effort needed to reduce TP loads in the watershed. The estimated percent reduction needed to meet each TMDL was calculated by comparing the average of annual growing season means of observed (monitored) concentrations, which were collected from the June to September.

Annual load reduction and percent reduction are also presented for each source of loading (e.g., SSTS, internal load).

4.3.9 TMDL summary

This section provides the TMDLs for lakes with aquatic recreation use impairments. See Section 3.5.2 for an explanation of the water quality data summaries and refer to Appendix B for additional water quality analysis and model development and calibration.

Loading from the various sources to each lake are, in some cases, not easily controlled and are considered background (such as atmospheric deposition), while others are potentially controllable (such as improving septic system safety and health compliance). External loading reductions were targeted for all lakes to achieve the TP water quality standards based on assumptions of upstream lake TMDLs being met, septic system compliance, reduced watershed loads (usually the bulk of the required reductions), and reduction in explicitly quantified internal loading (for Elk Lake, Millstone Lake, and Little Mary North Bay). The total reductions required for each source type are determined using the TMDL allocation scenario from BATHTUB with additional reductions to account for the explicit MOS. The BATHTUB model outputs for the individual source load targets are not equivalent to the TMDL allocations because the model output does not include the explicit 10% MOS. The TMDL scenarios are further described in Section 4.3.1.

Additional calculations included for TMDL tables are as follows:

- Existing load: sum of all sources based on existing observed conditions.
- Load reduction: sum of individual load reductions needed.
- Percent reduction: total load reduction as a percent reduction of existing load; provides a rough approximation of the overall reduction needed for the lakes to meet the targets proposed in this report.

Summary of results by TMDL parameter and reference descriptions are presented as pounds per year and pounds per day. Loads in the TP TMDL tables are rounded to two significant digits, except in the case of values greater than 100, which are rounded to the nearest whole number. Where percent reductions are relatively small, allocations are rounded to three significant digits. Percent reductions are rounded to the nearest whole percentage point.

4.3.9.1 Eagle Lake (AUID 71-0067-00)

Eagle Lake exceeds standards (Table 62) and a TP TMDL was developed (Table 63).

The Eagle Lake modeling and evaluation in the *Big Eagle Lake Water Quality Assessment and Load Source Assessment* (WSB 2020) differs from the TMDL modeling (see Section 3.6.3.3). Although the TMDL model does not explicitly quantify internal loading, internal loading to the lake impacts lake water quality, and information from both models can be used to guide management actions.

Table 62. Eagle Lake (71-0067-00-204) water quality data summary, 2012–2021.
Values in red indicate violations of the standard.

Parameter	Years	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard [a]
TP (µg/L)	2019–2020	**54**	≤40
Chl *a* (µg/L)	2019–2020	**37**	≤14
Secchi (m)	2019–2020	**1.2**	≥1.4

a. North Central Hardwood Forest ecoregion lake standard.

Table 63. TP TMDL summary, Eagle Lake (AUID 71-0067-00).

- 303(d) listing year: 2022
- Baseline year: 2016
- Use class: 2B
- Numeric standard used to calculate TMDL: 40 µg/L TP
- Standard applicable: June–September

TMDL parameter		Existing load	TMDL allocation		Load reduction needed	
		lb/year	lb/year	lb/day	lb/year	%
WLA	Construction stormwater	0.87	0.87	0.0024	0	0%
	Big Lake Township (MS400234)	17	9.3	0.025	7.7	45%
	Becker Township (future MS4)	44 [a]	24	0.066	20	45%
	Total WLA	**62**	**34**	**0.093**	**28**	**45%**
LA	Watershed Runoff (unregulated)	304	166	0.45	138	45%
	SSTS	181	127	0.35	54	30%
	Atmospheric Deposition	110	110	0.30	0	0%
	Total LA	**595**	**403**	**1.1**	**192**	**32%**
MOS		**-**	**49**	**0.13**	**-**	**-**
Total Load		**657**	**486**	**1.3**	**220**	**33%**

a. The existing load from Becker Township is represented as future MS4.

4.3.9.2 Elk Lake (AUID 71-0055-00)

Elk Lake exceeds standards (Table 64), and a TP TMDL was developed (Table 65).

Table 64. Elk Lake (71-0055-00-202) water quality data summary, 2012–2021.
Values in red indicate violations of the standard.

Parameter	Years	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard [a]
TP (µg/L)	2019	**89**	≤60
Chl *a* (µg/L)	2019	**48**	≤20
Secchi (m)	2012–2021	**0.88**	≥1.0

a. North Central Hardwood Forest ecoregion lake standard for shallow lakes.

Table 65. TP TMDL summary, Elk Lake (AUID 71-0055-00).

- 303(d) listing year: 2012
- Baseline year: 2016
- Use class: 2B
- Numeric standard used to calculate TMDL: 60 µg/L TP
- Standard applicable: June–September

TMDL parameter		Existing load	TMDL allocation		Load reduction needed	
		lb/year	lb/year	lb/day	lb/year	%
Boundary condition at Diann Lake (71-0046-00) [a]		**377**	**306**	**0.84**	**71**	**19%**
WLA	Construction stormwater	5.1	5.1	0.014	0	0%
	Industrial stormwater	2.5	2.5	0.0068	0	0%
	Knife River Central Minnesota (MNG490003)	9.8	9.8	0.027	0	0%
	Baldwin Township (future MS4)	792 [b]	528	1.4	264	33%
	Total WLA	**809**	**545**	**1.4**	264	33%
LA	Watershed Runoff (unregulated)	2,304	1,537	4.2	767	33%
	SSTS	112	78	0.21	34	30%
	Atmospheric Deposition	86	86	0.24	0	0%
	Internal Loading	529	0	0	529	100% [c]
	Total LA	**3,031**	**1,701**	**4.7**	1,330	44%
MOS		**-**	**284**	**0.77**	**-**	**-**
Total Load		**4,217**	**2,836**	**7.7**	**1,665**	**39%**

a. The Diann Lake boundary condition addresses the load from the Diann Lake outlet (Section 4.3.2).

b. The existing load from Baldwin Township is represented as future MS4.

c. 100% reduction in internal load assumes that the additional internal load is removed, and the remaining internal load to the lake equals the average rate of internal loading that is implicit in BATHTUB.

4.3.9.3 Fremont Lake (AUID 71-0016-00)

Fremont Lake is on the impaired waters list, but recent data show the lake meeting the TP standard (Table 66). A TP TMDL was developed to ensure that TP remains below the TP standard (Table 67). The TMDL reflects Sherburne SWCD's goal for Fremont Lake, which is a 5% reduction in phosphorus loads to the lake, corresponding to a lake target of 42 µg/L TP.

Table 66. Fremont Lake (AUID 71-0016-202) water quality data summary, 2012–2021.
Values in red indicate violations of the standard.

Parameter	Years	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard [a]
TP (µg/L)	2019–2020	46	≤60
Chl *a* (µg/L)	2019–2020	**21**	≤20
Secchi (m)	2019–2020	1.1	≥1.0

a. North Central Hardwood Forest ecoregion lake standard for shallow lakes.

Table 67. TP TMDL summary, Fremont Lake (AUID 71-0016-00).

- 303(d) listing year: 2012
- Baseline year: 2016
- Use class: 2B
- Numeric target used to calculate TMDL: 44 µg/L TP
  (The numeric standard for this lake is 60 µg/L but the lake currently meets this standard. The target represents the expected lake concentration that results from a 5% reduction in phosphorus loads to the lake.)
- Standard applicable: June–September

TMDL parameter		Existing load [a]	TMDL allocation		Load reduction needed	
		lb/year	lb/year	lb/day	lb/year	%
WLA	Construction stormwater	0.83	0.83	0.0023	0	0%
	Baldwin Township (future MS4)	24.3	23.8	0.065	0.5	2% [b]
	Livonia Township (future MS4)	163	160	0.44	3.0	2%
	Zimmerman City (future MS4)	11.9	11.7	0.032	0.2	2%
	Total WLA	**200**	**196**	**0.54**	**3.7**	2%
LA	SSTS	167	147 [c]	0.40	20	12%
	Atmospheric Deposition	118	118	0.32	0	0%
	Total LA	**285**	**265**	**0.72**	**20**	**7%**
Total Load		**485**	**461**	**1.3**	**24**	**5%**

a. The entire Fremont Lake drainage area is future MS4. The existing load from the area is represented as future MS4 area.

b. A nominal reduction was chosen for presumed future MS4s in the Fremont Lake Watershed. Although the lake currently meets water quality standards, all sources, including MS4s, should be reduced to ensure maintenance of lake water quality conditions.

c. The SSTS LA represents a portion of all SSTS around the lake being in compliance; additional reductions could be achieved with 100% compliance.

4.3.9.4 Little Mary Lake–North Bay (AUID 86-0139-02)

Little Mary Lake–North Bay exceeds standards (Table 68) and a TP TMDL was developed (Table 69).

Table 68. Little Mary Lake–North Bay (AUID 86-0139-02-201) water quality data summary, 2012–2022. Values in red indicate violations of the standard.

Parameter	Years	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard [a]
TP (µg/L)	2022	**138**	≤60
Chl *a* (µg/L)	2022	**92**	≤20
Secchi (m)	2022 [b]	**0.34**	≥1.0

a. North Central Hardwood Forest ecoregion lake standard for shallow lakes.
b. One sample was omitted in the calculation: July 17, 2016 (3.5 meters), which was the only 2016 sample.

Table 69. TP TMDL summary, Little Mary Lake–North Bay (AUID 86-0139-02).

- 303(d) listing year: 2012
- Baseline year: 2016
- Use class: 2B
- Numeric standard used to calculate TMDL: 60 µg/L TP
- Standard applicable: June–September

TMDL parameter		Existing load	TMDL allocation		Load reduction needed	
		lb/year	lb/year	lb/day	lb/year	%
WLA	Construction stormwater	1.4	1.4	0.0038	0	0%
	Total WLA	**1.4**	**1.4**	**0.0038**	**0**	**0%**
LA	Watershed Runoff	605	286	0.78	319	53%
	Atmospheric Deposition	21	21	0.058	0	0%
	Internal Loading	1,392	378	1.0	1,015	73%
	Total LA	**2,018**	**685**	**1.8**	**1,334**	**66%**
MOS		**-**	**76**	**0.21**	**-**	**-**
Total Load		**2,019**	**762**	**2.1**	**1,334**	**66%**

4.3.9.5 Little Mary Lake–South Bay (AUID 86-0139-01)

Little Mary Lake–South Bay exceeds standards (Table 70) and a TP TMDL was developed (Table 71).

Table 70. Little Mary Lake–South Bay (AUID 86-0139-01-201) water quality data summary, 2012–2022. Values in red indicate violations of the standard.

Parameter	Years	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard [a]
TP (µg/L)	2022	**143**	≤60
Chl *a* (µg/L)	2022	**92**	≤20
Secchi (m)	2022	**0.46**	≥1.0

a. North Central Hardwood Forest ecoregion lake standard for shallow lakes.

Table 71. TP TMDL summary, Little Mary Lake–South Bay (AUID 86-0139-01).

- 303(d) listing year: 2012
- Baseline year: 2016
- Use class: 2B
- Numeric standard used to calculate TMDL: 60 µg/L TP
- Standard applicable: June–September

TMDL parameter		Existing load	TMDL allocation		Load reduction needed	
		lb/year	lb/year	lb/day	lb/year	%
Boundary condition at Silver Lake (86-0140-00) [a]		**2,193**	**1,110**	**3.0**	**1,082**	**49%**
Boundary condition at Little Mary North Bay (86-0139-02)		**2,019**	**762**	**2.1**	**1,257**	**62%**
WLA	Construction stormwater	3.8	3.8	0.010	0	0%
	Total WLA	**3.8**	**3.8**	**0.010**	**0**	**0%**
LA	Watershed Runoff	14.5	5.5	0.015	9	62%
	Atmospheric Deposition	3.5	3.5	0.010	0	0%
	Total LA	**18.1**	**9.0**	**0.025**	**9.0**	**62%**
MOS [b]		**-**	**-**	**-**	**-**	**-**
Total Load		**4,234**	**1,885**	**5.1**	**2,348**	**55%**

a. Industrial stormwater permittees are located upstream of Silver Lake

b. An explicit MOS is not allocated to Little Mary Lake–South Bay. The North Bay and South Bay were simulated together in the same BATHTUB model, and explicit MOS was assigned to the Little Mary Lake–North Bay TMDL (Table 69). Additionally, explicit MOS was allocated in the Silver Lake TMDL. Together, the Little Mary Lake–North Bay and Silver Lake boundary conditions are >99% of the allocated load to Little Mary Lake–South Bay. Including an additional explicit MOS for the South Bay would be overly conservative.

4.3.9.6 Millstone Lake (AUID 80-0152-00)

Millstone Lake exceeds standards (Table 72) and a TP TMDL was developed (Table 73).

Table 72. Millstone Lake (AUID 80-0152-00-201) water quality data summary, 2012–2022.
Values in red indicate violations of the standard.

Parameter	Years	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard [a]
TP (µg/L)	2022	**223**	≤60
Chl *a* (µg/L)	2022	**126**	≤20
Secchi (m)	2022	**0.20**	≥1.0

a. North Central Hardwood Forest ecoregion lake standard for shallow lakes.

Table 73. TP TMDL summary, Millstone Lake (AUID 80-0152-00).

- 303(d) listing year: 2012
- Baseline year: 2016
- Use class: 2B
- Numeric standard used to calculate TMDL: 60 µg/L TP
- Standard applicable: June–September

TMDL parameter		Existing load	TMDL allocations		Load reduction needed	
		lb/year	lb/year	lb/day	lb/year	%
WLA	Construction stormwater	1.3	1.3	0.0036	0	0%
	Total WLA	**1.3**	**1.3**	**0.0036**	**0**	**0%**
LA	Watershed Runoff	199	57	0.16	142	71%
	Atmospheric Deposition	48	48	0.13	0	0%
	Internal loading	388	51	0.14	337	87%
	Total LA	**635**	**156**	**0.43**	**479**	**75%**
MOS		**-**	**18**	**0.048**	**-**	**-**
Total Load		**636**	**175**	**0.48**	**479**	**75%**

5.0 Future growth considerations

Land use in the MRSC is largely agricultural; however, the two large urban areas around St. Cloud and northwest of the Twin Cities metropolitan area are expected to continue to increase. Considerable development has been occurring recently along the I-94 corridor that connects the city of St. Cloud to the Twin Cities. From 2000 to 2005, Stearns County's population grew by 7.1%, much higher than the statewide average of 4.2% for the same period (Stearns County 2008). Over the next three decades, the Minnesota State Demographic Center projects growth in Benton, Sherburne, Stearns, and Wright counties (Table 74).

Table 74. Estimated population growth.

Jurisdiction	Population on April 1, 2020 [a]	Future Growth [b]
Benton County	41,379	10–20%
Sherburne County	97,183	20–30%
Stearns County	158,292	10–20%
Wright County	141,377	30–40%

a. U.S. Census 2020

b. Minnesota State Demographic Center projections for growth between 2018–2053.

5.1 New or expanding permitted MS4 WLA transfer process

Future transfer of watershed runoff loads in this TMDL may be necessary if any of the following scenarios occur within the project watershed boundaries.

1. New development occurs within a permitted MS4. Newly developed areas that are not already included in the WLA must be transferred from the LA to the WLA to account for the growth.
2. One permitted MS4 acquires land from another permitted MS4. Examples include annexation or highway expansions. In these cases, the transfer is WLA to WLA.
3. One or more nonpermitted MS4s become permitted. If this has not been accounted for in the WLA, then a transfer must occur from the LA.
4. Expansion of a U.S. Census Bureau Urbanized Area encompasses new regulated areas for existing permittees. An example is existing state highways that were outside an urban area at the time the TMDL was completed but are now inside a newly expanded urban area. This will require either a WLA to WLA transfer or a LA to WLA transfer.
5. A new MS4 or other stormwater-related source is identified and is covered under an NPDES/SDS permit. In this situation, a transfer must occur from the LA.

Load transfers will be based on methods consistent with those used in setting the allocations in this TMDL. In cases where WLA is transferred from or to a permitted MS4, the permittees will be notified of the transfer and have an opportunity to comment.

The areal target loading rates for watershed runoff (both MS4 and non-MS4) in Table 75 reflect the combined TMDL TP allocated loads from these sources divided by the total drainage area of the watershed. These rates should be used for allocation transfers within the impaired lake watersheds.

Table 75. Unit area loading rates of watershed phosphorus loading to be used in allocation transfers

Impaired lake	Areal loading rate (lb/acre-year)
Eagle Lake (AUID 71-0067-00)	0.043
Elk Lake (AUID 71-0055-00)	0.16 [a]
Fremont Lake (AUID 71-0016-00	0.093
Little Mary Lake–North Bay (AUID 86-0139-02)	0.050
Little Mary Lake–South Bay (AUID 86-0139-01)	0.059
Millstone Lake (AUID 80-0152-00)	0.13

[a] Watershed runoff (unregulated and MS4) allocations for the Battle Brook Subwatershed (95% of the TMDL subwatershed area, not counting the Diann Lake Subwatershed) represent the load that reaches Elk Lake. Assuming that loads in the Battle Brook Subwatershed are attenuated by 33% (simulated in the HSPF model), the watershed runoff LA and MS4 WLA equate to an areal phosphorus loading rate of 0.16 lb/acre-year, averaged over the Battle Brook and direct drainage subwatersheds.

5.2 New or expanding wastewater

The MPCA, in coordination with the EPA Region 5, has developed a streamlined process for setting or revising WLAs for new or expanding wastewater discharges to water bodies with an EPA approved TMDL for TSS or *E. coli* (described in MPCA 2012a). This procedure will be used to update WLAs in approved TMDLs for new or expanding wastewater dischargers whose permitted effluent limits are at or below the instream target and will ensure that the effluent concentrations will not exceed applicable water quality standards or surrogate measures. The process for modifying any and all WLAs will be overseen by the MPCA, with input and involvement by the EPA, once a permit request or reissuance is submitted. The overall process will use the permitting public notice process to allow for the public and EPA to comment on the permit changes based on the proposed WLA modification(s). Once any comments or concerns are addressed, and the MPCA determines that the new or expanded wastewater discharge is consistent with the applicable water quality standards, the permit will be issued and any updates to the TMDL WLA(s) will be made.

6.0 Reasonable assurance

“Reasonable assurance” shows that elements are in place, for both permitted and nonpermitted sources, that are making (or will make) progress toward needed pollutant reductions.

6.1 Reduction of permitted sources

6.1.1 Permitted MS4s

The MPCA is responsible for applying federal and state regulations to protect and enhance water quality in Minnesota. The MPCA oversees stormwater management accounting activities for all permitted MS4 entities listed in this TMDL report. The MS4 General Permit requires regulated municipalities to implement BMPs that reduce pollutants in stormwater to the maximum extent practicable. A critical component of permit compliance is the requirement for the owners or operators of a permitted MS4 conveyance to develop a SWPPP. The SWPPP addresses all permit requirements, including the following six measures:

- Public education and outreach
- Public participation
- Illicit discharge detection and elimination program
- Construction site runoff controls
- Post-construction runoff controls
- Pollution prevention and municipal good housekeeping measures

A SWPPP is a management plan that describes the MS4 permittee’s activities for managing stormwater within their regulated area. In the event of a completed TMDL study, MS4 permittees must document the WLA in their future NPDES/SDS permit application and provide an outline of the BMPs to be implemented that address needed reductions. The MPCA requires MS4 owners or operators to submit their application and corresponding SWPPP document to the MPCA for review. Once the application and SWPPP are deemed adequate by the MPCA, all application materials are placed on 30-day public notice, allowing the public an opportunity to review and comment on the prospective program. Once NPDES/SDS permit coverage is granted, permittees must implement the activities described within their SWPPP and submit an annual report to the MPCA documenting the implementation activities completed within the previous year, along with an estimate of the cumulative pollutant reduction achieved by those activities.

This TMDL report assigns WLAs to permitted MS4s in the study area. The MS4 General Permit requires permittees to develop compliance schedules for EPA approved TMDL WLAs not already being met at the time of permit application. A compliance schedule includes BMPs that will be implemented over the permit term, a timeline for their implementation, and a long-term strategy for continuing progress towards assigned WLAs. For WLAs being met at the time of permit application, the same level of treatment must be maintained in the future. Regardless of WLA attainment, all permitted MS4s are still required to reduce pollutant loadings to the maximum extent practicable.

The MPCA’s stormwater program and its NPDES/SDS permit program are regulatory activities providing reasonable assurance that implementation activities are initiated, maintained, and consistent with WLAs assigned in this study.

6.1.2 Permitted construction stormwater

Regulated construction stormwater was given a categorical WLA is this study. Construction activities disturbing one acre or more are required to obtain NPDES/SDS permit coverage through the MPCA. Compliance with TMDL requirements is assumed when a construction site owner/operator meets the conditions of the Construction General Permit and properly selects, installs, and maintains all BMPs required under the permit, including any applicable additional BMPs required in Section 23 of the Construction General Permit for discharges to impaired waters, or compliance with local construction stormwater requirements if they are more restrictive than those in the State General Permit.

6.1.3 Permitted industrial stormwater

Industrial stormwater was given a categorical WLA in this study. Industrial activities require permit coverage under the state's NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) or NPDES/SDS Nonmetallic Mining/Associated Activities General Permit (MNG490000). If a facility owner/operator obtains stormwater coverage under the appropriate NPDES/SDS permit and properly selects, installs, and maintains BMPs sufficient to meet the benchmark values in the permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL report.

6.1.4 Permitted wastewater

Any NPDES/SDS permitted facility discharging wastewater that has a reasonable potential to cause or contribute to the water quality impairments addressed by these TMDLs include, or will include upon permit reissuance, water quality based effluent limits that are consistent with the assumptions and requirements of these TMDL WLAs. Discharge monitoring is conducted by permittees and routinely submitted to the MPCA for review.

NPDES/SDS permits for discharges that may cause or have reasonable potential to cause or contribute to an exceedance of a water quality standard are required to contain water quality-based effluent limits (WQBELs) consistent with the assumptions and requirements of the WLAs in this TMDL report. Attaining the WLAs, as developed and presented in this TMDL report, is assumed to ensure meeting the water quality standards for the relevant impaired waters listings. During the permit issuance or reissuance process, wastewater discharges will be evaluated for the potential to cause or contribute to violations of water quality standards. WQBELs will be developed for facilities whose discharges are found to have a reasonable potential to cause or contribute to exceedances of applicable water quality standards. The WQBELs will be calculated based on low flow conditions, may vary slightly from the TMDL WLAs, and may include concentration based effluent limitations.

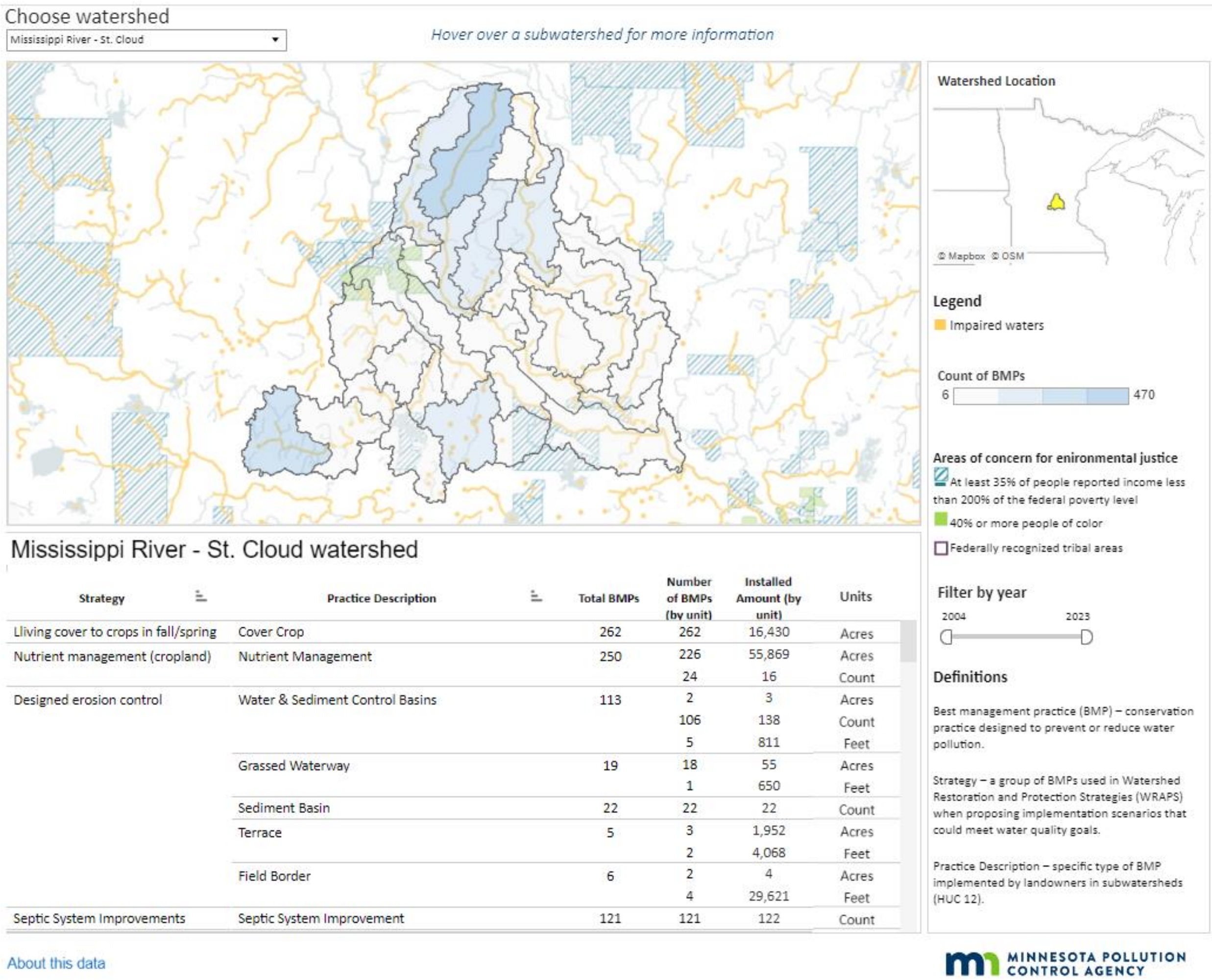
6.1.5 Permitted feedlots

See the discussion of the state’s Feedlot Program in Section 6.2.2, which applies to both permitted and nonpermitted feedlots.

6.2 Reduction of nonpermitted sources

Several nonpermitted reduction programs exist to support implementation of nonpoint source reduction BMPs in the MRSCW. These programs identify BMPs, provide means of focusing BMPs, and support their implementation via state initiatives, ordinances, and/or dedicated funding. Figure 39 shows the number of BMPs per subwatershed, as tracked on the MPCA's Healthier Watersheds website (https://www.pca.state.mn.us/water/healthier-watersheds).

Figure 39. Number of BMPs per subwatershed; data from the MPCA's Healthier Watersheds website (November 2023).



Strategy	Practice Description	Total BMPs	Number of BMPs (by unit)	Installed Amount (by unit)	Units
Lliving cover to crops in fall/spring	Cover Crop	262	262	16,430	Acres
Nutrient management (cropland)	Nutrient Management	250	226	55,869	Acres
			24	16	Count
Designed erosion control	Water & Sediment Control Basins	113	2	3	Acres
			106	138	Count
			5	811	Feet
	Grassed Waterway	19	18	55	Acres
			1	650	Feet
	Sediment Basin	22	22	22	Count
	Terrace	5	3	1,952	Acres
			2	4,068	Feet
	Field Border	6	2	4	Acres
			4	29,621	Feet
Septic System Improvements	Septic System Improvement	121	121	122	Count

Many soil and water conservation districts (SWCDs) are active in the project area, and many provide technical and financial assistance on topics; refer to Section 6.4 for discussions of assistance provided by the Benton, Sherburne, and Stearns SWCDs.

The following examples describe large-scale programs that have proven to be effective and/or will reduce pollutant loads going forward.

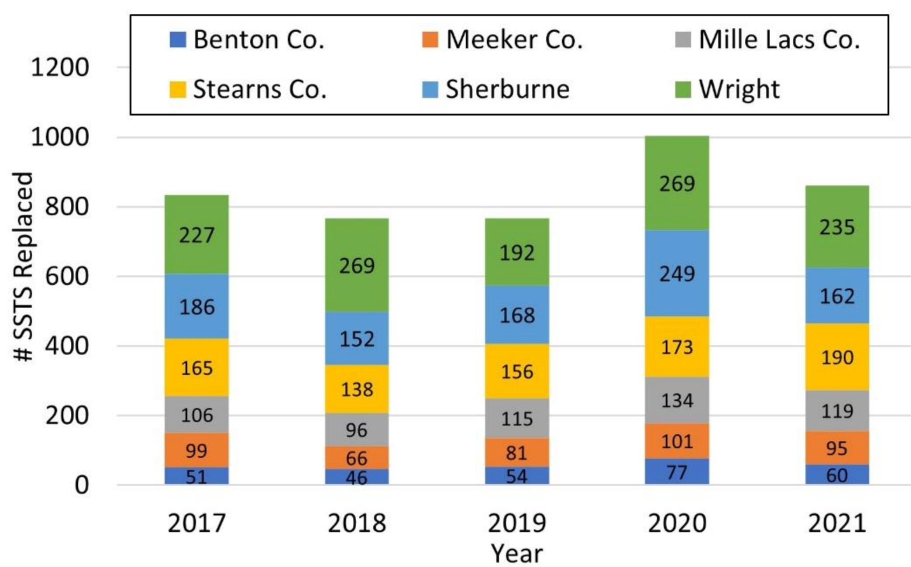
6.2.1 SSTS regulation

SSTSs are regulated through Minn. Stat. §§ 115.55 and 115.56. SSTS specific rule requirements can be found in Minn. R. 7080 through 7083. Regulations include the following:

- Minimum technical standards for design and installation of individual and mid-size SSTS
- A framework for local units of government to administer SSTS programs
- Statewide licensing and certification of SSTS professionals, SSTS product review and registration, and establishment of the SSTS Advisory Committee
- Various ordinances for SSTS installation, maintenance, and inspection

Each county maintains an SSTS ordinance, in accordance with Minn. Stat. and Minn. R., establishing minimum requirements for regulation of SSTS, for the treatment and dispersal of sewage within the applicable jurisdiction of the county, to protect public health and safety, to protect groundwater quality, and to prevent or eliminate the development of public nuisances. Ordinances serve the best interests of the county's residents by protecting health, safety, general welfare, and natural resources. In addition, each county zoning ordinance prescribes the technical standards that on-site septic systems are required to meet for compliance and outlines the requirements for the upgrade of systems found not to be in compliance. This includes systems subject to inspection at transfer of property, upon the addition of living space that includes a bedroom and/or a bathroom, and at discovery of the failure of an existing system. Since 2017, the counties within the MRSCW have, on average, replaced 846 systems per year (Figure 40).

Figure 40. SSTS replacements by county by year.



All known ITPHS are recorded in a statewide database by the MPCA. From 2006 to 2019, 797 alleged straight pipes were tracked by the MPCA statewide, 765 of which were abandoned, fixed, or were found not to be a straight pipe system. The remaining known, unfixed, straight pipe systems have received a notice of noncompliance and are currently within the 10-month deadline to be fixed, have been issued Administrative Penalty Orders, or are docketed in court. The MPCA, through the Clean Water

Partnership (CWP) Loan Program, awarded $1,000,000 to Wright County to provide low interest loans for SSTS upgrades in 2021. In April 2023, through this same CWP Loan program, the MPCA executed an agreement with Benton County for $750,000 for the period of April 2023 through April 2026. More information on SSTS financial assistance can be found at the following URL: https://www.pca.state.mn.us/water/ssts-financial-assistance.

6.2.2 Feedlot Program

This section describes the MPCA's Feedlot Program, which addresses both permitted and nonpermitted feedlots. The Feedlot Program implements rules governing the collection, transportation, storage, processing, and disposal of animal manure and other livestock operation wastes. Minn. R. ch. 7020 regulates feedlots in the state of Minnesota. All feedlots are subject to this rule. The focus of the rule is on animal feedlots and manure storage areas that have the greatest potential for environmental impact. All feedlots capable of holding 50 or more AUs, or 10 in shoreland areas, are required to register. A feedlot holding 1,000 or more AUs is required to obtain a permit.

The Feedlot Program is implemented through cooperation between MPCA and delegated county governments in 50 counties in the state. The MPCA works with county representatives to provide training, program oversight, policy and technical support, and formal enforcement support when needed. A county participating in the program has been delegated authority by the MPCA to administer the Feedlot Program. These delegated counties receive state grants to help fund their feedlot programs based on the number of feedlots in the county and the level of inspections they complete. In recent years, annual grants given to these counties statewide totaled about two million dollars (MPCA 2017). The delegated counties in the project area for this report are Meeker, Stearns, and Wright, and the counties that are not delegated are Benton, Mille Lacs, and Sherburne. In the counties that are not delegated, the MPCA is tasked with running the Feedlot Program.

From 2016 through 2021, 37 feedlot facilities were inspected in the *E. coli* impaired subwatersheds in the MRSCW, with 33 of those inspections occurring at non-CAFO facilities and 4 at CAFO facilities. There has been an additional one facility (a CAFO) with a manure application review within the *E. coli* impaired subwatersheds.

6.2.3 Minnesota buffer law

Minnesota's buffer law (Minn. Stat. § 103F.48) requires perennial vegetative buffers of up to 50 feet along lakes, rivers, and streams and buffers of 16.5 feet along ditches. These buffers help filter out phosphorus, nitrogen, and sediment. Alternative practices are allowed in place of a perennial buffer in some cases. Amendments enacted in 2017 clarify the application of the buffer requirement to public waters, provide additional statutory authority for alternative practices, address concerns over the potential spread of invasive species through buffer establishment, establish a riparian protection aid program to fund local government buffer law enforcement and implementation, and allowed landowners to be granted a compliance waiver until July 1, 2018, when they filed a compliance plan with the appropriate SWCD.

The Board of Water and Soil Resources (BWSR) provides oversight of the buffer program, which is primarily administered at the local level. Compliance with the buffer law ranges from 95% to 100% for all counties in the MRSCW as of January 2023.

6.2.4 Minnesota Agricultural Water Quality Certification Program

The Minnesota Agricultural Water Quality Certification Program (MAWQCP) is a voluntary opportunity for farmers and agricultural landowners to take the lead in implementing conservation practices that protect our water. Those who implement and maintain approved farm management practices will be certified and, in turn, obtain regulatory certainty for a period of 10 years.

Through this program, certified producers receive:

- Regulatory certainty: certified producers are deemed to be in compliance with any new water quality rules or laws during the period of certification
- Recognition: certified producers may use their status to promote their business as protective of water quality
- Priority for technical assistance: producers seeking certification can obtain specially designated technical and financial assistance to implement practices that promote water quality

Through this program, the public receives assurance that certified producers are using conservation practices to protect Minnesota's lakes, rivers, and streams. Since the start of the program in 2014 through April 2024, the program has achieved the following:

- Enrolled over 1,070,000 acres
- Included 1,487 producers
- Added more than 2,880 new conservation practices
- Kept over 48,200 tons of sediment out of Minnesota rivers
- Saved 144,000 tons of soil and 60,300 pounds of phosphorus on farms
- Cut greenhouse gas emissions by more than 52,500 tons annually
- Approximately 23,987 acres in the MRSCW are certified under the MAWQCP.

6.2.5 Minnesota Nutrient Reduction Strategy

The *Minnesota Nutrient Reduction Strategy* (MPCA 2014) guides activities that support nitrogen and phosphorus reductions in Minnesota water bodies and water bodies downstream of the state (e.g., Lake Winnipeg, Lake Superior, and the Gulf of Mexico). The Nutrient Reduction Strategy was developed by an interagency steering team with help from public input, and a progress report was completed in 2020. The *5-year Progress Report on Minnesota's Nutrient Reduction Strategy* (MPCA 2020) provides an update on progress made in the state towards achieving the nutrient reduction goals and associated BMP implementation outlined in the original 2014 strategy. *Watershed Nutrient Loads to Accomplish Minnesota's Nutrient Reduction Strategy Goals* (MPCA 2022e) integrates the state's nutrient reduction strategy into local watershed work by developing load reduction planning goals on a HUC-8 watershed basis.

Fundamental elements of the *Minnesota Nutrient Reduction Strategy* include:

- Defining progress with clear goals
- Building on current strategies and success
- Prioritizing problems and solutions
- Supporting local planning and implementation
- Improving tracking and accountability

Included within the strategy discussion are alternatives and tools for consideration by drainage authorities and local water resource managers, information on available approaches for reducing phosphorus and nitrogen loading and tracking efforts within a watershed, and additional research priorities. The *Minnesota Nutrient Reduction Strategy* is focused on incremental progress and provides meaningful and achievable nutrient load reduction milestones that allow for better understanding of incremental and adaptive progress toward final goals. The strategy set a reduction goal of 45% for both phosphorus and nitrogen in the Mississippi River Basin (relative to average 1980 to 1996 conditions), a similar level of nutrient reduction for the Red River/Lake Winnipeg basin (relative to the mid to late 1990s), and a no net increase goal from the 1970s for the Lake Superior Basin. The strategy also emphasizes the need to achieve local nutrient reduction needs within HUC-8 watersheds.

Successful implementation of the *Minnesota Nutrient Reduction Strategy* will continue to require broad support, coordination, and collaboration among agencies, academia, local government, and private industry. Minnesota is implementing a watershed approach to integrate its water quality management programs on a major watershed scale, a process that includes:

- IWM
- Assessment of watershed health
- Development of WRAPS reports that include BMP scenarios to achieve nutrient load reductions
- Management of NPDES/SDS and other regulatory and assistance programs

This framework will result in nutrient reduction for the basin as a whole and the major watersheds within the basin.

6.2.6 Conservation easements

Conservation easements are a critical component of the state's efforts to improve water quality by reducing soil erosion, reducing phosphorus and nitrogen loading, and improving wildlife habitat and flood attenuation on private lands. Easements protect the state's water and soil resources by permanently restoring wetlands, adjacent native grassland wildlife habitat complexes, and permanent riparian buffers. In cooperation with county SWCDs, state and federal programs compensate landowners for granting conservation easements and establishing native vegetation habitat on economically marginal, flood prone, environmentally sensitive, or highly erodible lands. These easements vary in length of time from 10 years to permanent/perpetual easements. Conservation easement types in Minnesota include CRP, Conservation Reserve Enhancement Program (CREP), Reinvest in Minnesota (RIM), and the Wetland Reserve Program (WRP) or Permanent Wetland Preserve

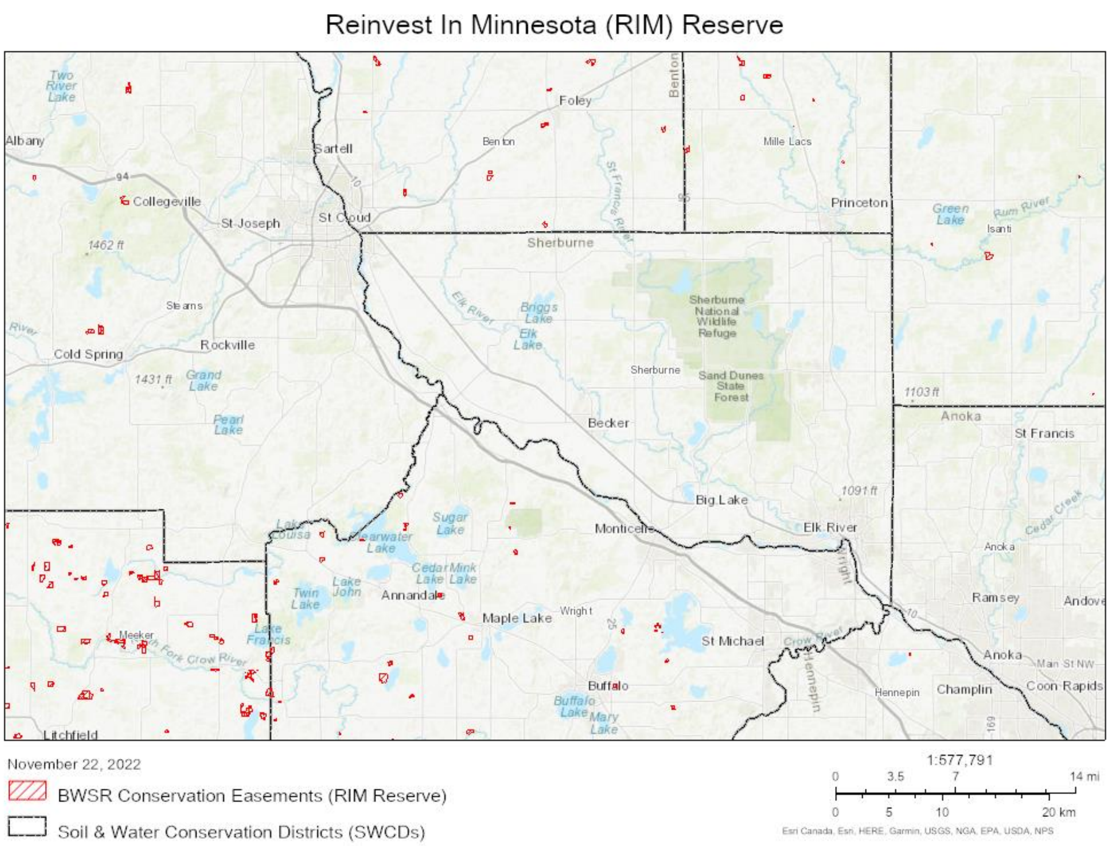
(PWP). As of August 24, 2021, in the counties that are in the MRSCW, there were 46,808 acres of short-term conservation easements such as CRP and 8,931 acres of long term or permanent easements (CREP, RIM, WRP; Table 76). Meeker, Stearns, and Wright counties are 3 of 54 counties in Minnesota eligible for CREP.

Table 76. Conservation easements as of July 26, 2023 (data from BWSR downloaded November 2023, available on BWSR website under Summary of Conservation Lands by County).

County	CRP	CREP	RIM	RIM/WRP	WRP
Benton	2,630	0	961	0	0
Meeker	19,680	1096	3,717	453	151
Mille Lacs	711	0	299	0	0
Sherburne	1,280	0	0	0	51
Stearns	18,711	644	1,008	120	211
Wright	4,185	19	882	292	128

CREP = Conservation Reserve Enhancement Program; CRP = Conservation Reserve Program; RIM = Reinvest in Minnesota; WRP = Wetland Reserve Program.

Figure 41. RIM Reserve state-funded conservation easements in the counties that are located in MRSCW (data from BWSR).



6.3 Summary of local plans

Minnesota has a long history of water management by local government, which included developing water management plans along county boundaries since the 1980s. The BWSR-led 1W1P program is rooted in work initiated by the Local Government Water Roundtable (Association of Minnesota Counties, Minnesota Association of Watershed Districts, and Minnesota Association of SWCDs). The Roundtable recommended that local governments organize to develop focused implementation plans based on watershed boundaries. That recommendation was followed by the legislation (Minn. Stat. § 103B.801) that established the 1W1P program, which provides policy, guidance, and support for developing Comprehensive Watershed Management Plan (CWMP):

- Align local water planning purposes and procedures on watershed boundaries to create a systematic, watershed-wide, science-based approach to watershed management.
- Acknowledge and build off of existing local government structure, water plan services, and local capacity.
- Incorporate and make use of data and information, including WRAPS.
- Solicit input and engage experts from agencies, residents, and stakeholder groups; focus on implementation of prioritized and targeted actions capable of achieving measurable progress.
- Serve as a substitute for a comprehensive plan, local water management plan, or watershed management plan developed or amended, approved, and adopted.

In 2021, the Benton SWCD was awarded a planning grant from BWSR to work on development of the MRSCW CWMP. The boundary of the watershed and planning area are the same as the MRSC in this TMDL. The Benton SWCD has contracted with ISG Inc., to assist the local partners in development of this CWMP. The planning processed is slated for completion in June 2024.

Until the completion of a CWMP in the MRSCW, county water plans remain in effect per the Comprehensive Local Water Management Act (Minn. Stat. § 103B.301). Those plans may be updated with new information, or their expiration dates may be extended pending future participation in the 1W1P program. Local water plans incorporate implementation strategies aligned with or called for in TMDLs and WRAPS and are implemented by SWCDs, counties, state and federal agencies, and other partners.

The following is a list of local county water plans for major counties (excluding Morrison and Mille Lacs Counties due to limited land in this watershed) in the MRSCW and a brief description of how each plan addresses the water quality issues identified in this report.

Benton County Comprehensive Local Water Management Plan 2008-2018

The plan addresses four priority concerns:

- Feedlot and Nutrient Management: Protect surface water quality by encouraging proper nutrient management of animal manure and fertilizers.
- Erosion and Sedimentation: Excess runoff and sediment in surface waters can have negative impacts on surface water quality.

- Development: Water resources have the potential to be adversely affected by residential, commercial, and industrial growth and development, as well as rural land use changes.
- Surface and Groundwater Quality and Quantity: Protect water resources from increasing demands to prevent potential problems with water quantity. Protect and prevent surface and groundwater from contamination and other impairment factors which negatively affect water quality.

For the Elk River Watershed, this plan highlights that as of 2017, approximately 260 BMPs were installed since 1994 with assistance and support from the Elk River Watershed Association. This does not include projects that were completed using only federal funding. BMP categories applicable to this TMDL include cropland erosion control, filter strips, manure, nutrient and pasture management, rain gardens, riparian and shoreland buffers, stormwater erosion control and wetland restoration.

Clearwater River Watershed District CWMP 2021–2030

The Clearwater River Watershed District, which covers portions of Meeker, Stearns, and Wright counties, has adopted its own CWMP. This plan identified the following priority issues:

- Threatened and impaired surface water quality and natural resources
- Climate change
- Localized flooding and navigation obstructions
- Aquatic invasive species and nuisance species management
- Sustainable administration and funding
- Operation and maintenance

Fairhaven Creek (-565), which received an *E. coli* TMDL presented in this TMDL report, has projects scheduled for 2022 and 2024. These projects will improve water quality and habitat, with a focus on nutrients, temperature, sediment, and morphometry.

Meeker County Comprehensive Local Water Plan 2013–2023

The Meeker County Water Plan includes the following priority concerns:

- Protect and improve surface water quality by reducing priority pollutants. This includes feedlots and nutrient management, SSTS and wastewater management, shoreland, lake and land management.
- Erosion and sediment control
- Surface water management to include agricultural drainage, stormwater management and wetlands and water storage/retention.
- Groundwater quality and quantity
- Plan administration and coordination

The land in Meeker County that is part of the MRSCW is also included in the Clearwater River Watershed District and actions in that plan will also be applicable.

Sherburne County Local Water Management Plan 2018–2028

The Sherburne County Local Water Management Plan identified three priority concerns:

- Surface water quality: "Cumulative impacts of land use in directly connected and/or riparian areas which have a direct impact on surface water quality."
- Ground water quality and quantity: "High levels of nitrates in groundwater and quantity in areas identified as sensitive."
- Aquatic invasive species: "Introduction and spread of aquatic invasive species and their negative effect on water quality, navigation, recreation and fisheries."

The surface water quality priority includes an objective focused on restoration of water bodies with excessive nutrient, fecal coliform and DO impairments and references implementation of actions in the 2015 TMDL and WRAPS reports.

Stearns County Local Water Management Plan Amendment

(Extended through 2025 per Stearns County website: https://www.stearnscountymn.gov/747/Comprehensive-Water-Planning)

The Stearns County Local Water Management Plan identified the following priority concerns:

- Source water protection – actions are focused around assisting public water suppliers developing Source Water Protection Plans.
- Development impacts – actions are focused around reducing stormwater runoff and erosion, negative changes to stream flow, aquatic habitat, and water quality.
- Impaired waters – actions are focused on water sampling, assessment, and prioritization, and agricultural BMPs.

Wright County Local Water Management Plan 2017 Amendment

The Wright County Local Water Management Plan as amended in December 2017 includes the following priority concerns:

- Groundwater quality
- Surface water quality
- Development pressure
- Agricultural issues

The agricultural issues priority actions focus on ensuring feedlot compliance and other BMPs to reduce negative impacts. The surface water quality priority focuses on TMDL completion for impaired waters.

6.4 Examples of pollution reduction efforts

The SWCDs in Benton, Sherburne, and Stearns counties have completed many projects throughout the MRSC to address aquatic recreation use impairments in streams due to *E. coli* and lakes due to TP. The following three subsections present projects in impaired subwatersheds to address the pollutants of concern in the MRSC portions of these three counties.

6.4.1 Benton SWCD

The Benton SWCD has completed several watershed improvement projects to address stream *E. coli* impairments over the past five years in the MRSCW:

- Feedlot/Manure Storage (2018). In the Mayhew Creek Watershed, a cement-lined manure pit and stacking slab were installed to store all feedlot runoff and milk house waste. The estimated reductions are 24 lb/yr phosphorus, 75 lb/yr nitrogen, 301 lb/yr biochemical oxygen demand (BOD), 1,356 lb/yr chemical oxygen demand (COD), and 408 trillion cfu/yr of fecal coliform.
- Prescribed Grazing Project (2019). Along the St. Francis River, 7.6 acres of cropland and 8.7 acres of continuously grazed pasture was converted to a prescribed grazing operation for 12 calf/cow pairs. This project installed 2,724 feet of pipeline, 2,510 feet of fence, 3 waterers, and 2 heavy use pads.
- ITPHS SSTS Replacement (2021). In the Elk River Watershed, an ITPHS SSTS with a 1,000-gallon seepage tank, for a four-bedroom house, that was discharging sewage to a drainage ditch was replaced with a new mound system. The estimated reductions are 451 lb/yr TSS, 249 lb/yr phosphorus, 77 trillion cfu/yr.
- Manure Management Plans (Continuous). Multiple projects to assist producers, each with 500 to 2,000 acres, with manure management. Benton SWCD issued manure and fertilizer recommendations based on manure testing, spreader calibrations, soil testing, crop rotations, and yield goals. The SWCD also helped the producers with certifications for state and federal manure application requirements.

Benton SWCD worked with a landowner in the Elk River Watershed to improve a feedlot in 2022. The landowner has 100 to 150 steers on a 2.5-acre dirt lot that would become a “hole” that would fill with rainwater and potentially with groundwater due to the high water table. The feedlot would overflow into a small drainage ditch that discharges to the Elk River. To eliminate the pollution, the landowner has abandoned the dirt feedlot and plans to plant crops there. A new feedlot was constructed with a 340-foot by 74-foot roof, 300-foot by 57-foot by 12-foot manure pit under the floor (Figure 42). The structure can hold up to 500 steers and store 1.9 million gallons of manure (i.e., one year’s worth).

Figure 42. Former dirt feedlot (left) and new feedlot structure (right).

6.4.2 Sherburne SWCD

Sherburne SWCD completed several watershed improvement projects over the last few years. Some of the projects implemented in the MRSCW include:

- Shoreline Restoration (2004–2022): Shorelines were stabilized at 78 locations along lakes throughout Sherburne County.
- Habitat BMPs (2009–2022): Habitat was restored or enhanced at over 90 locations, including prairies, meadows, and pollinator habitat. Prairie projects included installation, reseeding, and maintenance.
- Stormwater BMPs (2012–2022): Stormwater improvement projects were implemented in 32 locations. Raingardens were installed in the Sherburne County neighborhoods around the city of St. Cloud: 20 were installed in 2011, 13 in 2014, and 2 in 2015.
- Agricultural BMPs (2015–2022): Agricultural BMPs were installed at 43 locations across Sherburne County. Practice-oriented BMPs included cover crops, nutrient management, pasture management (10 projects), and strip-till. Structural BMPs included animal waste facilities (5 projects). Examples include:
    - Pasture renovation (2015). Half of a pasture (five acres) in the Elk River Watershed was renovated and reseeded. An estimated three pounds/acre of phosphorus was removed.
    - Pasture planting and stormwater reduction (2016). Project in the Elk River Watershed replanted eight acres of pasture and installed gutters and a French drain at a horse barn. An estimated three pounds/acre of phosphorus was removed. Bacteria-laden runoff was also likely reduced.
    - Animal waste storage facility (2017). A pond and channel lined with high density polyethylene were installed to capture feedlot runoff. Diversions were also constructed to divert clean water away from the pond.

Sherburne SWCD also completed projects for erosion control, irrigation, and well-sealing.

Birch Lake (71-0057-00) is a success story. In 2006, Birch Lake was listed as impaired for its aquatic recreation use due to elevated nutrients. In 2013–2014, Sherburne SWCD developed a subwatershed analysis to determine the likely sources of phosphorus and to identify and prioritize BMPs.

With a Minnesota Clean Water Funds grant, Sherburne SWCD worked with local landowners on shoreline restoration projects and with Big Lake Township, a regulated MS4, with stormwater management projects. Big Lake Township installed stormwater infiltration basins on the west side of Birch Lake to reduce the amount of phosphorus that enters the lake.

Birch Lake was sampled in 2019 and 2020 as part of IWM program during Cycle 2. Results from all 10 samples showed that TP and Secchi depth met the deep lakes standards. Only 6 of 10 samples met the Chl-*a* deep lake standard. These results indicate that Birch Lake is no longer impaired, and MPCA delisted Birch Lake in 2022. However, the story is not over. Sherburne SWCD will continue to work with stakeholders to protect Birch Lake and address the high Chl-*a*.

6.4.3 Stearns SWCD

In the past several years, the Stearns SWCD has completed watershed improvement projects to address sources of nutrients, sediment, and *E. coli* in the MRSCW.

- Alternative Tile Inlets (2016). Ten rock inlets were installed to replace the open tile inlets on crop land and pasture. The drainage area totaled 410.9 acre with an estimated sediment reduction of 57.5 tons/yr and phosphorus reduction of 66.2 lb/yr These practices also reduce runoff that can include *E. coli* bacteria from livestock waste and manure.
- Erosion control (2017). Grassed waterways and water and sediment control basins were installed to reduce gully erosion and reduce/manage sediment runoff that can include bacteria. Total estimated reductions are 716 tons/yr sediment and 608 lb/yr phosphorus.
- Animal waste storage facility (2018). A concrete tank was constructed to store manure, milkhouse water, and feedlot runoff. Rain gutters were installed to prevent clean water from entering the concrete tank. The estimated reductions are 1,657 lb/yr COD, 23 lb/yr phosphorus, 86 lb/yr nitrogen, 420 trillion cfu/yr, and 368 lb/yr 5-day BOD.
- Cover crops (2018–2023). In 2018 through 2022, multi-species cover crops were planted on 98 acres with an estimated reduction of 17.3 tons/yr sediment and 23.7 lb/yr phosphorus. In 2019 through 2023, ongoing planting of multi-species cover crops on 323 acres with estimated sediment reductions of 598.1 tons/yr.
- Pasture planting and prescribed grazing (2020). The estimated sediment reduction was 105.6 tons/year for the 16 acres of pasture.
- Stormwater buffers were installed at St. Cloud State University to treat 6.7 acres of urban stormwater runoff. The estimated reductions are 3,841 lb/yr sediment and 12 lb/yr phosphorus. Urban stormwater runoff also contains bacteria.
- MAWQCP (multiple years). Whole farm assessments were conducted and certified for eight producers in Stearns County in the MRSCW.

Stearns SWCD worked with the Plum Creek Neighborhood Network, MPCA. Linden Township, the University of Minnesota, and St. John's University to monitor *E. coli* in the formerly listed Plum Creek. The identified soil from field erosion and streambed sediments as the source of *E. coli*. BMPs were installed to reduce erosion, SSTS were upgraded or replaced, water quality and erosion control structures were installed at key locations, and a buffer was installed near Plum Creek. Stearns SWCD monitoring in 2019 indicated that *E. coli* levels decreased significantly. The MPCA delisted Plum Creek in Minnesota's 2020 Integrated Report. This success story is published online[9]: EPA (2020).

6.4.4 Wright SWCD

In the past decade Wright SWCD with its local partners has completed several watershed improvement projects.

- From 2012 through 2019 Wright County gave 29 low interest loans for septic improvements. These improvements are estimated to have reduced phosphorus loading by 292 lb/year.
- In 2017, Wright SWCD began a Cover Crop Cost Share program to help producers offset the cost of cover crop seed. From 2017 to 2023 cover crops were added to over 250 acres of farm for an estimated phosphorus reduction of 226 lb/year and sediment reduction of 157 tons/year.
- Wright SWCD built several critical area plantings of native vegetation reducing phosphorus load by 31 lb/year and sediment loading by 16 tons /year.
- Since 2014, 12 water and sediment control basins were built to prevent erosion reducing phosphorus loading by 130 lb/year and sediment loading by 123 tons/year.
- In 2017, a limestone filter was constructed at the inlet of Mink Lake to capture phosphorus. It is expected to reduce phosphorus loading by 190 lb/year and sediment loading by 104 tons/year.

6.5 Funding

Funding sources to implement TMDLs can come from local, state, federal, and/or private sources. Examples of some of the major funding sources include BWSR's Watershed-based Implementation Funding (WBIF), Clean Water Fund Competitive Grants (e.g., Projects and Practices), and conservation funds from Natural Resources Conservation Service (NRCS) (e.g., Environmental Quality Incentives Program and Conservation Stewardship Program).

WBIF is a noncompetitive process to fund water quality improvement and protection projects for lakes, rivers/streams, and groundwater. This funding allows collaborating local governments to pursue timely solutions based on a watershed's highest priority needs. The approach depends on the completion of a CWMP developed under the 1W1P program to provide assurance that actions are prioritized, targeted, and measurable. The MRSCW will become eligible to receive WBIF when its 1W1P CWMP is approved, likely in mid-2024.

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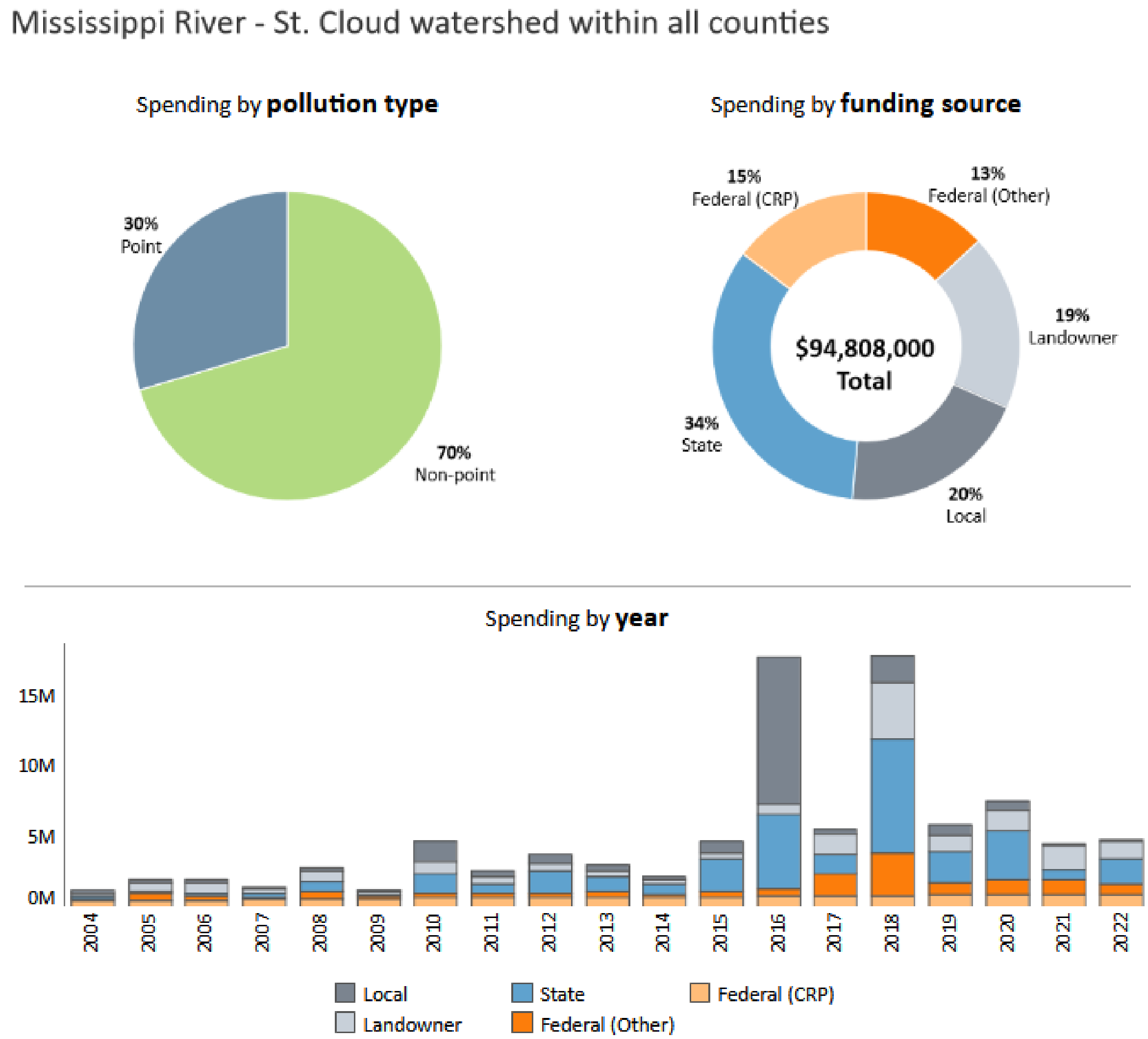
[9] https://www.epa.gov/sites/default/files/2020-10/documents/mn_plum_creek_1923_508.pdf

BWSR has been moving more of its available funding away from competitive grants and toward WBIF to accelerate water management outcomes, enhance accountability, and improve consistency and efficiency across the state. This approach allows more clean water projects identified through planning to be implemented without having to compete for funds, and helps local governments spend limited resources where they are most needed.

WBIF assurance measures summarize and systematically evaluate how WBIF dollars are being used to achieve clean water goals identified in comprehensive watershed plans. The measures will be used by BWSR to provide additional context about watershed plan implementation challenges and opportunities. The following assurance measures are supplemental to existing reporting and on-going grant monitoring efforts:

- Understand contributions of prioritized, targeted, and measurable work in achieving clean water goals.
- Review progress of programs, projects, and practices implemented in identified priority areas.
- Complete Clean Water Fund grant work on schedule and on budget.
- Leverage funds beyond the state grant.
- More than $94M (all non-WBIF) has been spent on watershed implementation projects in the MRSCW from 2004 through 2022 (Figure 43).

Figure 43. Spending for watershed implementation projects; data from the MPCA's Healthier Watersheds website (November 2023).



6.6 Other partners and organizations

The MRSCW is a watershed that has benefited a great deal over the years from the development of strong partnerships. This strong partner network has helped in the implementation of numerous BMPs/conservation projects within the last decade, resulting in several water quality impairment delistings and success stories. In addition to the government partners mentioned in previous sections, nongovernmental funding and participating in water quality projects in the MRSCW has come from organizations such as Pheasants Forever, Ducks Unlimited, Trout Unlimited, The Nature Conservancy, the Minnesota Land Trust, and local civic organizations such as lake associations.

6.7 Reasonable assurance conclusion

In summary, significant time and resources have been devoted to identifying the best BMPs, providing means of focusing them in MRSCW, and supporting their implementation via state, local, and federal initiatives and dedicated funding. The MRSC WRAPS and TMDL process engaged partners to arrive at reasonable scenarios of BMP combinations that attain pollutant reduction goals. Completion of the MRSCW CWMP in 2024 will provide even more targeted and funded implementation. Minnesota is a leader in watershed planning as well as monitoring and tracking progress toward water quality goals and pollutant load reductions.

7.0 Monitoring

This monitoring plan provides an overview of what is expected to occur at many scales in multiple subwatersheds within the MRSC, subject to availability of monitoring resources. The designated uses of aquatic life and aquatic recreation will be the ultimate measures of water quality. Improving the state of these designated uses depends on many factors, and improvements may not be detected over the next 5 to 10 years. Consequently, a monitoring plan is needed to track shorter- and longer-term changes in water quality and land management. 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.

7.1 Water Quality Monitoring Programs

Minnesota's Water Quality Monitoring Strategy 2021 through 2031 (MPCA 2021b) establishes three types of monitoring:

- **Condition monitoring**: This type of monitoring is used to identify overall environmental status and trends by examining the condition of individual water bodies or aquifers in terms of their ability to meet established standards and criteria.
- **Problem investigation monitoring**: This monitoring involves investigating specific problems or protection concerns to allow for the development of a management approach to protect or improve the resource. It is also used to determine the actions needed to return a resource to a condition that meets standards or goals.
- **Effectiveness monitoring**: This type of monitoring is used to determine the effectiveness of a specific regulatory or voluntary management action taken to improve impaired waters or remediate contaminated groundwater.

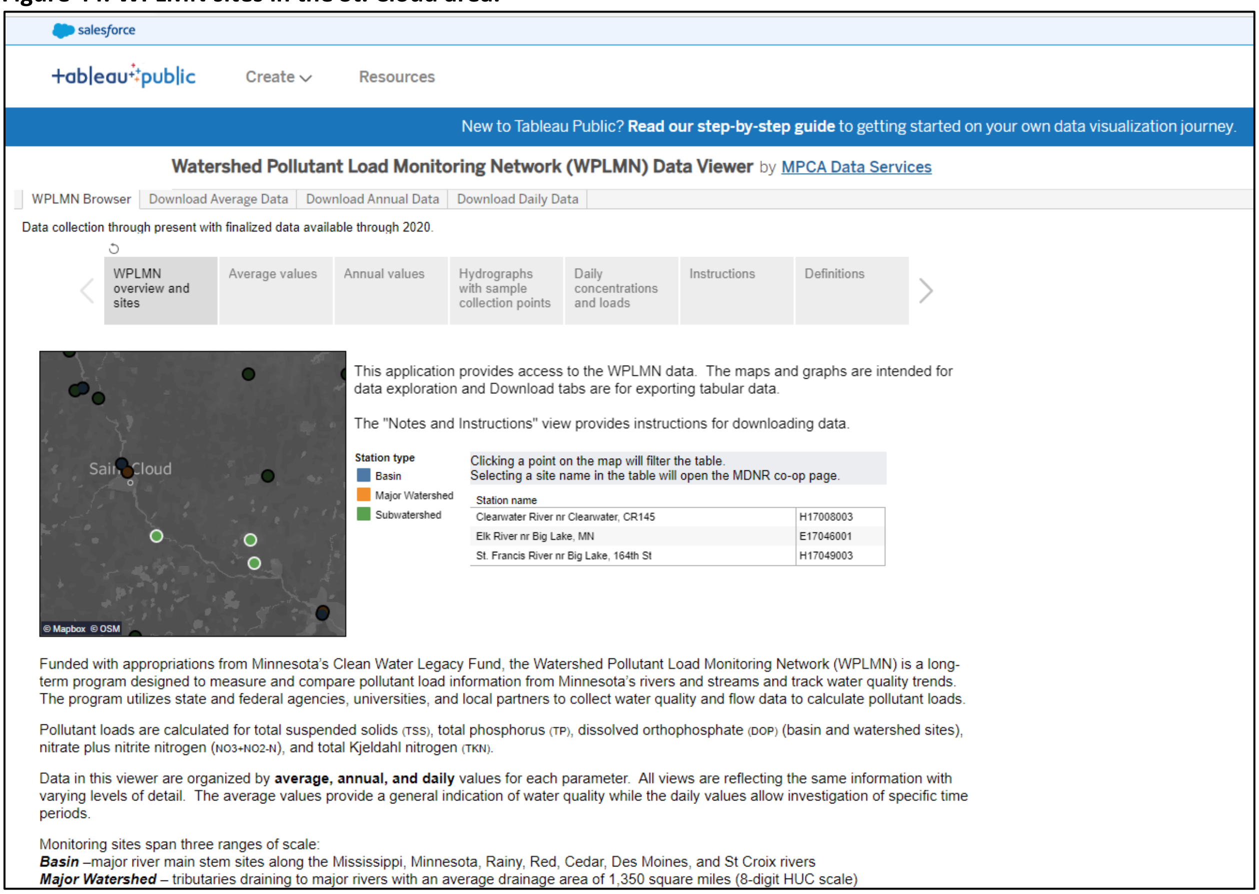
There are many monitoring efforts in place to address each of the types of monitoring. Several key monitoring programs will provide the information to track trends in water quality and evaluate compliance with TMDLs:

- Intensive monitoring and assessment at the HUC-8 scale associated with Minnesota's watershed approach. This monitoring effort is conducted approximately every 10 years for each HUC-8; the MRSCW was last sampled in 2019. An outcome of this monitoring effort is the identification of waters that are impaired (i.e., do not meet standards and need restoration) and waters in need of protection to prevent impairment. The first cycle of monitoring focused more on identifying impairments, while the second cycle focused more on identifying changes from the first cycle (MPCA 2021b). Over time, condition monitoring can also identify trends in water quality. This helps determine whether water quality conditions are improving or declining, and it identifies how management actions are improving the state's waters overall.
- The MPCA's Watershed Pollutant Load Monitoring Network (WPLMN; MPCA 2019) 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. Data are collected

along major river main stems, at major watershed (i.e., HUC-8) outlets to major rivers, and in several subwatersheds. In the MRSCW, a mainstream WPLMN site was located at St. Cloud (site 17022001); three subwatershed sites are located along the Clearwater River near Clearwater CR145 (17008003), the Elk River near Big Lake (17046001), and the St. Francis River near Big Lake 164th Street (17049003). This long-term monitoring program began in 2007. Figure 44 presents a screenshot of the WPLMN *Data Viewer.*

- Implementation monitoring is conducted by both BWSR (i.e., eLINK database) and the U.S. Department of Agriculture. Both agencies track the locations of BMP installations. Tillage transects and crop residue data are collected periodically and reported through the Minnesota Tillage Transect Survey Data Center. BMP tracking information is readily available through the MPCA's *Healthier Watersheds* webpage.
- Discharges from permitted municipal and industrial wastewater sources are reported through discharge monitoring reports (see Section 3.6.1.1); these reports are used to evaluate compliance with NPDES/SDS permits. Summaries of discharge monitoring reports are available through the MPCA's *Wastewater Data Browser*.

Figure 44. WPLMN sites in the St. Cloud area.



7.2 Optional monitoring by AUID

Optional monitoring could be used to investigate sources of impairment to Eagle Lake and the unnamed creek locally known as Otsego Creek.

7.2.1 Eagle Lake (AUID 71-6700-00)

Additional monitoring is recommended in the Eagle Lake Subwatershed.

No data in EQuIS were identified for the main inlet to Eagle Lake, which is the small stream that flows from the Uncas Dunes State Nature Area to the northeast shore of Eagle Lake. Sherburne SWCD collected 11 samples at this inlet (i.e., site 100, BELIA inlet #15) in May to September 2019 (WSB 2020). TP ranged from 49 to 127 µg/L, with a median of 65 µg/L. For reference, the TP standard for North Central Hardwood Forest ecoregion lakes is 40 µg/L, which is the standard for Eagle Lake.

Monitoring should be completed to quantify the TP loading at the main inlet to Eagle Lake. The MPCA and DNR could collect samples in Eagle Lake and the outlet of the wetlands in the Uncas Dunes State Nature Area. This monitoring could help determine the fate and transport of TP from the Uncas Dunes State Nature Area and Sand Dunes State Forest and determine if the TP loads reach Eagle Lake.

7.2.2 Unnamed Creek (AUID 07010203-528)

Unnamed creek, locally known as Otsego Creek, is impaired for its aquatic life use due to bioassessments of fish and macroinvertebrates.

The only recently collected in-stream TSS monitoring data is a single sample collected on 6/19/2019 at S007-014 that was 33.2 mg/L, which exceeds the TSS standard of 30 mg/L.

Additional in-stream monitoring data should be collected from the unnamed creek to characterize stream TSS conditions and potential sources of sediment loading. An evaluation of the stream channel is also recommended. Future monitoring should determine if the source of sediment is within the impaired segment of unnamed creek or an upstream segment and can be used to update the estimated percent reduction needed to meet water quality standards in Otsego Creek.

8.0 Implementation strategy summary

Minnesota's watershed approach to restoring and protecting water quality is based on a major watershed, or HUC-8, scale. This watershed-level planning occurs on a 10-year cycle beginning with IWM and culminates in local implementation. A WRAPS report is produced as part of this approach and addresses restoration of impaired subwatersheds and protection of unimpaired waters in each HUC-8 watershed. These high-level reports are then used to inform local watershed management plans that focus on local priorities and knowledge to identify prioritized, targeted, and measurable actions and locally based strategies. These plans further define specific actions, measures, roles, and financing for accomplishing water resource goals. Implementation activities in the MRSC WRAPS Report will heavily influence and support implementation of this TMDL.

Figure 45. Example BMP to protect a lake.
Source: Sherburne SWCD, December 26, 2017.

Priority sources of *E. coli* to target for TMDL implementation are livestock in feedlots and pastures, ITPHS, and stormwater runoff. Agricultural runoff (cropland and livestock operations) and stormwater runoff are the priority sources of phosphorus to target for implementation. SSTSs that are failing to protect groundwater are required by state law to be addressed and are therefore also considered a priority source of phosphorus. Priority sources of TSS are increased and altered flows from urban and cropland areas that lead to channel and streambank erosion, and TSS in cropland runoff and TSS in urban stormwater.

8.1 Permitted sources

Implementation of the MRSC TMDL for permitted sources will consist of permit compliance as explained below.

8.1.1 Construction stormwater

The WLA for stormwater discharges from sites where there is construction activity reflects the number of construction sites greater than one acre expected to be active in the watershed at any one time, and the BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at construction sites are defined in Minnesota's NPDES/SDS General Stormwater Permit for Construction Activity (MNR100001). If a construction site owner/operator obtains coverage under the NPDES/SDS General Stormwater Permit and properly selects, installs, and maintains all BMPs required under the permit, including those related to impaired waters discharges and any applicable additional requirements found in Section 23 of the Construction Stormwater General Permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. Construction activity must also meet all local government construction stormwater requirements.

8.1.2 Industrial stormwater

The WLA for stormwater discharges from sites where there is industrial activity reflects the number of sites in the watershed for which NPDES/SDS industrial stormwater permit coverage is required, and the BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. Minnesota's NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) and NPDES/SDS Nonmetallic Mining/Associated Activities General Permit (MNG490000) establish benchmark concentrations for pollutants in industrial stormwater discharges. If a facility owner/operator obtains stormwater coverage under the appropriate NPDES/SDS Permit and properly selects, installs, and maintains BMPs sufficient to meet the benchmark values in the permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL report. Industrial activity must also meet all local government stormwater requirements.

8.1.3 Municipal separate storm sewer systems

Prior to implementation, permitted MS4s are encouraged to compare their sewersheds (e.g., catchments, pipesheds) with the drainage areas for each impaired water body to ensure appropriate BMP crediting. If a permitted MS4 sewershed is different from what is defined as the drainage area in this report, the sewershed should be considered part of the MS4 contribution to the impaired water if sufficient evidence of the appropriate sewershed area is provided to the MPCA. With Agency approval, any wasteload-reducing BMP implemented since the TMDL baseline year within the sewershed of an impaired water will be creditable towards an MS4's load reduction for purposes of annual reporting and demonstrating progress towards meeting the WLA(s). Urban stormwater runoff control practices that could be used to meet the WLA(s) for MS4s are included in Table 77.

8.1.3.1 *E. coli* implementation

MS4 permittees are expected to follow MS4 General Permit requirements for *E. coli* reductions. This is expected to include developing or maintaining a written or mapped inventory of potential areas and sources of bacteria and developing and maintaining a written plan to prioritize reduction activities to address the areas and sources identified in the inventory.

8.1.3.2 TSS implementation

To evaluate compliance with the TSS TMDL WLA, MS4 permittees should use the 10% reduction target from their baseline loads in 2019. Any BMPs implemented within the delineated subwatershed after 2019 can be considered progress toward meeting the WLA. Progress for MNDOT can be counted within MNDOT owned or operated MS4 in any Census defined urban area with a population over 50,000 within the subwatershed.

8.1.3.3 Phosphorus implementation

Eagle Lake is the only lake requiring reductions from a current MS4 permittee. The 45% reduction target should be used in evaluation of MS4 General Permit compliance. Eagle, Elk, and Fremont lakes require reductions for future MS4 permittees. Reductions for future MS4 permittees are set equal to the reductions for nonpoint source watershed runoff. The reduction targets are 45% for Eagle Lake, 33% for Elk Lake, and 2% for Fremont Lake, and are relative to the existing loading from the area, which is not currently regulated MS4. The baseline year for all the phosphorus TMDLs is 2016. Any BMPs implemented within the delineated subwatershed after 2016 can be considered progress toward meeting the WLA. See Section 8.3, which references previously completed management plans for Elk and Fremont Lake.

8.1.4 Wastewater

NPDES/SDS permits for municipal wastewater include effluent limits designed to meet phosphorus, TSS, and *E. coli* water quality standards along with monitoring and reporting requirements to ensure effluent limits are met. Five municipal wastewater treatment facilities are assigned *E. coli* WLAs in this TMDL report and two are assigned TSS WLAs. The wastewater WLAs are all consistent with existing permit limits.

8.1.5 Feedlots

The NPDES and SDS feedlot permits include design, construction, operation, and maintenance standards that all CAFOs must follow. WLAs are not assigned to CAFOs in this TMDL report, including CAFOs with NPDES or SDS permits, and CAFOs not requiring permits; this is equivalent to a WLA of zero. If the CAFOs are properly permitted and operate under the applicable NPDES or SDS permit, then the CAFOs are expected to be consistent with this TMDL. MPCA inspections of large CAFOs focus on high-risk facilities located within or near environmental justice areas, waters impaired by *E. coli* or excess nutrients, drinking water supply and vulnerable groundwater areas, and other sensitive water features, and on facilities that haven’t been inspected in the most recent five years. CAFOs that are found to be noncompliant are required to return to compliance in accordance with applicable NPDES or SDS conditions and Minn. R. ch. 7020.

8.2 Nonpermitted sources

Implementation of the MRSC TMDL for nonpermitted sources will consist of a variety of BMPs.

Although there is evidence that internal phosphorus loading occurs within the impaired lakes, it is assumed that the rate of internal loading will decrease as the lake and sediments equilibrate to lower external phosphorus loads. Implementation strategies to decrease internal phosphorus loading could be considered if in-lake TP and eutrophication response variables do not improve, or are slow to improve,

Figure 46. Strip-till demonstration.
Source: Sherburne SWCD, September 26, 2022.

after significant watershed reductions are achieved. These strategies could include, but are not limited to water level drawdown, sediment dredging, sediment phosphorus immobilization or chemical treatment (e.g., alum), and biomanipulation (e.g., carp management). Sequencing of in-lake management strategies both relative to each other as well as relative to external load reduction is important to evaluate and consider. In general, external loading, if moderate to high, should be the initial priority for reduction efforts. In-lake management efforts involving chemical treatment (e.g., alum) should follow after substantial external load reduction has occurred. The success of alum treatments depends on several factors including lake morphometry, water residence time, alum dose used, and presence of benthic-feeding fish. The MPCA recommends feasibility studies for any lakes in which major in-lake management strategies are proposed. The *Minnesota State and Regional Government Review of Internal Phosphorus Load Control* paper (MPCA et al. 2020) provides more information on internal load BMPs and considerations.

Figure 46 presents an example of an agricultural BMP to address phosphorus losses. Table 77 summarizes example BMPs that can be implemented to achieve goals of the TMDL.

Table 77. Example BMPs for TMDL implementation.

Strategy	BMP examples	Targeted pollutant(s)
Agricultural runoff control and soil improvements	Conservation tillage	Phosphorus
	Cover crops	Phosphorus, TSS
	Filter strips and field borders	*E. coli*, phosphorus
	Water and sediment control basins	TSS
Feedlot runoff control	Feedlot runoff reduction and treatment	*E. coli*, phosphorus
	Feedlot manure/storage addition	*E. coli*, phosphorus
	Increased education for hobby farmers	*E. coli*, phosphorus
Nutrient Management	Nutrient management	*E. coli*, phosphorus
	Manure incorporation within 24 hours	*E. coli*, phosphorus
Pasture management	Conventional pasture to prescribed rotational grazing	*E. coli*, phosphorus
	Livestock access control	*E. coli*, phosphorus, TSS
	Increased education for hobby farmers	*E. coli*, phosphorus, TSS
Buffers and filters	Riparian buffers and field borders	*E. coli*, phosphorus, TSS
Converting land to perennials	Conservation cover perennials	Phosphorus, TSS
Septic system improvements	Septic system improvement (maintenance and replacement)	*E. coli*, phosphorus
Urban stormwater runoff control	Green infrastructure practices that increase infiltration	*E. coli*, phosphorus, TSS
	Improve lawn/turf vegetation and soil practices	*E. coli*, phosphorus
Stream restoration	Channel stabilization, in-stream structures (e.g., grade-control structures, deflectors), habitat restoration (e.g., large woody debris, LUNKERS (Little Underwater	TSS

Strategy	BMP examples	Targeted pollutant(s)
	Neighborhood Keepers Encompassing Rheotactic Salmonids))	
Internal load reductions in lakes	Water level drawdown	Phosphorus
	Sediment phosphorus immobilization	
	Alum treatment	
	Aquatic vegetation and fisheries management	

Descriptions of BMP examples can be found in the *Agricultural BMP Handbook for Minnesota* (Lenhart et al. 2017), the *Minnesota Stormwater Manual* (Minnesota Stormwater Manual contributors 2022), the MPCA's Lake Protection and Management website, and the University of Minnesota Extension's Onsite Sewage Treatment Program website.

Sherburne SWCD has identified a need for educating hobby farm owners with pasture management, stormwater management and manure management. As previously discussed, hobby farms are small operations with too few livestock to be registered or permitted. Hobby farms are located throughout the MRSCW, and a study commissioned by Sherburne SWCD in 2017 and 2018 identified about 700 hobby farms in Sherburne County. This study also found that hobby farm owners had "a wide range of experience and knowledge pertaining to manure management, pasture management, etc."[10]

Though beyond the scope of this TMDL report, public swimming beaches in Orono Lake, which is a flow-through lake along the Elk River, may be affected by implementation efforts to address upstream *E. coli* impairments. The city of Elk River monitors *E. coli* levels at North, Middle, and South beaches and detects high levels of *E. coli* (i.e., greater than 235 org./100mL) several days each recreation season. Over the past decade, the city of Elk River closed the beaches once (June 2014) and posted notices twice (July 2019 and June 2021) during weeks when high levels of *E. coli* were detected. The city has attributed high levels of *E. coli* detected on certain days to flocks of waterfowl. Local sources of pathogens are likely the main causes of high *E. coli* levels at the public bathing beaches; however, sources identified within the Elk River Watershed (and described in Section 3.6.1) may also contribute.

8.3 Existing management plans with implementation recommendations

The implementation strategy for the MSRCW TMDL should incorporate strategies from existing plans in the watershed to the extent possible. For example, Sherburne SWCD (2020) and the city of Zimmerman completed a subwatershed assessment for Fremont Lake and Sherburne SWCD (2021) and Baldwin Township completed a subwatershed assessment of Elk Lake. Both assessments sought to identify sources of TP, TSS, and high runoff volume, delineate subwatersheds, prioritize subwatersheds for structural BMP installation, site structural BMPs to specific locations, estimate BMP installation costs, and estimate BMP load reductions.

[10] Dan Cibulka, Senior Water Resources Specialist, Sherburne SWCD, electronic communication, September 28, 2023.

- Fremont Lake: The assessment delineated 26 subwatersheds, prioritized 14 subwatersheds, and ranked 40 BMPs. The sited BMPs were filter strips, hydrodynamic devices, infiltration basins, raingardens, and vegetated swales (Sherburne SWCD 2020).
- Elk Lake: The assessment delineated 36 subwatersheds, prioritized 14 subwatersheds, and ranked 55 BMPs. The sited urban BMPs were grass swales, hydrodynamic devices, infiltration basins, and rain gardens, while the sited rural BMPs were conservation tillage, cover crops, filter strip, grassed waterway, gully stabilization, pasture and manure management, permanent vegetation, and water and sediment control basin (Sherburne SWCD 2021).

8.4 Water quality trading

Water quality trading can help achieve compliance with WLAs or water quality based effluent limits. Water quality trading can also offset increased pollutant loads in accordance with antidegradation regulations. Water quality trading reduces pollutants (e.g., TP or TSS) in rivers and lakes by allowing a permitted discharger to enter into agreements under which the permittee “offsets” its pollutant load by obtaining reductions in a pollutant load discharged by another permitted source or a nonpermitted source or sources in the same watershed. The MPCA must establish specific conditions governing trading in the discharger’s NPDES/SDS permit or in a general permit that covers discharger. The MPCA implements water quality trading through permits. See MPCA’s *Water Quality Trading Guidance* (MPCA 2021c) for more information.

8.5 Cost

8.5.1 Implementation cost

TMDLs are required to include an overall approximation of implementation costs (Minn. Stat. § 114D.25). The costs to implement the activities outlined in the strategy are approximately $8 to $11 million dollars over the next 20 years. This range reflects the level of uncertainty in the source assessment and addresses the likely sources identified in Section 3.6. The cost includes increasing local capacity to oversee implementation in the watershed and the voluntary actions needed to achieve necessary TMDL reductions. Costs for implementing the TMDL and achieving the required pollutant load reductions were estimated by developing an implementation scenario with cost effective and practical options. Actual implementation will likely differ.

The cost of required actions, such as the replacement of ITPHS systems and SSTS maintenance, were not considered in the overall cost calculation because their costs are already accounted for in existing programs. The expected pollutant reductions of these required actions, however, were accounted for in the implementation scenario to achieve required TMDL reductions.

Sherburne SWCD (2020, 2021) estimated costs to implement BMPs to address TP, TSS, and high-runoff in Fremont Lake and Elk Lake. The 40 proposed BMPs for Fremont Lake cost an estimated $670,210, while the 55 proposed BMPs for Elk Lake cost an estimated $608,251. Refer to Section 8.3 for a summary of these subwatershed assessments.

8.5.2 Phosphorus reduction cost methodology

Costs for phosphorus reductions in the six TMDL lakes were determined by estimating the level of BMPs necessary to meet the overall estimated percent reduction needed to meet the TMDLs (Table 63, Table 65, Table 67, Table 69, Table 71, and Table 73). BMPs used in the phosphorus scenario calculation are:

- Conservation tillage
- Cover crops
- Nutrient management planning
- Field borders/buffers
- Alum treatment

Levels of implementation vary by BMP and impaired lake subwatershed.

In the Eagle Lake Subwatershed, cropland BMPs will only achieve about a third of the necessary watershed runoff TP load reduction (assuming reasonable levels of implementation). Additional load reduction will be necessary from developed lands (non-MS4) and other land covers (e.g., forest, grassland).

In the Little Mary Lake–South Bay Subwatershed, >99% of the TP load is from upstream subwatersheds (i.e., Silver Lake and Little Mary Lake–North Bay). Implementation of upstream lake TP TMDLs will be necessary in order for South Bay to meet water quality standards.

8.5.3 *E. coli* reduction cost methodology

Costs to achieve the required *E. coli* reductions were calculated using the most likely sources (Section 3.6.1) and the overall estimated percent reductions needed to meet each TMDL (Section 4.1). This cost assessment accounts for the uncertainty of a qualitative *E. coli* source assessment. BMPs used in the *E. coli* scenario calculation are:

- Feedlot BMPs
    - Filter strips around feedlots
    - Composting facilities
    - Comprehensive nutrient management planning
- SSTS maintenance and ITPHS replacement

BMPs were applied to all *E. coli* impaired subwatersheds. It was assumed that approximately 50% of existing feedlots are already implementing feedlot BMPs and do not need improvements.

8.5.4 TSS reduction cost methodology

A 10% TSS reduction is necessary to meet the TMDL. BMPs are necessary to address bank erosion/failure, degraded habitat, and altered hydrology that impair aquatic life. BMPs used in the TSS scenario calculation are:

- Bank erosion/failure (within impaired segment)

- Channel stabilization via installation of grade-control structures (e.g., rock chute) and deflectors (e.g., rock or riprap)
    - Streambank stabilization via installation of forested riparian buffers and bioengineering streambanks
- Degraded habitat (within impaired segment)
    - Habitat restoration via installation of in-stream habitat: large woody debris and LUNKERS.
- Altered hydrology
    - Urban stormwater infiltration practices (upstream of impaired segment)
    - Agricultural runoff control via drainage water management (e.g., control structures, improved drainage water management design)

Channel and streambank stabilization and habitat restoration BMPs feasibility and placement were assumed for coarse cost estimation via cursory review of aerial imagery. Implementors will need to consider site-scale factors (including construction access and easements) during engineering design.

8.5.5 Cost references

The costs to implement the activities outlined in the strategy are derived from costs presented in the Environmental Quality Incentives Program (NRCS 2023) and the *Agricultural BMP Handbook for Minnesota* (Lenhart et al. 2017). Cost estimates also relied on several assumptions.

The pertinent costs and assumptions are as follows:

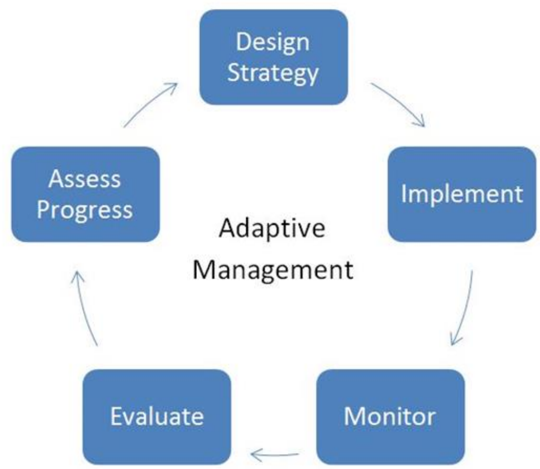
- Alum treatment costs (MPCA n.d.)
- Channel bed stabilization costs (NRCS 2023)
- Composting bins costs (NRCS 2023)
- Comprehensive nutrient management planning costs (NRCS 2023)
- Conservation tillage cost and TP reduction (Lenhart et al. 2017)
- Cover crops TP reduction (Tomlinson et al. 2015)
- Cover crop costs (Lenhart et al. 2017)
- Feedlot areas per animal unit (Murphy and Harner 2001)
- Field border buffers costs and TP reduction (Lenhart et al. 2017)
- Filter strip costs (Lenhart et al. 2017)
- Grade stabilization structure (rock chute) costs (NRCS 2023)
- Instream wood placement costs (NRCS 2023)
- LUNKERS costs (NRCS 2023)

- Manure volumes per animal unit (Livestock and Poultry Environmental Learning Community 2019)
- Nutrient management planning costs and TP reduction (Lenhart et al. 2017)
- Riparian forest buffer (bare root, hand-planted) costs (NRCS 2023)
- Streambank and shoreline protection (bioengineering) costs (NRCS 2023)

8.6 Adaptive management

The TMDL implementation strategies and the WRAPS report prepared concurrently with this TMDL report, are based on the principle of adaptive management (Figure 47). Continued monitoring and "course corrections" responding to monitoring results are the most appropriate strategy for attaining the water quality goals established in this TMDL report. Management activities will be changed or refined as appropriate over time to efficiently meet the TMDL and lay the groundwork for de-listing the impaired water bodies.

Figure 47. Adaptive management.



9.0 Public participation

Several virtual meetings and other informal communications with county and SWCD staff, MS4 representatives, other state agency staff, and other stakeholders were held throughout the development of the TMDL. Opportunities were given to provide feedback on the TMDL methodology and review draft versions of the TMDL report. All input, comments, responses, and suggestions from project meetings were taken into consideration in developing the TMDL, and the comments from the public notice period were addressed. An opportunity for public comment on the draft TMDL report was provided via a public notice in the State Register from May 13, 2024 through June 12, 2024. This included a Public Information Meeting on the project held virtually via Webex on May 23, 2024.

There were three comment letters received and responded to as a result of the public comment period. All three comments pertained to MS4 boundaries and wasteload allocations.

- The city of St. Cloud submitted information regarding Elk River subwatersheds -507 and -548. Approximately 139 acres discharges to the Mississippi River instead of the Elk River watershed. As this was 0.1% of the subwatershed for -507, and 0.04% of the subwatershed for -548, no changes were made to the TMDL allocations. However, the MPCA geodatabase for MS4 wasteloads will reflect the corrected drainage.
- MnDOT Metro MS4 submitted updated boundaries for the division between the Metro and Outstate District MS4s. It was demonstrated that MnDOT Metro does not own or operate conveyance within any of the impairment subwatersheds, so any WLAs previously assigned to MnDOT Metro MS4 were shifted to MnDOT Outstate MS4.
- Benton County demonstrated that their conveyance within the revised Donovan Lake subwatershed discharges outside of the watershed, and the TMDL impairment boundary was modified.

As a result of public comments, in order to better illustrate MS4 and impairment subwatershed boundaries, Appendices C and D were added to the TMDL report.

In addition, the MRSCW hosted a traveling educational exhibit “We Are Water MN” to connect and engage with the community during the development of the WRAPS and TMDL for this watershed. We Are Water MN is a program led by the Minnesota Humanities Center in partnership with the MPCA, the Minnesota Historical Society, the Minnesota Departments of Agriculture, Health, and Natural Resources, the Board of Water and Soil Resources, and the University of Minnesota Extension Water Resources Center. It is funded in part by the National Endowment for the Humanities and with money from the Clean Water Fund and the Arts and Cultural Heritage Fund that were created with the vote of the people of Minnesota on November 4, 2008. In addition to featuring a traveling exhibit with displays about water topics prominent to the State of Minnesota and local region, We Are Water is a program that encourages its hosts to develop events to draw community members together to share stories and information about the importance of water in our everyday lives.

From March 2023 to July 2023, the MRSCW hosted several events:

- Opening Ceremony (March 2, 2023): The We Are Water Exhibit opened at the Sherburne History Center in Becker, Minnesota. Staff from the collaborative facilitated tours of the exhibit, offered free samples at a Water Bar, and encouraged attendees to share a story about their experience with water.
- World Water Day (March 22, 2023): Along with tours of the exhibit, attendees again were offered samples of water from three different locations at a Water Bar, were provided a presentation of local water quality trends, and had access to free well water nitrate testing.
- Harmful Algae Blooms (April 20, 2023): Steve McComas, "The Lake Detective" was a guest speaker to shed light on the mysterious circumstances surrounding blue-green algae and toxic algae blooms, which is an emerging concern. Following the presentation, guests asked questions and shared their experiences with algae blooms and ways they felt they could, as individuals, protect their local lakes and streams.
- Youth Water Festival (April 24, 2023): Youth of all ages visited the exhibit and stayed to enjoy interactive experiences learning how watersheds work, a theatrical performance on aquatic invasive species, learning about soil health, and creating "butterfly bombs".
- Agricultural Conservation Field Day (July 13, 2023): The Kaschmitter brothers hosted this event on their farm to showcase conservation practices that help to improve water quality including conservation tillage, irrigation technology, and other soil health practices. Specialty equipment was available for display and guest speakers from the Irrigators Association of Minnesota and Natural Resource Conservation Service spoke about the importance of water conservation.

The events ranged between 30 to 45 attendees while the Sherburne History Center saw a two-fold increase in walk-in traffic during the timeline of the exhibit (March through April 2023). The MRSCW enjoyed engaging with the community through the We Are Water MN program and views this effort not only as successful on its own accord, but as a valuable companion piece to the development of the Cycle II WRAPS and TMDLs.

For further information on public participation for this TMDL report, please see the WRAPS report.

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Appendices

Appendix A. Impairments

This appendix lists all of the impairments in the MRSCW along with the TMDL status of each impairment (Table 78).

Table 78. Impaired water bodies in the Mississippi River–St. Cloud Watershed.

Water body name	Water body description	WID	Use class [a]	Year added to list	Affected designated use [b]	Listing parameter	Confirmed stressors to bioassessment impairments	Inconclusive stressors to bioassessment impairments	EPA category in next impaired waters list [c]	TMDL developed in this report
Donovan (main bay)	Lake or Reservoir	05-0004-02	2B	2010	AQR	Nutrients	N/A	N/A	4A	No
Mayhew	Lake or Reservoir	05-0007-00	2B	1998	AQC	Mercury in fish tissue	N/A	N/A	4A	No
				2008	AQR	Nutrients	N/A	N/A	4A	No
Elk River	Mayhew Cr to Rice Cr	07010203-507	2Bg	2002	AQC	Mercury in fish tissue	N/A	N/A	4A	No
				2012	AQR	Escherichia coli (*E. coli*)	N/A	N/A	4A	Yes
Elk River	Headwaters to Mayhew Cr	07010203-508	2Bg	2002	AQC	Mercury in fish tissue	N/A	N/A	4A	No
				2012	AQL	Benthic macroinvertebrates bioassessments	DO, habitat, nutrients, hydrology / channelization [f]	–	4C	No
				2012	AQL	Fish bioassessments	DO, habitat, nutrients, hydrology / channelization [f]	–	4C	No
				2012	AQR	Escherichia coli (*E. coli*)	N/A	N/A	4A	Yes
Clearwater River	Clearwater Lk to Mississippi R	07010203-511	2Bg	2006	AQL	Dissolved oxygen	N/A	N/A	4A	No
				2012	AQL	Fish bioassessments	DO, hydrology / channelization, connectivity [f]	–	5	No
Rice Creek	Rice Lk to Elk R	07010203-512	2Bg	2006	AQL	Dissolved oxygen	N/A	N/A	4A	No
				2012	AQR	Escherichia coli (*E. coli*)	N/A	N/A	4A	Yes
Unnamed ditch	Headwaters (Lk Fremont 71-0016-00) to Tibbets Bk	07010203-523	2Bg	2020	AQL	Benthic macroinvertebrates bioassessments	Hydrology / geomorphology and habitat [e]	–	5	No
Elk River	Orono Lk to Mississippi R	07010203-525	2Bg	2004	AQC	Mercury in fish tissue	N/A	N/A	4A	No

Water body name	**Water body description**	**WID**	**Use class** [a]	**Year added to list**	**Affected designated use** [b]	**Listing parameter**	**Confirmed stressors to bioassessment impairments**	**Inconclusive stressors to bioassessment impairments**	**EPA category in next impaired waters list** [c]	**TMDL developed in this report**
Unnamed creek	T121 R23W S19, south line to Mississippi R	07010203-528	2Bg	2012	AQL	Benthic macroinvertebrates bioassessments	DO, habitat, hydrology / channelization [f]	–	4A	Yes
				2012	AQL	Fish bioassessments	DO, habitat, hydrology / channelization [f]	–	4A	Yes
				2014	AQR	Escherichia coli (*E. coli*)	N/A	N/A	4A	No
Snake River	Unnamed cr to Eagle Lk outlet	07010203-529	1B, 2Ag	2022	AQL	Fish bioassessments	Connectivity, hydrology / geomorphology and habitat [e]	–	5	No
				2012	AQR	Escherichia coli (*E. coli*)	N/A	N/A	4A	Yes
Battle Brook	CD 18 to Elk Lk	07010203-535	2Bg	2006	AQL	Benthic macroinvertebrates bioassessments	DO, habitat, hydrology / channelization, connectivity [f]	–	4A	No
				2012	AQL	Fish bioassessments	DO, habitat, hydrology / channelization, connectivity [f]	–	5	No
				2012	AQR	Escherichia coli (*E. coli*)	N/A	N/A	4A	Yes
Threemile Creek	Unnamed stream outlet of Lk Lura to T122 R28W S36, west line	07010203-545	1B, 2Ag	2022	AQL	Fish bioassessments	Hydrology / geomorphology [e]	TSS [e]	5	No
Elk River	St Francis R to Orono Lk	07010203-548	2Bg	2002	AQC	Mercury in fish tissue	N/A	N/A	4A	No
				2012	AQR	Escherichia coli (*E. coli*)	N/A	N/A	4A	Yes
Clearwater River	CD 44 to Lk Betsy	07010203-549	2Bg	2022	AQL	Total suspended solids (TSS)	N/A	N/A	5	No
				1996	AQR	Fecal coliform	N/A	N/A	4A	No

Water body name	Water body description	WID	Use class [a]	Year added to list	Affected designated use [b]	Listing parameter	Confirmed stressors to bioassessment impairments	Inconclusive stressors to bioassessment impairments	EPA category in next impaired waters list [c]	TMDL developed in this report
County Ditch 44	Clear Lk to Clearwater R	07010203-550	2Bg	2020	AQL	Benthic macroinvertebrates bioassessments	DO, Phosphorus, TSS, hydrology / geomorphology, habitat, flow [e]	–	5	No
				2020	AQL	Fish bioassessments	DO, Phosphorus, TSS, hydrology / geomorphology, habitat, flow [e]	–	5	No
Silver Creek	Locke Lk to Mississippi R	07010203-557	2Bg	2012	AQL	Benthic macroinvertebrates bioassessments	DO, nutrients, hydrology / channelization, connectivity [f]	–	5	No
				2012	AQL	Fish bioassessments	DO, nutrients, hydrology / channelization, connectivity [f]	–	5	No
				2012	AQR	Escherichia coli (*E. coli*)	N/A	N/A	4A	No
Snake River	Headwaters to Unnamed cr	07010203-558	1B, 2Ag	2022	AQL	Fish bioassessments [e]	Connectivity, hydrology / geomorphology, habitat [e]	–	5	No
Unnamed creek (Luxemburg Creek)	T123 R28W S30, south line to Johnson Cr	07010203-561	1B, 2Ag	2012	AQR	Escherichia coli (*E. coli*)	N/A	N/A	4A	No
Threemile Creek (Hanson Brook)	T122 R28W S21, west line to Unnamed cr	07010203-564	1B, 2Ag	2022	AQL	Benthic macroinvertebrates bioassessments	Hydrology / geomorphology [e]	TSS [e]	5	No
				2022	AQL	Fish bioassessments	Hydrology / geomorphology [e]	TSS [e]	5	No
Unnamed creek (Fairhaven Creek)	Headwaters to Lk Marie	07010203-565	1B, 2Ag	2012	AQR	Escherichia coli (*E. coli*)	N/A	N/A	4A	Yes
Elk River			2Bg	2002	AQC	Mercury in fish tissue	N/A	N/A	4A	No

Water body name	Water body description	WID	Use class [a]	Year added to list	Affected designated use [b]	Listing parameter	Confirmed stressors to bioassessment impairments	Inconclusive stressors to bioassessment impairments	EPA category in next impaired waters list [c]	TMDL developed in this report
	Elk Lk to St Francis R	07010203-579		2012	AQL	Fish bioassessments	Nutrients, hydrology / channelization, TSS [f]	–	5	No
				2008	AQR	Fecal coliform	N/A	N/A	4A	No
Elk River	Rice Cr to Elk Lk	07010203-581	2Bg	2002	AQC	Mercury in fish tissue	N/A	N/A	4A	No
Johnson Creek (Meyer Creek)	Unnamed cr to Unnamed cr	07010203-633	1B, 2Ag	2022	AQR	Escherichia coli (*E. coli*)	N/A	N/A	4A	No
Johnson Creek (Meyer Creek)	Unnamed cr to Unnamed cr	07010203-635	1B, 2Ag	2012	AQR	Escherichia coli (*E. coli*)	N/A	N/A	4A	No
Johnson Creek (Meyer Creek)	T123 R28W S14, west line to Mississippi R	07010203-639	2Bg	2012	AQL	Fish bioassessments	Hydrology / geomorphology, habitat [e]	–	5	No
				2012	AQR	Escherichia coli (*E. coli*)	N/A	N/A	4A	No
Silver Creek	Unnamed cr to Silver Lk	07010203-662	2Bg	2012	AQL	Benthic macroinvertebrates bioassessments	Phosphorus, connectivity, hydrology / geomorphology, habitat, flow [e]	DO, TSS [e]	5	No
				2012	AQL	Fish bioassessments	Phosphorus, connectivity, hydrology / geomorphology, habitat, flow [e]	DO, TSS [e]	5	No
Mayhew Creek	Unnamed cr to CD 7	07010203-675	2Bg	2012	AQL	Benthic macroinvertebrates bioassessments	DO, habitat, nutrients, hydrology / channelization [f]	–	5	No
				2012	AQL	Fish bioassessments	DO, habitat, nutrients, hydrology / channelization [f]	–	5	No

Water body name	Water body description	WID	Use class [a]	Year added to list	Affected designated use [b]	Listing parameter	Confirmed stressors to bioassessment impairments	Inconclusive stressors to bioassessment impairments	EPA category in next impaired waters list [c]	TMDL developed in this report
West Branch (St Francis River, West Branch)	Unnamed cr to St Francis R	07010203-693	2Bg	2020	AQL	Benthic macroinvertebrates bioassessments	Phosphorus, connectivity, hydrology / geomorphology, flow [f]	–	5	No
				2020	AQL	Fish bioassessments	Phosphorus, connectivity, hydrology / geomorphology, flow [e]	–	5	No
County Ditch 22	Headwaters to St Francis R	07010203-695	2Bg	2020	AQL	Fish bioassessments	Connectivity, hydrology / geomorphology, habitat, flow [e]	–	5	No
St Francis River	Headwaters to Unnamed lk (71-0371-00)	07010203-700	2Bg	2012	AQL	Fish bioassessments	DO, habitat, nutrients, hydrology / channelization, connectivity [f]	–	5	No
				2012	AQR	Escherichia coli (*E. coli*)	N/A	N/A	4A	Yes
St Francis River	Rice Lk to Elk R	07010203-702	2Bg	2012	AQL	Fish bioassessments	DO, habitat, nutrients, hydrology / channelization, connectivity [f]	–	5	No
St Francis River	Unnamed lk (71-0731-00) to Rice Lk	07010203-704	2Bg	2012	AQL	Fish bioassessments	DO, habitat, nutrients, hydrology / channelization, connectivity [f]	–	5	No
Clearwater River	Scott Lk to Lk Louisa	07010203-717	2Bg	2012	AQL	Fish bioassessments	DO, hydrology / channelization, connectivity [f]	–	5	No
Unnamed creek (Robinson Hill Creek)	CD 14 to CSAH 136	07010203-724	1B, 2Bdg	2012	AQR	Escherichia coli (*E. coli*)	N/A	N/A	4A	No

Water body name	Water body description	WID	Use class [a]	Year added to list	Affected designated use [b]	Listing parameter	Confirmed stressors to bioassessment impairments	Inconclusive stressors to bioassessment impairments	EPA category in next impaired waters list [c]	TMDL developed in this report
Mississippi River	Sauk R to Clearwater R	07010203-728	1C, 2Bdg	1998	AQC	Mercury in fish tissue	N/A	N/A	4A	No
Mississippi River	Clearwater R to Crow R	07010203-729	1C, 2Bdg	1998	AQC	Mercury in fish tissue	N/A	N/A	4A	No
				1998	AQC	PCBs in fish tissue	N/A	N/A	5	No
				2002	AQR	Fecal coliform	N/A	N/A	5	No
Tibbets Brook	Unnamed ditch to Elk R	07010203-736	2Bg	2012	AQR	Escherichia coli (*E. coli*)	N/A	N/A	4A	Yes
County Ditch 20	Hwy 55 to Unnamed cr	07010203-738	2Bg	2020	AQL	Benthic macroinvertebrates bioassessments	DO, phosphorus, TSS, hydrology / geomorphology, habitat, flow [e]	Connectivity [f]	5	No
				2020	AQL	Fish bioassessments	DO, phosphorus, TSS, hydrology / geomorphology, habitat, flow [e]	Connectivity [f]	5	No
Plum Creek	13th Ave to CSAH 45	07010203-740	2Bg	2020	AQL	Fish bioassessments	Hydrology / geomorphology, habitat, flow [e]	DO, phosphorus, TSS [f]	5	No
Unnamed creek	-93.994 45.503 to -93.986 45.496	07010203-743	2Bg	2020	AQL	Fish bioassessments	Connectivity, hydrology / geomorphology, habitat [e]	–	5	No
Unnamed creek	Unnamed cr to -93.855 45.428	07010203-745	2Bg	2020	AQL	Fish bioassessments	Hydrology / geomorphology, habitat [e]	Phosphorus [f]	5	No
Mayhew Creek	Unnamed cr to T36 R30W S20, east line	07010203-749	2Bg	2012	AQL	Dissolved oxygen	N/A	N/A	5	No
Mayhew Creek	T36 R30W S21, west line to Elk R	07010203-750 [d]	2Bg	2012	AQL	Dissolved oxygen	N/A	N/A	5	No
				2002	AQL	Fish bioassessments	DO, habitat, nutrients, hydrology / channelization [f]	–	5	No
				2012	AQR	Escherichia coli (*E. coli*)	N/A	N/A	4A	Yes

Water body name	Water body description	WID	Use class [a]	Year added to list	Affected designated use [b]	Listing parameter	Confirmed stressors to bioassessment impairments	Inconclusive stressors to bioassessment impairments	EPA category in next impaired waters list [c]	TMDL developed in this report
Betty	Lake or Reservoir	47-0042-00	2B	2010	AQC	Mercury in fish tissue	N/A	N/A	4A	No
				2022	AQL	Fish bioassessments			5	No
				2008	AQR	Nutrients	N/A	N/A	4A	No
Clear	Lake or Reservoir	47-0095-00	2B	2020	AQC	Mercury in fish tissue	N/A	N/A	4A	No
				2008	AQR	Nutrients	N/A	N/A	4A	No
Upper Orono	Lake or Reservoir	71-0013-01	2B	2010	AQC	Mercury in fish tissue	N/A	N/A	4A	No
				2008	AQR	Nutrients	N/A	N/A	4A	No
Lower Orono	Lake or Reservoir	71-0013-02	2B	2010	AQC	Mercury in fish tissue	N/A	N/A	4A	No
				2008	AQR	Nutrients	N/A	N/A	4A	No
Fremont	Lake or Reservoir	71-0016-00	2B	2012	AQR	Nutrients	N/A	N/A	4A	Yes
Diann	Lake or Reservoir	71-0046-00	2B	2012	AQR	Nutrients	N/A	N/A	5	No
Elk	Lake or Reservoir	71-0055-00	2B	2012	AQR	Nutrients	N/A	N/A	4A	Yes
Eagle	Lake or Reservoir	71-0067-00	2B	2022	AQR	Nutrients	N/A	N/A	4A	Yes
Mitchell	Lake or Reservoir	71-0081-00	2B	2008	AQC	Mercury in fish tissue	N/A	N/A	4A	No
				2022	AQL	Fish bioassessments			5	No
Big	Lake or Reservoir	71-0082-00	2B	2008	AQC	Mercury in fish tissue	N/A	N/A	4A	No
				2022	AQL	Fish bioassessments			5	No
Elk	Lake or Reservoir	71-0141-00	2B	2008	AQR	Nutrients	N/A	N/A	4A	No
Rice	Lake or Reservoir	71-0142-00	2B	2020	Wild Rice Production	Sulfate	N/A	N/A	5	No
Julia	Lake or Reservoir	71-0145-00	2B	2008	AQR	Nutrients	N/A	N/A	4A	No
Briggs	Lake or Reservoir	71-0146-00	2B	2018	AQC	Mercury in fish tissue	N/A	N/A	4A	No
				2022	AQL	Fish bioassessments			5	No
				2008	AQR	Nutrients	N/A	N/A	4A	No

Water body name	Water body description	WID	Use class [a]	Year added to list	Affected designated use [b]	Listing parameter	Confirmed stressors to bioassessment impairments	Inconclusive stressors to bioassessment impairments	EPA category in next impaired waters list [c]	TMDL developed in this report
Rush	Lake or Reservoir	71-0147-00	2B	2008	AQR	Nutrients	N/A	N/A	4A	No
Marie	Lake or Reservoir	73-0014-00	2B	2008	AQR	Nutrients	N/A	N/A	4A	No
School	Lake or Reservoir	86-0025-00	2B	2012	AQR	Nutrients	N/A	N/A	5	No
Hunters	Lake or Reservoir	86-0026-00	2B	2012	AQR	Nutrients	N/A	N/A	5	No
Little Mary (South Bay)	Lake or Reservoir	86-0139-01	2B	2012	AQR	Nutrients	N/A	N/A	4A	Yes
Little Mary (North Bay)	Lake or Reservoir	86-0139-02	2B	2012	AQR	Nutrients	N/A	N/A	4A	Yes
Silver	Lake or Reservoir	86-0140-00	2B	1998	AQC	Mercury in fish tissue	N/A	N/A	4A	No
				2008	AQR	Nutrients	N/A	N/A	4A	No
Ida	Lake or Reservoir	86-0146-00	2B	2014	AQC	Mercury in fish tissue	N/A	N/A	4A	No
Eagle	Lake or Reservoir	86-0148-00	2B	2022	AQL	Fish bioassessments			5	No
Millstone	Lake or Reservoir	86-0152-00	2B	2012	AQR	Nutrients	N/A	N/A	4A	Yes
Mary	Lake or Reservoir	86-0156-00	2B	2020	AQC	Mercury in fish tissue	N/A	N/A	4A	No
				2022	AQL	Fish bioassessments			5	No
Locke	Lake or Reservoir	86-0168-00	2B	2022	AQL	Fish bioassessments			5	No
				2006	AQR	Nutrients	N/A	N/A	4A	No
Fish	Lake or Reservoir	86-0183-00	2B	2008	AQR	Nutrients	N/A	N/A	4A	No
Swartout	Lake or Reservoir	86-0208-00	2B	2008	AQR	Nutrients	N/A	N/A	4A	No
Albion	Lake or Reservoir	86-0212-00	2B	2008	AQR	Nutrients	N/A	N/A	4A	No
Henshaw	Lake or Reservoir	86-0213-00	2B	2008	AQR	Nutrients	N/A	N/A	4A	No

Water body name	Water body description	WID	Use class [a]	Year added to list	Affected designated use [b]	Listing parameter	Confirmed stressors to bioassessment impairments	Inconclusive stressors to bioassessment impairments	EPA category in next impaired waters list [c]	TMDL developed in this report
Indian	Lake or Reservoir	86-0223-00	2B	2008	AQR	Nutrients	N/A	N/A	4A	No
Cedar	Lake or Reservoir	86-0227-00	2B	1998	AQC	Mercury in fish tissue	N/A	N/A	4A	No
Mink	Lake or Reservoir	86-0229-00	2B	2018	AQC	Mercury in fish tissue	N/A	N/A	4A	No
				2008	AQR	Nutrients	N/A	N/A	4A	No
Somers	Lake or Reservoir	86-0230-00	2B	2018	AQC	Mercury in fish tissue	N/A	N/A	5	No
				2008	AQR	Nutrients	N/A	N/A	4A	No
Pleasant	Lake or Reservoir	86-0251-00	2B	1998	AQC	Mercury in fish tissue	N/A	N/A	4A	No
Clearwater (East)	Lake or Reservoir	86-0252-01	2B	1998	AQC	Mercury in fish tissue	N/A	N/A	5	No
Clearwater (West)	Lake or Reservoir	86-0252-02	2B	1998	AQC	Mercury in fish tissue	N/A	N/A	5	No
Caroline	Lake or Reservoir	86-0281-00	2B	2008	AQR	Nutrients	N/A	N/A	4A	No
Louisa	Lake or Reservoir	86-0282-00	2B	2002	AQR	Nutrients	N/A	N/A	4A	No
Scott	Lake or Reservoir	86-0297-00	2B	2008	AQR	Nutrients	N/A	N/A	4A	No
Union	Lake or Reservoir	86-0298-00	2B	2010	AQC	Mercury in fish tissue	N/A	N/A	4A	No

Unless otherwise noted with footnotes "f" or "g", all data in this table has been populated using Minnesota's 2022 Impaired Waters List produced on April 29, 2022.

a. 1B: domestic consumption with minimal disinfection; 1C: domestic consumption with moderate treatment; 2Ag: aquatic life and recreation—general cold water habitat; 2B: aquatic life and recreation—cool or warm water habitat; 2Bg: aquatic life and recreation—general warm water habitat; 2Bdg: aquatic life and recreation—general warm water habitat where "d" indicates the stream is also protected as a source of drinking water.

b. AQR: aquatic recreation, AQL: aquatic life, AQC: aquatic consumption

c. 4A: Impaired and a TMDL study has been approved by EPA. All TMDLs needed to result in attainment of applicable water quality standards for this impairment have been approved or established by EPA. For biological impairments, there are no remaining inconclusive stressors.
4C: Impaired but a TMDL study is not required because the impairment is not caused by a pollutant.
5: Impaired and a TMDL study has not been approved by EPA.

d. At the time this appendix was created, the Mayhew Creek *E. coli* impairment is listed with a WID of 07010203-750 in MPCA's Impaired Waters List. However, the Mayhew Creek *E. coli* impairment in the previous Impaired Waters List was listed with a WID of 07010203-509.

e. These stressors to bioassessment impairments were obtained from the Mississippi River–St. Cloud Watershed SID Update, 2022 report. These stressors are reported at an AUID scale. https://www.pca.state.mn.us/sites/default/files/wq-ws3-07010203e.pdf
f. These stressors to bioassessment impairments were obtained from the Mississippi River–St. Cloud SID Report from 2013. These stressors are reported on a watershed scale. https://www.pca.state.mn.us/sites/default/files/wq-ws3-07010203c.pdf

Appendix B. BATHTUB Modeling

This appendix documents model construction, calibration/validation, and scenario development and evaluation.

B.1 Model Development

Lakes impaired by phosphorus in the MRSCW that are addressed in this report are in Table 79. Two of the lakes addressed in this report are impacted by upstream lake impairments, some upstream lake impairments have completed TMDLs, and some do not. For a map of the lakes and their subwatersheds, refer to Figure 5 in Section 3.0 of the main report.

Table 79. Impaired lakes identified for BATHTUB modeling.

Lake	AUID	County	HUC-12	Upstream Impaired Lakes	Additional Upstream Water bodies
Fremont	71-0016-00	Sherburne	Tibbets Brook	None	None
Elk	71-0055-00	Sherburne	Battle Brook	Diann [c]	Helene Lake, Cantlin Lake, Rice Lake, Prairie Hill Lake, Little Diann Lake
Eagle	71-0067-00	Sherburne	Snake River	None	Jensen Slough, Frederickson Slough
Millstone	86-0152-00	Wright	Silver Creek	None	None
Little Mary (South Bay)	86-0139-01	Wright	Silver Creek	Millstone [a] Little Mary North Bay [a] Indian [b] Silver [b] Mink [b] Somers [c]	Limestone Lake, Sugar Lake, Sandy Lake, Lake Mary
Little Mary (North Bay)	86-0139-02	Wright	Silver Creek	None	Maria Lake, West Lake, North Lake

a. Upstream TMDL was completed and is included in this TMDL report.
b. Upstream TMDL was completed as part of another TMDL report.
c. TMDL needed.

Little Mary Lake (north and south bays together; AUID 86-0139-00) is also referred to as Lake Maria in various reports, not to be mistaken with Maria Lake due southeast, which is also occasionally called Bjorkland Lake. Eagle Lake is also locally referred to as Big Eagle Lake.

B.1.1 Observed Water Quality Conditions

Lake data observations were summarized for the growing season (June through September) for the period of record (Figure 48 to Figure 58). Only the most recent 10 years of data (2012 through 2021 for Sherburne County lakes, 2013 through 2022 for Wright County lakes) were used to calculate the average of annual growing season means relative to the water quality standards (WQS) associated with lakes in the North Central Hardwood Forest ecoregion (Table 80). Shallow lakes (generally less than 15 feet deep and characterized by aquatic plants) are subject to different eutrophication standards than lakes that are not shallow (Minn. R. § 7050.0222). For all six of these lakes in the North Central Hardwood Forest ecoregion, Eagle Lake in Sherburne County is assessed as a lake, while the others are assessed as shallow lakes (Table 81).

Table 80. North Central Hardwood Forest ecoregion lake numeric water quality standards.

Lake Type	TP (µg/L) WQS	Chl-*a* (µg/L) WQS	Secchi Depth (m) WQS
Shallow lake	≤ 60	≤ 20	≥ 1.0
Lake (Eagle Lake only)	≤ 40	≤ 14	≥ 1.4

Water quality and field data used for the modeling analysis and lake condition evaluation are those collected directly by or under contract with MPCA; these data were downloaded from EQuIS. Additional Secchi depth data were available for the Wright County lakes via the University of Minnesota *LakeBrowser*; these data are included in the data summary below, although excluded from the TMDL evaluation. Data from summer 2022 (water quality, depth profiles, and aquatic vegetation surveys) collected by the Wright and Sherburne SWCDs were completed under contract to MPCA and were included. All recent data used for each lake to calculate observed water quality conditions in Table 81 are provided in Appendix B Section B.4.

Table 81. Annual average growing season mean water quality, 2012–2022.

Lake	Type	TP (µg/L)		Chl-*a* (µg/L)		Secchi Depth (m)	
		Data Count	Mean	Data Count	Mean	Data Count	Mean
Fremont	Shallow	12 (2019–2020)	46	12 (2019–2020)	**21**	33 (2015–2021)	1.1
Elk	Shallow	8 (2019)	**89**	8 (2019)	**48**	95 (2012–2021)	**0.9**
Eagle	Lake	8 (2019–2020)	**54**	8 (2019–2020)	**37**	16 (2019–2020)	**1.2**
Millstone	Shallow	8 (2022)	**223** [a]	8 (2022)	**126**	*34 (2017–2021[b])*	0.2
Little Mary (South Bay)	Shallow	8 (2022)	**143**	8 (2022)	**92**	*33 (2017–2021[b])*	1.2
Little Mary (North Bay)	Shallow	8 (2022)	**138**	8 (2022)	**92**	*36 (2016, 2017–2021[b])*	1.3

Bolded red results indicated that the average concentration exceeded the respective WQS

a. A single sample was collected in calendar year 2014, which is insufficient for calculating a growing season mean. This sample was omitted.

b. Non-EQuIS data were downloaded via the University of Minnesota *LakeBrowser* to supplement existing datasets.

Error bars shown around average observed water quality conditions illustrate standard error as a function of the standard deviation divided by the square root of the growing season mean (Figure 48, Figure 50, Figure 52, Figure 54, Figure 56, and Figure 57). In Sherburne County, there are correlations between TP and Chl-*a* concentrations in the two shallow lakes (Fremont and Elk; Figure 49 and Figure 51) which indicate that nuisance algae conditions are likely linked to excess nutrients. Eagle Lake is the deepest water body and does not exhibit a correlation between TP and chl-*a* (Figure 53). In Wright County, all three shallow lakes (Millstone, Little Mary South Bay and North Bay) also show some correlation between TP and chl-*a* (Figure 55 and Figure 58).

Lake-specific summaries of general water quality trends and observations follow:

- **Fremont Lake**: TP concentrations and Secchi depths meet WQS; however, chl-*a* exceeds WQS
- **Elk Lake**: TP and chl-*a* concentrations and Secchi depth do not meet WQS
- **Eagle Lake**: TP and chl-*a* concentrations and Secchi depth do not meet WQS

- **Millstone Lake**: High TP and chl-*a* concentrations do not meet WQS, insufficient Secchi data
- **Little Mary Lake (South Bay)**: High TP and chl-*a* concentrations do not meet WQS, insufficient Secchi data
- **Little Mary Lake (North Bay)**: High TP and chl-*a* concentrations do not meet WQS, insufficient Secchi data

Observed water quality conditions from the past 10 years (2012 through2021 for Sherburne County lakes, 2013 through 2022 for Wright County lakes) show exceedance of relevant numeric TP WQS for all lakes except for Fremont Lake, which has recently lower TP concentrations than have been historically observed.

Figure 48. Fremont Lake (71-0016-00) growing season water quality data, 2002–2022.

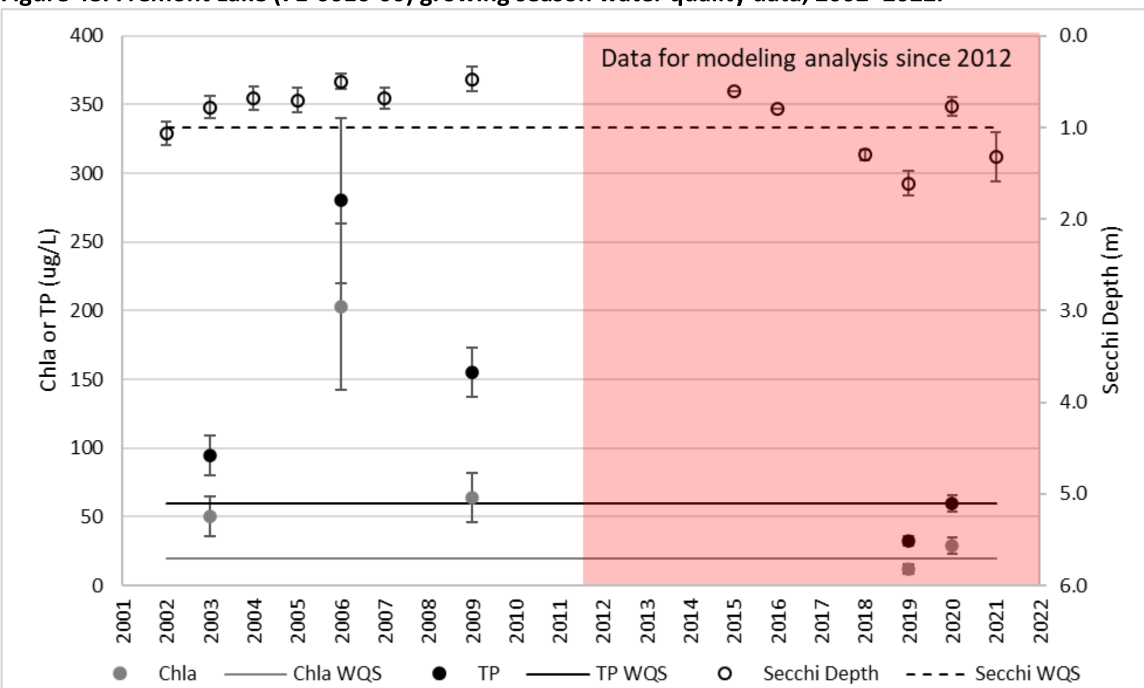


Figure 49. Fremont Lake (71-0016-00) growing season paired TP and Chl-a data, 2002–2022.

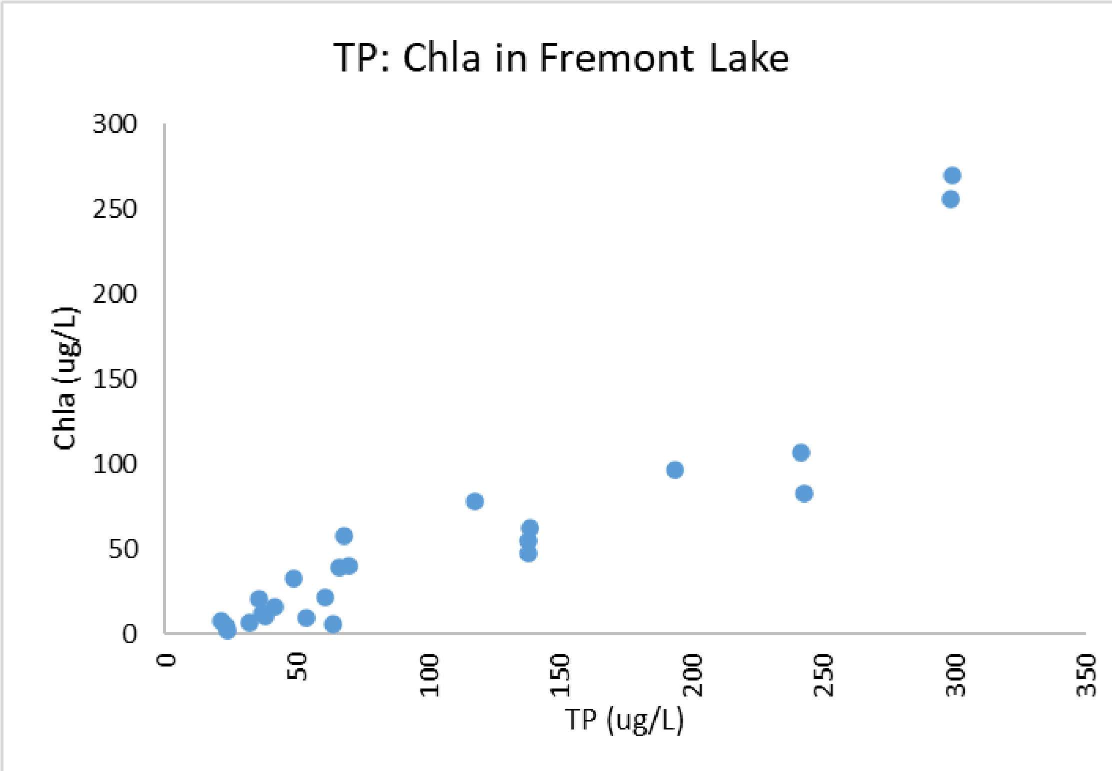


Figure 50. Elk Lake (71-0055-00) growing season water quality data, 1981–2022.

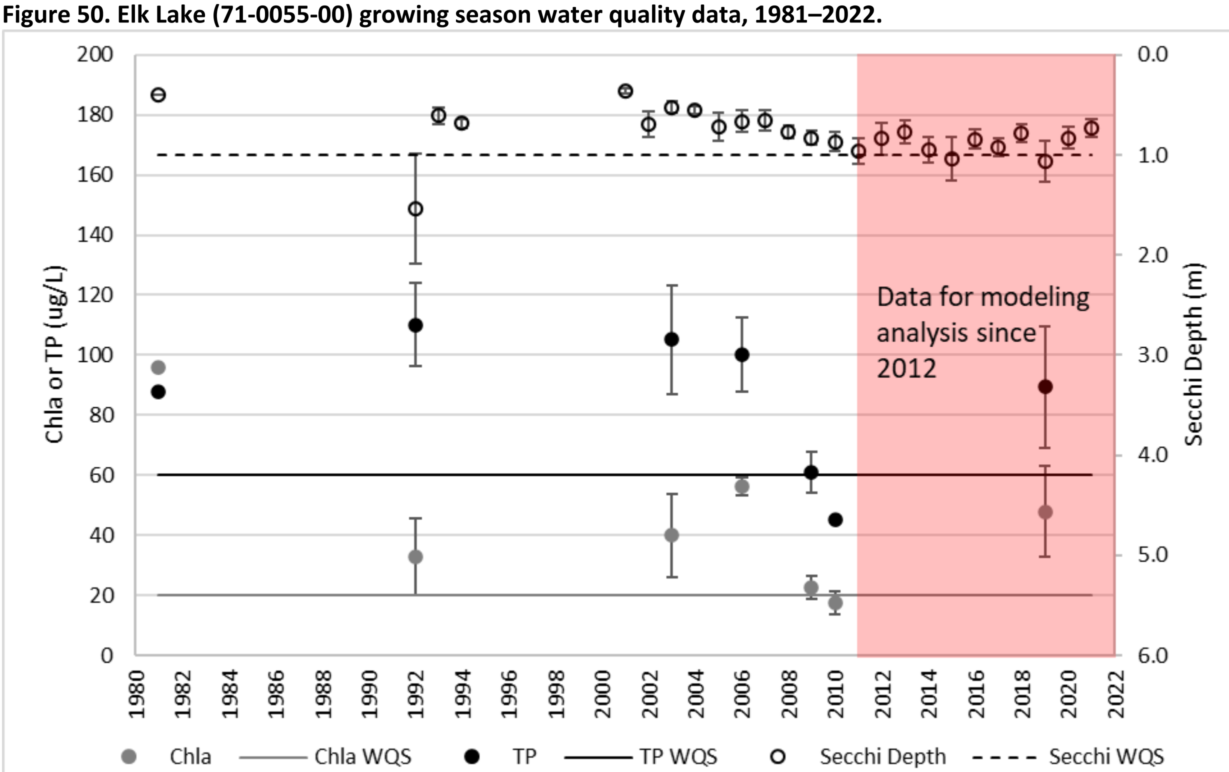


Figure 51. Elk Lake (71-0055-00) growing season paired TP and Chl-a data, 1981–2022.

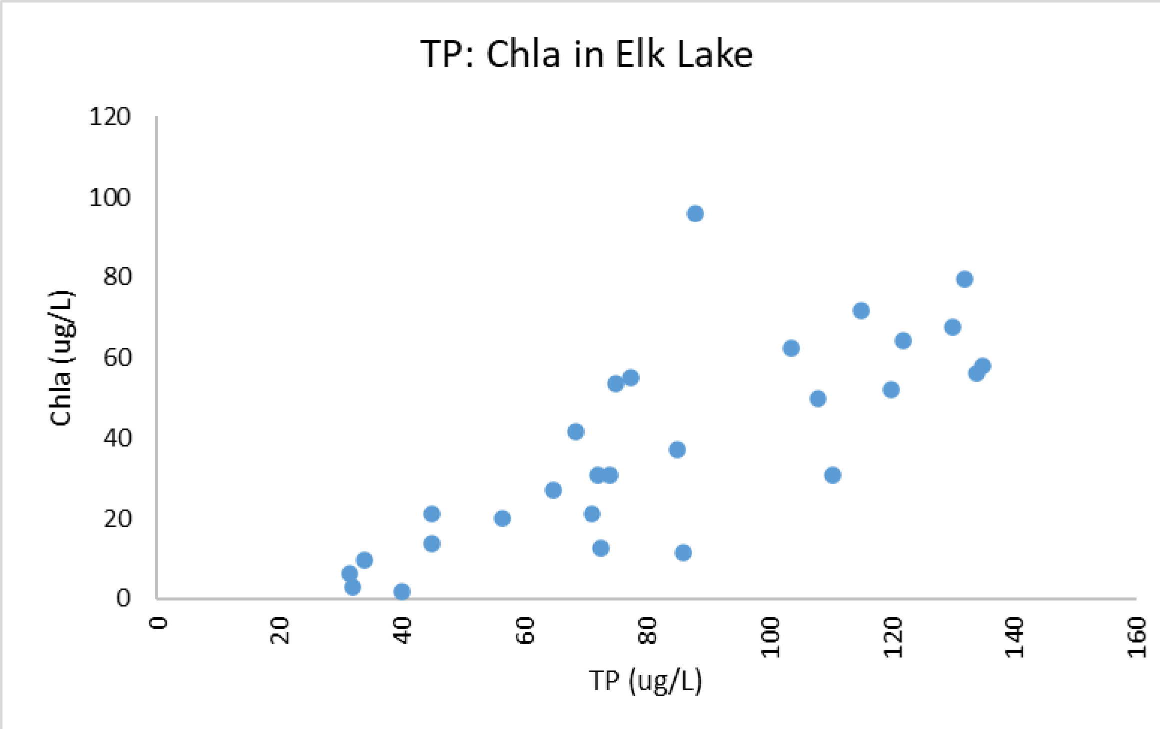


Figure 52. Eagle Lake (71-0067-00) growing season water quality data, 1982–2022 (deep water lake).

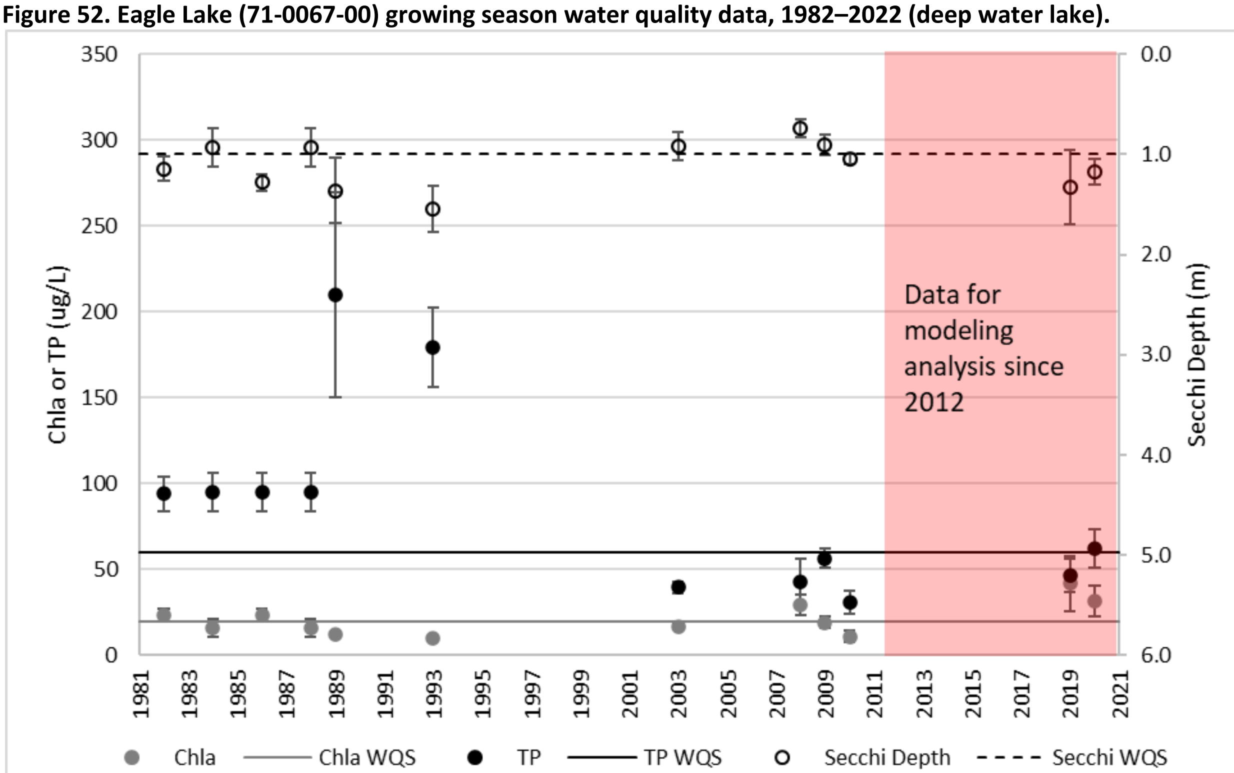


Figure 53. Eagle Lake (71-0067-00) growing season paired TP and Chl-*a* data, 1982–2022.

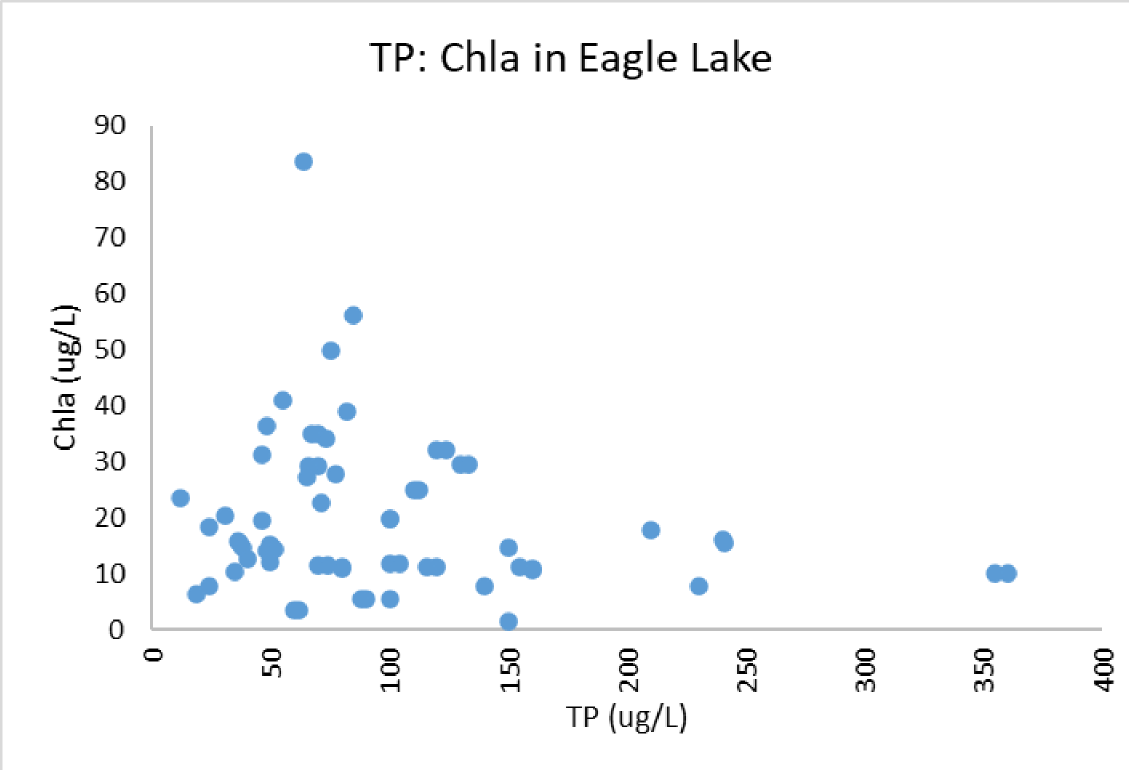


Figure 54. Millstone Lake (86-0152-00) water quality data, 2009–2022.

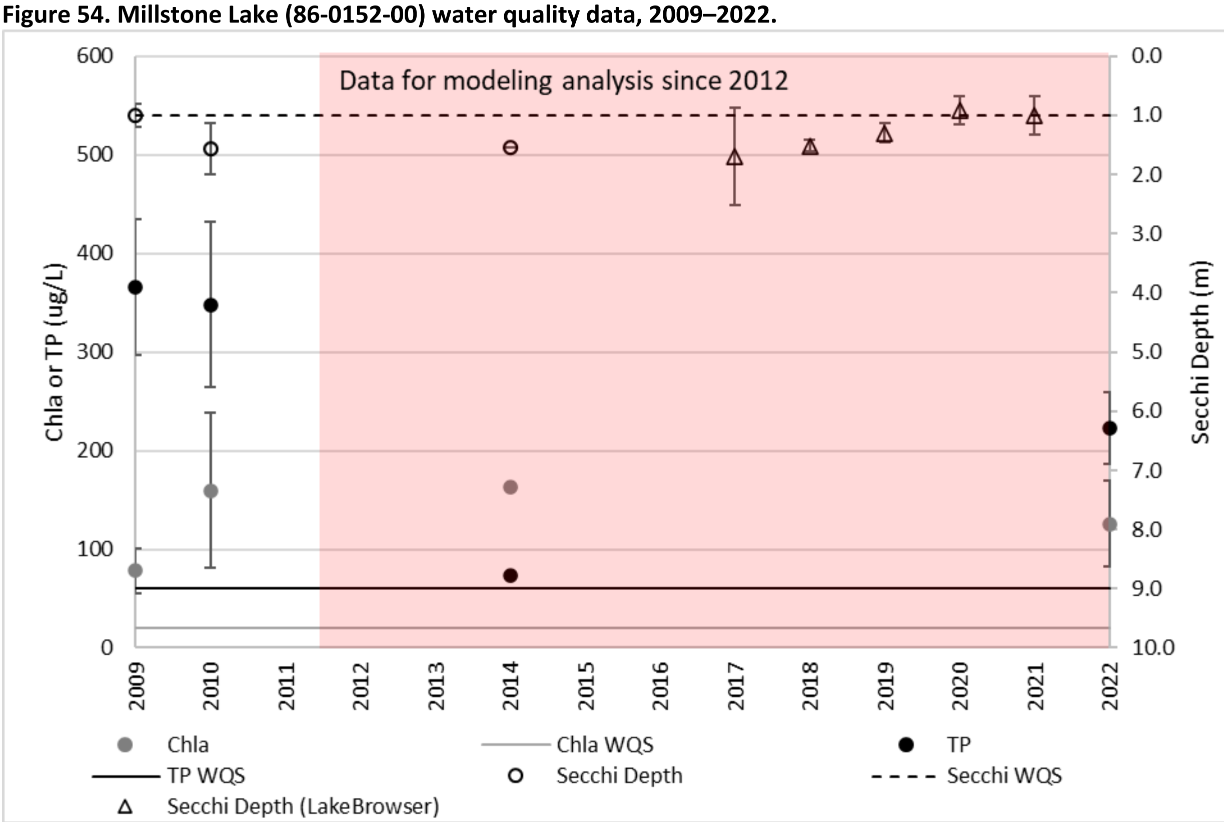


Figure 55. Millstone Lake (86-0152-00) growing season paired TP and Chl-*a* data, 2009–2022.

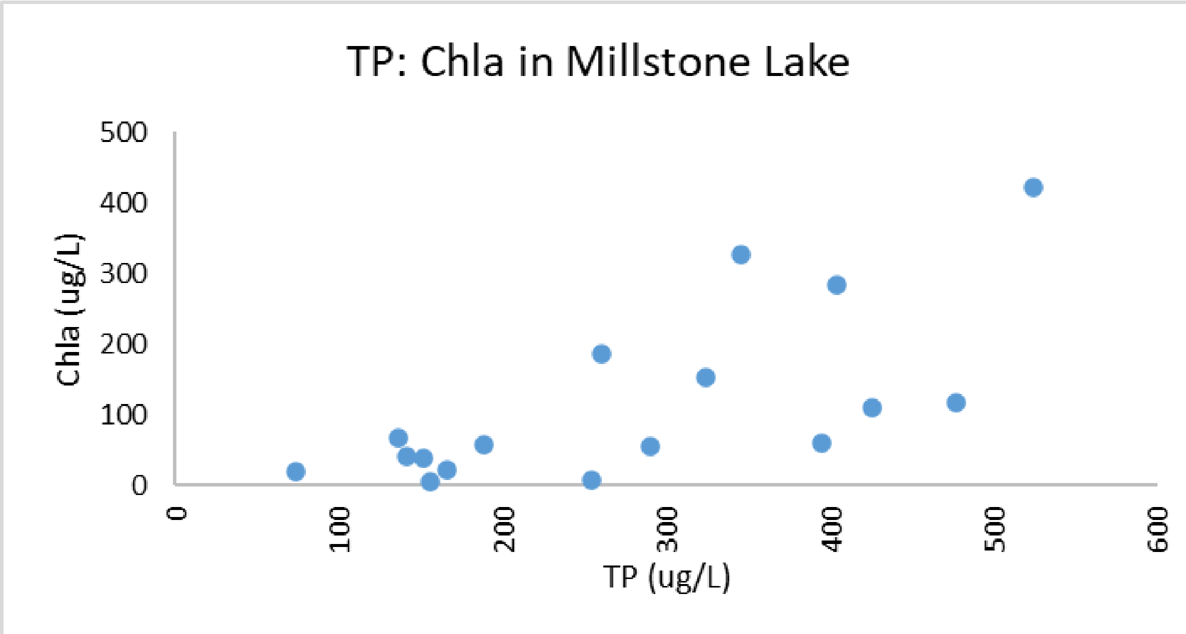


Figure 56. Little Mary Lake–South Bay (86-0139-01) water quality data, 2009–2022.

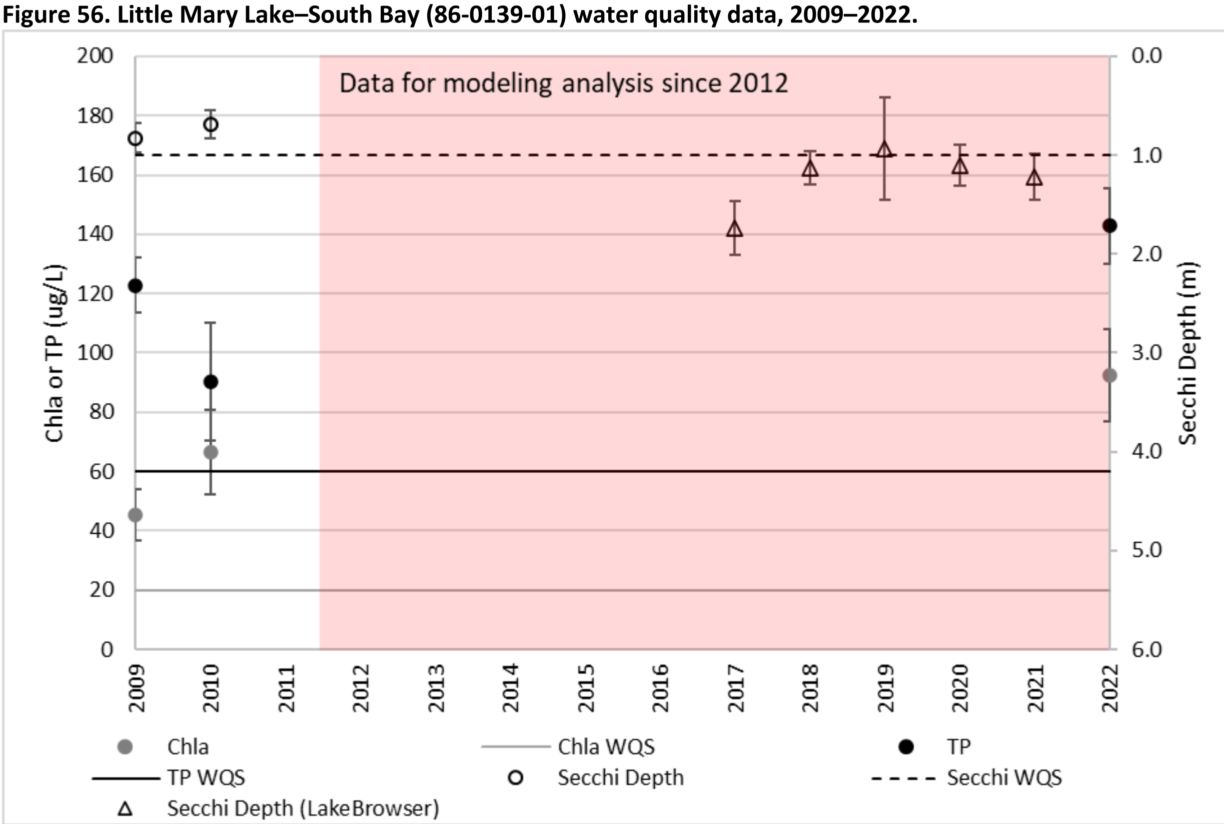


Figure 57. Little Mary Lake–North Bay (86-0139-02) water quality data, 2009–2022.

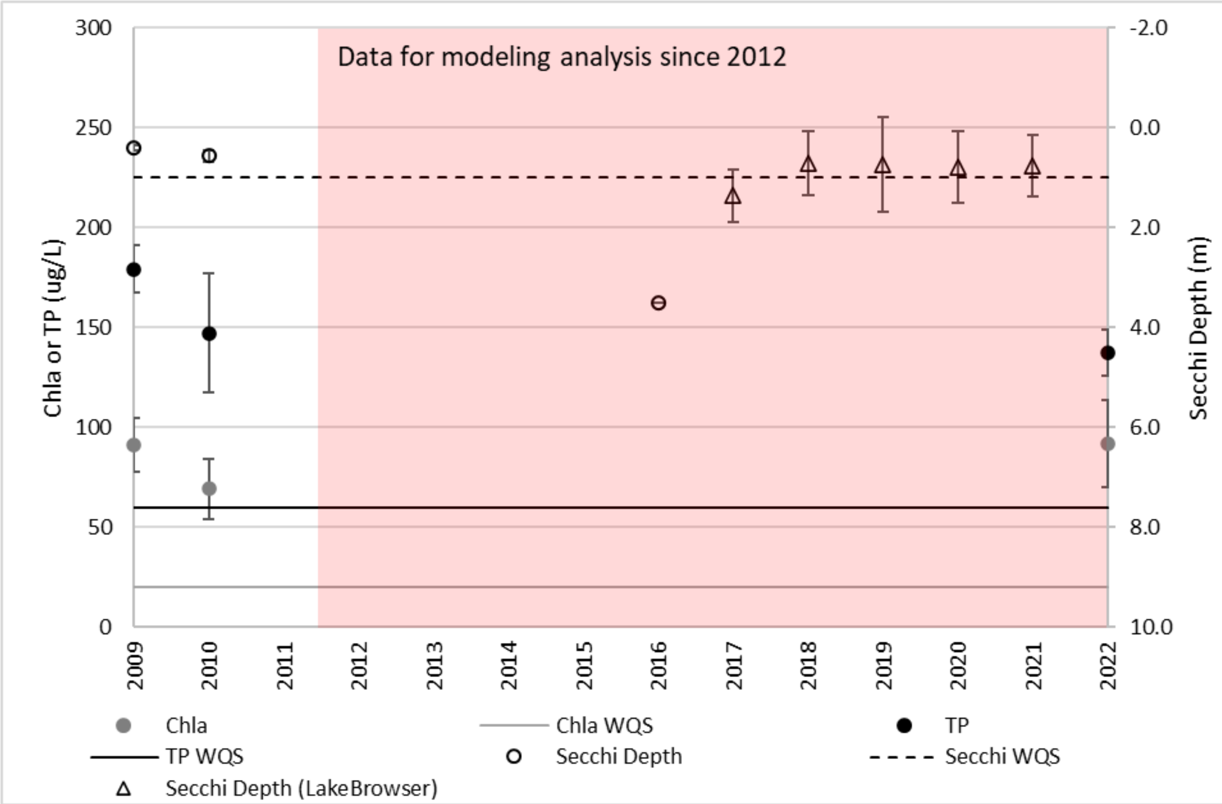
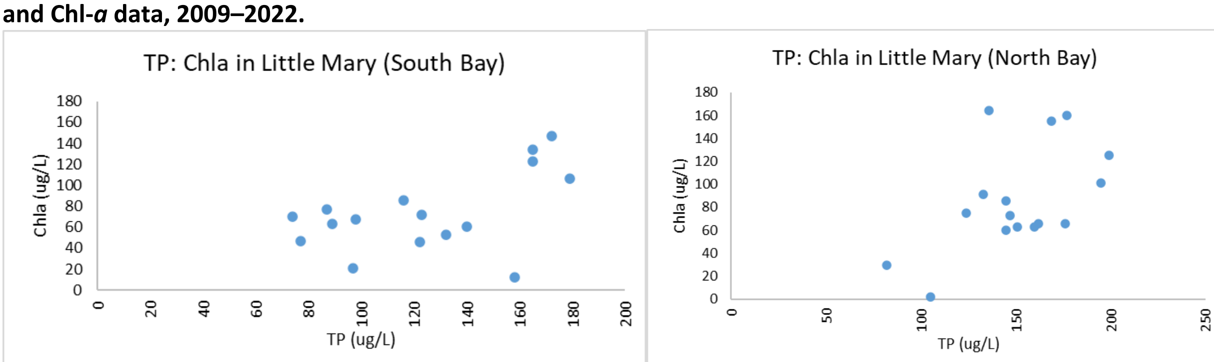


Figure 58. Little Mary Lake–South Bay (86-0139-01) left and North Bay (86-0139-02) growing season paired TP and Chl-*a* data, 2009–2022.



B.1.2 BATHTUB Model Setup

BATHTUB is an empirical model of reservoir eutrophication developed the U.S. Army Corps of Engineers (USACE). This model is used frequently for steady-state simulation of lake water quality and is capable of predicting in-lake conditions based on external and internal loading sources. Four of the six impaired lakes were modeled independently using the BATHTUB platform with model inputs developed from a suite of data sources, which are described in the following subsections. North and south bays of Little Mary Lake were simulated as one lake model.

During BATHTUB model development, the user must select a phosphorus-sedimentation model. For the MRSC, prior to calibration, each of the phosphorus-sedimentation models was individually explored for each lake to determine which phosphorus-sedimentation model minimized the differences between simulated and observed in-lake TP concentrations. The "Settling Velocity" phosphorus-sedimentation model (i.e., Option #7) was selected for each of the five MRSC lake models.

After each lake model was developed, the models were independently calibrated to best simulate existing conditions of long-term mean TP. After the models were successfully calibrated, load and allocation calculations were conducted. For this BATHTUB model application, the model application employed was the graphical user interface with associated Version 6.20 (USACE, 03/06/2014).

B.1.2.1 Lake Physical Parameters

Physical features of each impaired lake and its drainage area play an integral role in BATHTUB model setup and pre-model evaluation (Table 82). Most physical parameters were identified via the DNR *LakeFinder* application, or via geospatial analysis where the information was less readily available. DNR has identified some of these lakes as "groundwater dominated lakes" indicative of a watershed area to lake surface area ratio of 10 or less (for lakes greater than 10 acres but less than 100,000 acres in size). The groundwater-dominated lakes are Fremont and Millstone. Eagle Lake experiences some seasonal stratification with anoxic conditions at depth (Figure 59).

Note that the North Bay and South Bay of Little Mary Lake had the potential to be modeled as separate lakes with two BATHTUB models, or a single lake model with two distinct segments. Given the flow pattern (North Bay to South Bay) and the very similar TP concentrations between the two lakes relative to external loading, the decision was made to simulate Little Mary Lake with a single BATHTUB model with an independent segment for each bay. The distinct geometry and characteristics of both bays are still essential model inputs for parameterization.

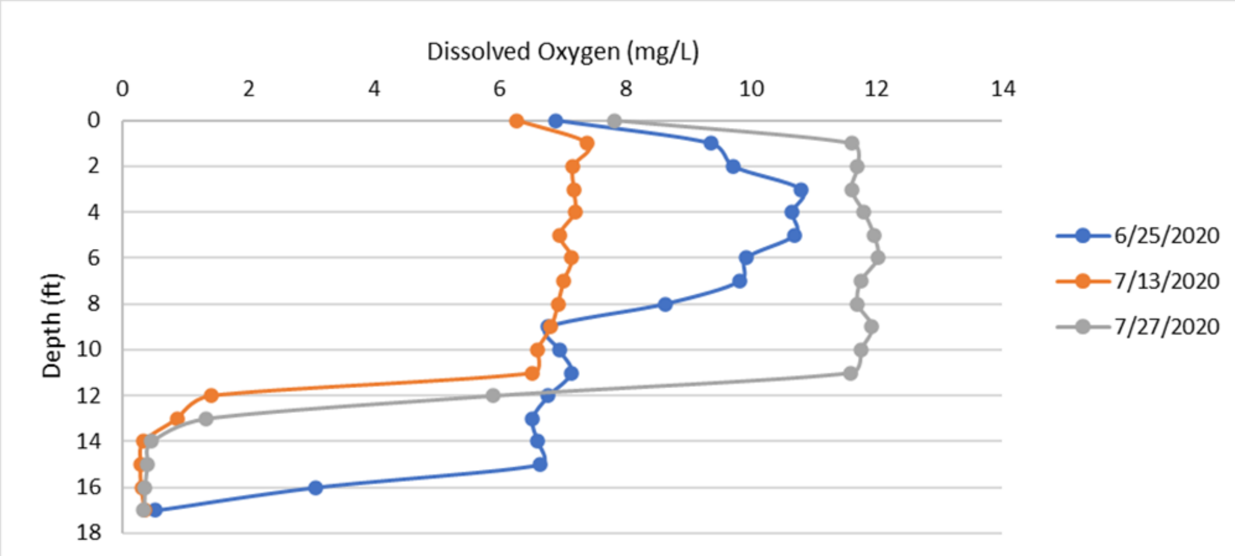
Watershed areas were tabulated based on the HSPF model subbasin boundaries for each of these lakes. Three lakes align with single HSPF subbasins: Fremont (subbasin 694), Eagle (subbasin 636), and Millstone (subbasin 336). Elk Lake drainage area includes subbasins 681, 684, and 686. A discrepancy was identified between the drainage areas to the North Bay and South Bay of Little Mary Lake, which resulted in a subdivision of subbasin 339: North Bay (subbasin 354 and 25% of subbasin 339) and South Bay (subbasins 346, 348, 342, 334, 352, 356, and 75% of subbasin 339).

Table 82. Physical parameters for impaired MRSC lakes covered in this report.

Lake	Surface Area (ac)	Mean Depth (m)	Max Depth (m)	Flow Path (km)	Littoral Area (ac)	Littoral Area (%)	Watershed Area (ac)[a]	Watershed Area[a]: Surface Area
Eagle	462	3.26	5.49	2.2	330	71%	5,114	11
Elk	362	2.13	4.57	2.2	362	100%	26,108	72
Fremont	493	1.58	2.44	2.2	493	100%	2,584	5
Little Mary (North Bay)	89	0.79	1.83	1.1	89	100%	5,682	64
Little Mary (South Bay)	16	0.49	4.57	0.5	16	100%	28,192	1,762
Millstone	200	1.28	2.59	1.1	200	100%	710	4

a. The watershed area includes the surface area of the lake.

Figure 59. Eagle Lake stratification with depth as observed with DO concentrations, summer 2020.



B.1.2.2 Averaging Period

Lake simulation averaging period in the BATHTUB model is a function of the mass balance between nutrient source loading and residence time in the water body.

$$Mass\ Residence\ Time\ (yr) = Nutrient\ Mass\ in\ Reservoir\ (kg)/External\ Nutrient\ Loading\ (kg/yr)$$

$$Nutrient\ Turnover\ Ratio = Averaging\ Period\ (yr)/Mass\ Residence\ Time\ (yr)$$

Residence times can be impacted by whether a lake is groundwater dominated, has perennial streams flowing in or out of the water body, and volume of loading to the lake from various sources in a watershed. Nutrient mass in reservoir was estimated as the existing long-term average TP concentration multiplied by the lake volume. External nutrient loading was calculated by adding up all TP sources, which includes atmospheric deposition, septic system loading, watershed runoff, and specific tributary inflow where applicable. Explicit breakdown of these loading sources is summarized in Section B.1.2.4.

An annual averaging period is appropriate for most lakes in Minnesota. Although the lake water quality standards apply only during the June through September growing season, annual phosphorus loads typically influence lake water quality conditions during the growing season. For lakes with high turnover ratios and low nutrient residence times (less than approximately two weeks), a shorter averaging period may be appropriate. The nutrient residence time for Little Mary Lake South Bay is less than one week (Table 83); therefore, the overall Little Mary Lake was modeled with a seasonal (June through September) averaging period. The remaining lakes were modeled with an annual averaging period.

Model inputs for each lake are calculated as a function of their selected averaging periods (for example, annual average TP atmospheric deposition to Fremont Lake versus seasonal average TP atmospheric deposition to Little Mary Lake).

Table 83. Averaging period determination for each MRSC lake BATHTUB model simulation.

Lake	Lake Segment	Nutrient Mass in Reservoir (kg)	External Nutrient Loading [a] (kg/yr)	Nutrient Turnover Ratio	Mass Residence Time, years (weeks)	Selected Averaging Period
Eagle	n/a	331	299	1	1.11 (58)	Annual
Elk	n/a	279	1,958	7	0.14 (7)	Annual
Fremont	n/a	146	219	2	0.67 (35)	Annual
Little Mary Lake	South Bay	5	1,921	128	<0.01 (<1)	Seasonal (Jun–Sep)
	North Bay	39	1,160	9	0.03 (2)	
Millstone	n/a	231	289	1	0.80 (42)	Annual

kg = kilogram; kg/yr = kilogram per year; n/a = not applicable.

[a] External nutrient load excludes internal loading.

B.1.2.3 Global Variables

Global parameterization for the BATHTUB model includes precipitation and evaporation rates, and atmospheric depositional loading of TP. Model inputs for the MRSCW are derived from estimates for the Upper Mississippi River Watershed (Barr 2007). Average annual precipitation for the watershed is 27.87 inches per year (0.708 meter per year [m/yr]) and the total atmospheric areal TP deposition rate on average is 0.268 kilograms per hectare per year (input as 26.8 milligrams per square meter). Lake evaporation was set equal to precipitation to simulate steady state conditions.

For lakes simulated with a seasonal averaging period, the same TP atmospheric deposition rate was applied, but a seasonally-modified precipitation of 0.376 m/yr based on a review of long-term monthly precipitation normals for the St. Cloud, Minnesota area for which June–September represents 53% of total annual rainfall.

B.1.2.4 Lake Source Assessment

Phosphorus sources to lakes may include permitted sources such as wastewater treatment plants (which does not apply these MRSC TMDL lakes), and nonpoint sources such as atmospheric deposition, discharge from SSTS (septic systems), watershed loading from the various land use types across the lake drainage area including MS4 service areas and/or tributaries, and internal loading due to accumulated phosphorus in lakebed sediment and vegetation. TP source loads are summarized in Table 88 following the detailed subsections below.

B.1.2.4.1 Atmospheric Deposition Loading

Lake area multiplied by rates presented in the Global Variables section are used to simulate combined wet and dry weather atmospheric deposition of phosphorus to each lake.

B.1.2.4.2 Septic System Loading

Loading from onsite septic systems was calculated based on the presence of numerous residential homes within a 1,000-foot buffer of a given lake. Review of aerial imagery indicated that a significant number of homes surround Fremont, Elk, and Eagle lakes. Due to the proximity of these homes, loading from onsite wastewater systems were calculated for these lakes. The number of homes around Fremont, Elk, and Eagle Lakes are 227, 285, and 245, respectively. Key assumptions for lake contributions from septic systems are included below, largely regionally specific to the Upper Mississippi River Watershed:

- Seasonal population: 15% (Barr Engineering 2004)
- Population per home: 2.32 (Barr Engineering 2004)
- Septic system effluent TP: 12.5 mg/L (Crites and Tchobanoglous 2008)
- Septic system flow: 60 gallons/capita/day (Lowe et al. 2009)
- Systems Failing to Protect Ground Water (FTPGW) (MPCA 2022)
    - 16.4% Wright County
    - 3.4% Sherburne County
- ITPHS (MPCA 2022)
    - 1.1% Wright County
    - 2.0% Sherburne County
- TP load arriving to waterway by system type: conforming 10%, FTPGW 30%, and ITPHS: 40% (Barr Engineering 2004)

Fremont, Elk, and Eagle Lakes BATHTUB model inputs for septic system flows in units required by the model are 0.0427 cubic hectometers per year (hm^3/yr), 0.0536 hm^3/season, and 0.0461 hm^3/yr, respectively. The TP concentrations associated with these flows are the same for each lake at 1,778 µg/L based on the flow-weighted contributions from each lake watershed and system types. The three lakes in Wright County are not surrounded by many septic systems in their immediate vicinities; therefore, septic loading inputs were not developed for these three water bodies.

B.1.2.4.3 Watershed and Upstream Loading

Model inputs for TP loading from contributing drainage areas were simulated based on watershed modeling output, known inputs from upstream lakes, and/or known inputs from observed tributary water quality. Watershed modeling used for some upland input components were derived from the HSPF model platform.

An HSPF model was developed and calibrated for the Upper Mississippi River Basin MRSCW in 2015 using data through 2009. RESPEC (2016) extended the model in time to 2015 without recalibration. Tetra Tech (2019) recalibrated the HSPF model for hydrology, sediment, and nutrients through its 2015 simulation period. The HSPF model included land use types simulated using the following land cover sources: NLCD 2006, Cropland Data Layer (CDL) 2016, and University of Minnesota Remote Sensing & Geospatial Analysis Laboratory (RSGAL) 2013.

For all six modeled lakes, average overland flows were extracted from the HSPF model simulation output from 2008 through 2015. These land use-based flows and TP loads were aggregated to approximate BATHTUB model inputs representing total upland annual or seasonal average watershed contributions to Fremont, Eagle, Millstone, and Little Mary North Bay (Table 84 and Table 85). Flows associated with Little Mary Lake North Bay were scaled to the seasonal averaging period based on the growing season precipitation fraction detailed in Section B.1.2.3. By contrast, upstream/watershed contributions to Elk and Little Mary South Bay were developed in three parts based on HSPF simulation of direct drainage area contributions, contributions from primary tributaries, and/or contributions from upstream lakes with existing or ongoing TMDL requirements (Table 86). Flows associated with Little Mary South Bay were scaled to the seasonal averaging period based on the growing season precipitation fraction detailed in Section B.1.2.3 just like Little Mary Lake North Bay.

Flow and TP loading contributions to Elk Lake include:

- Watershed contributions delivered via primary tributary Battle Brook: TP (73 µg/L) estimated via growing season average EQUIS data from station S004-704 at County Road 9 just north of the lake from 2011, 2019, and 2020 (approximately 17 observations) (Section B.4), flows from HSPF.
- Input from Diann Lake (*71-0046-00*), which is impaired and does not have a TMDL: TP concentration as growing season average from EQUIS data (11 TP observations at station 71-0046-00-201) from 2008 (74 µg/L), flows from HSPF.
- Direct drainage contributions: HSPF land use-based flows and loading.

Flow and TP loading contributions to Little Mary Lake South Bay include:

- Input from adjacent Little Mary Lake North Bay, part of this concurrent TMDL: with TP (138 µg/L) based on observed conditions, flows from HSPF.
- Input from Silver Lake (*86-0140-00*) with existing TMDL: TP (79 µg/L) from 2015 TMDL (MPCA 2015), flows from HSPF.
- Direct drainage contributions: HSPF land use-based flows and loading.

Watershed and upstream/upland-based flow and TP loading contributions play a significant role in the water balance and nutrient balance associated with these eutrophic water bodies.

Table 84. Average annual flow (ac-ft/yr), TP source load (lb/yr) associated TP concentration (µg/L) by land use, and percent of drainage area (DA) contributing to the lake (%): Fremont and Eagle.

	Fremont				Eagle			
Land Use	**DA**	**Flow**	**TP Load**	**TP Conc**	**DA**	**Flow**	**TP Load**	**TP Conc**
Developed	19%	309	41	49	15%	459	60	48
Forest	19%	305	42	51	37%	1,014	140	51
Grassland	11%	376	38	37	9%	583	59	37
Agriculture	44%	85	57	249	28%	94	63	249
Wetlands	7%	165	19	43	10%	385	45	43
Total Watershed Source Load	*100%*	*1,240*	*198*	-	100%	*2,535*	*367*	-
Total Watershed Inputs (model units) [a]	**-**	**1.53 hm³/yr**	**-**	**59 µg/L**	**-**	**3.13 hm³/yr**	**-**	**53 µg/L**

a. Total watershed inputs excludes atmospheric loading and SSTS.

Table 85. Average annual flow (ac-ft/yr), TP source load (lb/yr) associated TP concentration (µg/L) by land use, and percent of drainage area (DA) contributing to the lake (%): Millstone and Little Mary North Bay.

	Millstone				Little Mary North Bay			
Land Use	**DA**	**Flow**	**TP Load**	**TP Conc**	**DA**	**Flow**	**TP Load**	**TP Conc**
Developed	2%	41	6	51	2%	266	36	49
Forest	2%	45	6	49	8%	1,010	135	49
Grassland	1%	48	5	40	3%	597	64	40
Agriculture	94%	228	179	288	79%	949	744	288
Wetlands	1%	31	4	43	8%	1,354	157	43
Feedlots	1%	1	1	423	<1%	2	3	423
Pasture/Hay	-	-	-	-	<1%	21	6	101
Total Watershed Source Load	*100%*	*394*	*200*	-	*100%*	*4,200*	*1,185*	-
Total Watershed Inputs (model units) [a]	**-**	**0.49 hm³/yr**	**-**	**187 µg/L**	**-**	**5.18 hm³/yr**	**-**	**100 µg/L**

a. Total watershed inputs excludes atmospheric loading internal loading, and SSTS.

Table 86. Average annual flow and TP concentrations by upstream sources: Elk and Little Mary South Bay.

	Elk			Little Mary South Bay		
Boundary Conditions	**Flow, ac-ft/yr (hm^3/yr)**	**TP Load, lb/yr**	**TP Conc, µg/L**	**Flow, ac-ft/yr (hm^3/yr)**	**TP Load (lb/yr)**	**TP Conc, µg/L**
Direct Drainage Contribution [a]	659 **(0.81)**	16	**95**	60 **(0.07)**	19	**119**
Battle Brook tributary	14,828 **(18.29)**	2,944	**73**	-	-	-
Diann Lake *(TMDL needed)*	1,872 **(2.31)**	377	**74**	-	-	-
Silver Lake *(TMDL completed)*	-	-	-	19,210 **(23.69)**	2,193	**79**
Little Mary North Bay *(in this report)*	-	-	-	2,066 **(2.55)**	2,019	**138**

a. Direct drainage areas to Elk Lake and Little Mary South Bay excludes atmospheric loading and SSTS. Land use summary draining to Elk is 30% cropland, 28% wetland, 17% hay/pasture, 12% forest, 10% developed, 3% water, and <1% other natural area. Land use summary draining to Little Mary South Bay is 45% cropland, 13% forest, 12% wetland, 12% water, 10% hay/pasture, 7% developed, and 2% other natural area.

B.1.2.4.4 Permitted Source Loading

The watersheds to these six lakes have no permitted wastewater sources that discharge directly to surface water. Several regulated construction and industrial stormwater permittees; however, are present in some of the lakes' watersheds.

B.1.2.4.5 Internal Loading

The BATHTUB model governing equations for simulation of TP have an implicit inclusion of internal phosphorus loading from bed sediment due to the derivation of empirical formulas from a database of existing lakes and reservoirs. There are multiple mechanisms by which phosphorus can be released back into the water column as internal loading, such as:

- Low DO conditions in water overlying sediment can lead to P release from lakebed sediment when seasonal or intermittent turnover occurs (where stratification is clearly identified). Many shallow lakes will stratify for brief periods and mix several times throughout the summer growing season which leads to increased interaction between surface waters and the sediment P pool compared to deeper lakes.
- Curly-leaf pondweed (*Potamogeton crispus*), which can reach nuisance levels in shallow lakes, decays in the early summer and releases phosphorus to the water column (aquatic vegetation)
- Bottom-feeding fish such as carp and black bullhead forage in lake sediments, physically disturbing the lakebed sediment leading to release of phosphorus into the water column.
- Wind energy in shallow areas can result in mixing of the water column and disturbance of the lakebed sediments, releasing phosphorus into the water column.
- Other physical disturbances such as motorized boats in shallow areas can also disturb the bottom sediment and release phosphorus into the water column.

Lakes that are excessively high in TP concentrations on the order of > 100 µg/L TP may also be indicative of internal loading, particularly where in-lake TP concentrations regularly exceed the sum of all TP loading to the lake. These lakes are likely to have internal nutrient loading that result in increased TP concentrations.

Specific conditions related to internal loading potential for each of the MRSC lakes are summarized below based on recent data, aquatic vegetation, and fisheries surveys, etc. (Table 87). Generally speaking, when lake-specific conditions are observed in tandem it is possible to assess whether excessive internal phosphorus loading may be present in a manner that is not captured by the implicit inclusion of internal loading already present in the BATHTUB model. Some of the limitations associated with modeling internal loading in BATHTUB are the assumptions required to estimate based on the variety of complex physical and kinetic activities that cause internal loading. Additional limitations are related to how a waterbody can recover from high internal loading when the reason for internal loading may be tied back to long-term watershed loading and/or processes that have fed nutrients to the lake and lakebed over decades.

Based on the preponderance of evidence, it is most likely that the following lakes are impacted by excessive internal loading of P: Elk Lake, Little Mary North Bay, and Millstone Lake. These three lakes all have high observed TP concentrations that cannot be reasonably attributed to their associated TP loading sources; therefore, additional internal loading is required to account for observed excess TP observed. For the other three modeled lakes, the implicitly simulated internal loading was sufficient to account for observed TP concentrations relative to external loading sources.

Table 87. Internal loading potential for MRSC lakes by characteristic and description types.

Lake	Aquatic Vegetation	TP	Fish [a]	Stratification	Wind	Boating
Fremont	2008 Fish Survey indicates favorable conditions for widespread aquatic plant growth; curly-leaf pondweed present since 1957. 2002 Aquatic Veg Survey found curly-leaf pondweed dominated submerged plants	Mean TP 46 µg/L not excessively high	2008 Survey: common carp, fathead minnow, black bullhead	Shallow lake stratification cycles likely	Shallow, subject to turbulence	Concrete boat ramp
Elk	2012 Fisheries Lake Survey indicated that 2% of lake and 6% of shoreline were primarily cattail and yellow waterlily	Mean TP 89 µg/L not excessively high, but higher than source loading	2017 Survey: black crappie, bluegill, black bullhead	Shallow lake stratification cycles likely	Shallow, subject to turbulence	Concrete boat ramp, dock
Eagle [b]	2019–2020 Assessment Report indicated a dominance of curly-leaf pondweed in the spring, as well as presence of anoxic sediment and carp.	Mean TP 54 µg/L not excessively high	2020 Survey: bluegill, black crappie, yellow bullhead	Stratification observed (see The watershed area includes the surface area of the lake. Figure 59)	Although not a “shallow lake”, shallow enough to be subject to turbulence.	Concrete boat ramp, dock
Millstone	June 2022 survey found dominance of curly-leaf pondweed in significant abundance	Mean TP 223 µg/L is excessively high for its small watershed size	2019 Targeted Survey: bluegill, black bullhead	Shallow lake stratification cycles likely	Shallow, subject to turbulence	Concrete boat ramp
Little Mary South Bay	June 2022 survey found very little curly-leaf pondweed, dominance of northern milfoil	Mean TP 143 µg/L is excessively high	No Fisheries Lake Survey data available	Shallow lake stratification cycles likely	Shallow, subject to turbulence	No direct access, via North Bay
Little Mary North Bay	June 2022 survey found very little curly-leaf pondweed, dominance of northern milfoil	Mean TP 138 µg/L is excessively high	No Fisheries Lake Survey data available	Shallow lake stratification cycles likely	Shallow, may be subject to turbulence	Concrete boat ramp, 2 docks

a. Fish data reflect most common species by count
b. (WSB 2020)

B.1.2.4.6 Source Assessment Summary

Based on the previous subsections, the summary of all relevant TP sources to each of the six lakes indicate which sources have the greatest contribution to observed in-lake TP concentrations (Table 88).

Table 88. Source analysis: existing TP loading by source for each lake (lb/yr or lb/season*, and percent of total external load).

Loading Source	Eagle	Elk	Fremont	Little Mary (North Bay)	Little Mary (South Bay)	Millstone
Atmospheric Deposition	110 (17%)	86 (2%)	118 (24%)	21 (3%)	4 (<1%)	48 (19%)
Septic Systems	181 (28%)	112 (3%)	167 (35%)	-	-	-
Watershed and/or Tributary	366 (56%)	2,959 (84%)	199 (41%)	606 (97%)	19 (<1%)	202 (81%)
Upstream Impaired Lake	-	Diann Lake: 377 (11%)	-	-	North Bay: 2,019 (48%) Silver Lake: 2,193 (52%)	-
Total External Load	***657***	***3,534***	***485***	***628***	***4,235***	***250***
Additional Internal Loading	-	*Determined during model calibration (see Section B.2)*	-	*Determined during model calibration (see Section B.2)*	-	*Determined during model calibration (see Section B.2)*

*Little Mary Lake (North Bay and South Bay) simulated with a seasonal averaging period.

B.2 Model Calibration

BATHTUB lake model input files were developed based on the detailed analyses of Section B.1.2. Determination of the best model selection for TP across all lakes was made by comparing simulation results prior to model calibration to observed TP concentrations to identify which model best represented existing conditions. The TP model that provided accurate pre-calibration simulation across the most lakes was Model 7 (Settling Velocity), which calculates TP as an inverse relationship relative to lake depth. Each individual lake model was calibrated to best simulate observed water quality conditions summarized in Section B.1.1 with adjustment of default calibration factors as applied to sedimentation rates (Table 89).

Additional internal loading was required for Elk Lake, Millstone Lake, and Little Mary Lake (North Bay) due primarily to in-lake TP being observed in higher concentrations than are received by the waterway from summed external sources. All of these MRSC lakes likely experience internal loading of some kind; however, additional loading beyond that included implicitly in the model is what is accounted for during the model calibration process.

Table 89. TP calibration parameterization and simulation results for MRSC lakes.

<table>
<tr><th>Model Calibration Results</th><th>Eagle</th><th>Elk</th><th>Fremont</th><th>Little Mary (South Bay)</th><th>Little Mary (North Bay)</th><th>Millstone</th></tr>
<tr><td>TP Sedimentation Rate</td><td>1.25</td><td>0</td><td>1.60</td><td colspan="2">0</td><td>1.00</td></tr>
<tr><td>Additional Internal Loading Rate (mg/m^2/d)</td><td>-</td><td>0.45</td><td>-</td><td>-</td><td>4.8</td><td>0.595</td></tr>
<tr><td>Simulated TP (µg/L)</td><td>54</td><td>89</td><td>46</td><td colspan="2">Area-weighted mean: 139</td><td>223</td></tr>
<tr><td rowspan="2">Observed TP (µg/L)</td><td rowspan="2">54</td><td rowspan="2">89</td><td rowspan="2">46</td><td>143</td><td>138</td><td rowspan="2">223</td></tr>
<tr><td colspan="2">Area-weighted mean: 139</td></tr>
<tr><td>TP WQS (µg/L)</td><td>40</td><td>60</td><td>60</td><td>60</td><td>60</td><td>60</td></tr>
</table>

B.3 Phosphorus TMDL Summary

See Section 4.3 for the approach to developing the lake phosphorus TMDLs. TMDL tables are in Section 4.3.9

B.4 Recent Observed Water Quality

The following datasets were used to calculate mean annual average water quality values to represent observed conditions relevant to BATHTUB model calibration and TMDL model evaluations and calculations.

Table 90. Eagle Lake water quality data from June–September, 2012–2022.

Date	Chl-a (µg/L	Secchi (m)	TP (µg/L)
6/11/2019	6.2	2.4	19
7/16/2019	36.5	1.1	48
8/13/2019	83.7	0.7	64
9/17/2019	40.9	1.1	55
6/11/2020		2.3	
6/19/2020	12.5	1.7	40
6/25/2020		1.4	
7/13/2020		1.2	
7/16/2020	31.2	1.1	46
7/27/2020		0.8	
8/10/2020		0.9	
8/11/2020	56.1	1.1	85
8/24/2020		0.8	
9/14/2020		0.9	
9/18/2020	27.8	0.9	77
9/22/2020		1.1	

Table 91. Elk Lake water quality data from June–September, 2012–2022.

Date	Chl-a (µg/L)	Secchi (m)	TP (µg/L)	Date	Chl-a (µg/L	Secch i (m)	TP (µg/L)	Date	Chl-a (µg/L	Secchi (m)	TP (µg/L)
6/7/2012		1.7		6/8/2016		1.2		7/2/2019		1.1	
6/11/2012		1.2		6/15/2016		0.9		7/17/2019	41.4	0.8	68.5
7/3/2012		0.6		6/30/2016		0.9		7/25/2019		0.5	
7/27/2012		0.5		7/14/2016		0.8		7/29/2019	71.6	0.4	115
8/11/2012		0.5		7/30/2016		0.6		8/3/2019		0.5	
8/30/2012		0.5		8/31/2016		0.6		8/13/2019	64.1	0.5	122
9/17/2012		0.6		9/18/2016		0.6		8/14/2019	79.6	0.3	132
9/30/2012		1.1		9/30/2016		0.6		8/29/2019		0.3	
6/1/2013		1.1		6/4/2017		1.4		9/3/2019	67.6	0.3	130
6/12/2013		1.2		6/14/2017		1.2		9/11/2019		0.5	
7/1/2013		0.9		6/22/2017		1.2		9/17/2019	53.4	0.6	75
7/21/2013		0.5		6/30/2017		1.1		6/2/2020		1.5	
8/1/2013		0.5		7/8/2017		0.9		6/8/2020		1.4	
8/16/2013		0.6		7/22/2017		0.8		6/14/2020		1.2	
9/30/2013		0.6		8/3/2017		0.6		6/29/2020		0.8	
6/8/2014		1.4		9/4/2017		0.6		7/8/2020		0.8	
6/13/2014		1.5		9/15/2017		0.6		7/17/2020		0.6	
6/29/2014		1.1		9/26/2017		0.8		7/31/2020		0.6	
7/13/2014		0.8		6/7/2018		1.2		8/21/2020		0.6	
7/19/2014		0.8		6/15/2018		1.1		8/30/2020		0.5	
8/9/2014		0.6		6/22/2018		0.9		9/3/2020		0.6	
8/20/2014		0.6		7/11/2018		0.6		9/25/2020		0.6	
9/21/2014		0.8		7/27/2018		0.6		6/2/2021		1.2	
6/5/2015		1.8		8/19/2018		0.6		6/12/2021		1.1	
6/10/2015		2.1		8/31/2018		0.5		6/25/2021		0.8	
6/22/2015		1.2		9/29/2018		0.8		7/9/2021		0.8	
7/3/2015		0.8		6/1/2019		3.0		8/1/2021		0.6	

Date	Chl-a (µg/L)	Secchi (m)	TP (µg/L)
8/1/2015		0.6	
8/27/2015		0.6	
9/19/2015		0.6	
9/30/2015		0.6	
6/1/2016		1.4	

Date	Chl-a (µg/L	Secchi (m)	TP (µg/L)
6/7/2019		2.4	
6/11/2019	2.7	2.0	32
6/12/2019	1.9	1.4	40
6/14/2019		2.1	
6/20/2019		1.4	

Date	Chl-a (µg/L	Secchi (m)	TP (µg/L)
8/29/2021		0.5	
9/10/2021		0.6	
9/18/2021		0.5	
9/29/2021		0.6	

Table 92. EQuIS Battle Brook (tributary to Elk Lake) water quality data, 2009–2020.

Date	TP (µg/L)	Date	TP (µg/L)	Date	TP (µg/L)
6/1/2009	67	5/3/2011	49	5/21/2019	54
6/9/2009	87	6/6/2011	52	6/11/2019	99
6/18/2009	91	6/14/2011	72	7/16/2019	86
6/23/2009	81	6/28/2011	107	8/13/2019	54
7/13/2009	95	7/18/2011	85	9/17/2019	39
8/4/2009	60	8/9/2011	143	9/17/2019	38
8/14/2009	60	9/12/2011	75	5/26/2020	122
8/25/2009	36	9/19/2011	46	6/16/2020	112
9/11/2009	96	9/28/2011	41	7/14/2020	64
9/29/2009	42	10/26/2011	44	8/18/2020	44
10/7/2009	68	11/7/2011	63	9/15/2020	46
4/26/2011	44	11/17/2011	38		

Table 93. Fremont Lake water quality data from June–September, 2012–2022.

Date	Chl-a (µg/L	Secchi (m)	TP (µg/L)
6/2/2015		0.6	
9/15/2015		0.6	
6/24/2016		0.8	
6/20/2018		1.5	
7/17/2018		1.2	
7/31/2018		1.4	
8/16/2018		1.2	
9/7/2018		1.2	
6/4/2019		2.0	
6/11/2019	1.8	2.3	24
6/12/2019	4.5	2.0	23
6/28/2019		1.8	
7/16/2019		2.0	
7/17/2019	7.6	2.0	22
7/29/2019	6.4	1.5	32
8/13/2019	10.7	1.7	38
8/14/2019	12.3	1.0	37
8/15/2019		1.5	
9/3/2019	32.3	0.8	49
9/17/2019	20.5	1.1	36
9/19/2019		1.2	
6/2/2020		1.5	
6/19/2020	16.0	0.7	42
6/22/2020		0.9	
7/15/2020		0.8	

Date	Chl-a (µg/L	Secchi (m)	TP (µg/L)
7/16/2020	39.7	0.6	70
8/5/2020		0.6	
8/11/2020	39.2	0.5	66
9/15/2020		0.8	
9/18/2020	21.4	0.6	61
6/7/2021		1.8	
7/8/2021		1.2	
8/3/2021		0.9	

Table 94. Wright County water quality data, Jun–Sep, 2012–2022 (Millstone, Little Mary South Bay & North Bay).

	Millstone			Little Mary (South Bay)			Little Mary (North Bay)		
Date	Chl-a (µg/L)	Secchi Depth (m)	TP (µg/L)	Chl-a (µg/L)	Secchi Depth (m)	TP (µg/L)	Chl-a (µg/L)	Secchi Depth (m)	TP (µg/L)
6/25/2014	20.3	2.4	73	–	–	–	–	–	–
7/17/2016	–	–	–	–	–	–	–	3.5	–
6/14/2022	37.4	0.30	151	63.2	0.46	89	164	0.23	136
6/28/2022	58.7	0.23	188	67.6	0.69	98	65.9	0.23	162
7/11/2022	187	0.08	260	85.4	0.46	116	85.4	0.30	145
7/26/2022	283	0.08	404	134	0.38	165	160	0.23	177
8/9/2022	326	0.08	346	147	0.30	172	155	0.23	169
8/23/2022	66.8	0.38	136	123	0.46	165	74.8	0.46	124
9/15/2022	5.34	0.23	156	12.5	0.46	158	1.78	0.53	105
9/27/2022	40	0.23	141	106	–	179	29.4	0.53	82

B.5 Model Summaries

The U.S. Army Corps of Engineers lake model BATHTUB (Walker 1987) was used to model lake phosphorus concentration in each impaired lake (BATHTUB for Windows Version 6.20, 03/06/2014). The tables in this appendix show select model inputs and select outputs.

B.5.1 Eagle Lake

	Averaging period (yrs.)	1
	Precipitation and Evaporation (m/yr)	0.708
Global Variables	Atmospheric TP Load (mg/m^2-yr)	26.8
Model Options	P model and P calibration	Settling Velocity, Decay Rates
Model Coefficients	TP Coefficient	1.25
	Surface Area (km^2), Mean & Mixed Layer Depths (m)	1.87, 3.3, 3.3
	Observed and Target TP (µg/L)	54, 40
	Internal Loading (mg/mg^2-day)	0 (Baseline), 0 (TMDL)
Segment	Hydraulic residence time (yr), Overflow rate (m/yr)	1.9, 1.7
Watershed and	Watershed Loading: flow (hm^3/yr), TP (µg/L)	3.13, 53
Tributary Inputs*	Septic Loading: flow (hm^3/yr), TP (µg/L)	0.0461, 1778

*Total watershed area for Eagle Lake is 5,114 acres including the lake.

Parameter	Flow (hm^3/yr)	% Flow	TP load (kg/yr)	% TP load	TP concentration (µg/L)
Segment mass balance: Baseline					
Watershed Loading	3.1	69.6%	165.9	55.7%	53
Septic Loading	0.046	1.0%	82.0	27.5%	1778
Precipitation	1.3	29.4%	50.1	16.8%	38
TOTAL IN	**4.5**	**100%**	**298.0**	**100%**	**-**
Evaporation	1.3	29.4%	-	-	-
Retention	-	-	126.5	42.4%	-
Outflow	3.2	70.6%	171.5	57.6%	54
TOTAL OUT	**4.5**	**100%**	**298.0**	**100%**	**-**
Segment mass balance: Target					
Watershed Loading	3.1	69.6%	112.7	51.1%	36
Septic Loading	0.046	1.0%	57.6	26.1%	1250
Precipitation	1.3	29.4%	50.1	22.7%	38
TOTAL IN	**4.5**	**100%**	**220.4**	**100%**	**-**
Evaporation	1.3	29.4%	-	-	-
Retention	-	-	93.5	42.4%	-
Outflow	3.2	70.6%	126.9	57.6%	40
TOTAL OUT	**4.5**	**100%**	**220.4**	**100%**	**-**

B.5.2 Elk Lake

Global Variables	Averaging period (yrs.)	1
	Precipitation and Evaporation (m/yr)	0.708
	Atmospheric TP Load (mg/m^2-yr)	26.8
Model Options	P model and P calibration	Settling Velocity, Decay Rates
Model Coefficients	TP Coefficient	0
Segment	Surface Area (km^2), Mean & Mixed Layer Depths (m)	1.46, 2.1, 2.1
	Observed and Target TP (µg/L)	89, 60
	Internal Loading (mg/mg^2-day)	0.45 (Baseline), 0 (TMDL)
	Hydraulic residence time (yr), Overflow rate (m/yr)	0.15, 14.2
Watershed and Tributary Inputs	Direct Drainage: flow (hm^3/yr), TP (µg/L)	0.81, 95
	Battle Brook Tributary: flow (hm^3/yr), TP (µg/L)	18.29, 73
	Septic Loading: flow (hm^3/yr), TP (µg/L)	0.0285, 1778
	Diann Lake: flow (hm^3/yr), TP (µg/L)	2.31, 74

*Total watershed area for Elk Lake is 26,108 acres including the lake.

Parameter	Flow (hm^3/yr)	% Flow	TP load (kg/yr)	% TP load	TP concentration (µg/L)
Segment mass balance: Baseline					
Battle Brook	18.3	81.4%	1335.2	69.8%	73
Septic Loading	0.029	0.1%	50.7	2.6%	1778
Diann Lake	2.3	10.3%	170.9	8.9%	74
Direct Drainage	0.8	3.6%	76.9	4.0%	95
Precipitation	1.0	4.6%	39.1	2.0%	38
Internal Loading	-	-	240.0	12.5%	-
TOTAL IN	**21.7**	**100%**	**1912.8**	**100%**	**85**
Evaporation	1.0	4.6%	-	-	-
Retention	-	-	-	-	-
Outflow	20.7	95.4%	1912.8	100%	89
TOTAL OUT	**21.7**	**100%**	**1912.8**	**100%**	**89**
Segment mass balance: Target					
Battle Brook	18.3	81.4%	1024.2	79.6%	56
Septic Loading	0.029	0.1%	35.6	2.8%	1250
Diann Lake	2.3	10.3%	138.6	10.8%	60
Direct Drainage	0.8	3.6%	48.6	3.8%	60
Precipitation	1.0	4.6%	39.1	3.0%	38
Internal Loading	-	-	-	-	-
TOTAL IN	**22.4**	**100%**	**1286.2**	**100%**	**57**
Evaporation	1.0	4.6%	-	-	-
Retention	-	-	-	-	-
Outflow	21.4	95.4%	1286.2	100%	**60**
TOTAL OUT	**22.4**	**100%**	**1286.2**	**100%**	**-**

B.5.3 Fremont Lake

	Averaging period (yrs.)	1
	Precipitation and Evaporation (m/yr)	0.708
Global Variables	Atmospheric TP Load (mg/m^2-yr)	26.8
Model Options	P model and P calibration	Settling Velocity, Decay Rates
Model Coefficients	TP Coefficient	1.6
	Surface Area (km^2), Mean & Mixed Layer Depths (m)	2.0, 1.6, 1.6
	Observed and Target TP (µg/L)	46, 44
	Internal Loading (mg/mg^2-day)	0 (Baseline), 0 (TMDL)
Segment	Hydraulic residence time (yr), Overflow rate (m/yr)	2.0347, 0.8
Watershed and Tributary Inputs*	Watershed Loading: flow (hm^3/yr), TP (µg/L)	1.53, 59
	Septic Loading: flow (hm^3/yr), TP (µg/L)	0.0427, 1778

*Total watershed area for Fremont Lake is 2,584 acres including the lake.

Parameter	Flow (hm^3/yr)	% Flow	TP load (kg/yr)	% TP load	TP concentration (µg/L)
Segment mass balance: Baseline					
Precipitation	1.4	47.4%	53.6	24.4%	38
Septic Loading	0.043	1.4%	75.9	34.5%	1778
Watershed Runoff	1.5	51.2%	90.3	41.1%	59
TOTAL IN	**3.0**	**100%**	**219.8**	**100%**	**74**
Evaporation	1.4	47.4%	-	-	-
Retention	-	-	147.4	67.0%	-
Outflow	1.6	52.6%	72.3	100%	46
TOTAL OUT	**3.0**	**100%**	**219.8**	**100%**	**-**
Segment mass balance: TMDL					
Precipitation	1.4	47.4%	53.6	25.7%	38
Septic Loading	0.043	1.4%	66.8	32.0%	1,250
Watershed Runoff	1.5	51.2%	88.5	42.4%	59
TOTAL IN	**3.0**	**100%**	**208.9**	**100%**	**66**
Evaporation	1.4	47.4%	-	-	-
Retention	-	-	140.1	67.1%	-
Outflow	1.6	52.6%	68.8	32.9%	41
TOTAL OUT	**3.0**	**100%**	**208.9**	**100%**	**-**

B.5.4 Little Mary Lake (South Bay & North Bay)

		North Bay	South Bay
Global Variables	Averaging period (yrs.)	0.33	
	Precipitation and Evaporation (m/yr)	0.376, 0.376	
	Atmospheric TP Load (mg/m^2-yr)	26.8	
Model Options	P model and P calibration	Settling Velocity, Decay Rates	
Model Coefficients	TP Coefficient	0	
Segment	Surface Area (km^2), Mean & Mixed Layer Depths (m)	0.36, 0.8, 0.8	0.06, 0.5, 0.5
	Observed and Target TP (µg/L)	138, 60	143, 60
	Internal Loading (mg/mg^2-day)	4.8 (Baseline), 1.3 (TMDL)	0 (Baseline) 0 (TMDL)
	Hydraulic residence time (yr), Overflow rate (m/yr)	0.1047, 7.6	0.0019, 256.8
Watershed and Tributary Inputs*	Direct Drainage: flow (hm^3/yr), TP (µg/L)	2.75, 100	0.07, 119
	Silver Lake: flow (hm^3/yr), TP (µg/L)	-	12.59, 79

*Total watershed area for Little Mary North Bay is 5,682 acres. Little Mary South Bay has a small direct drainage area and is largely controlled by inflow from North Mary North Bay to the northeast and from Silver Lake to the west. The total sum of all watershed area that ends up draining through to Little Mary South Bay is 28,192 acres.

B.5.4.1 North Bay

Parameter	Flow (hm^3/yr)	% Flow	TP load (kg/yr)	% TP load	TP concentration (µg/L)
Segment mass balance: Baseline					
Watershed Loading	2.8	87.0%	275.0	30.0%	100
Precipitation	0.4	13.0%	9.6	1.1%	24
Internal Loading	-	-	631.2	68.9%	-
TOTAL IN	**3.2**	**100%**	**915.8**	**100%**	**290**
Evaporation	0.4	13.0%	-	-	-
Retention	-	-	-	-	-
Advective Outflow	2.8	87.0%	389.5	42.5%	142
Net Diffusive Outflow	-	-	526.3	57.5%	-
TOTAL OUT	**3.2**	**100%**	**915.8**	**100%**	**-**
Segment mass balance: Target					
Watershed Loading	2.8	87.0%	165.0	47.7%	60
Precipitation	0.4	13.0%	9.6	2.8%	24
Internal Loading	0	0.0%	170.9	49.5%	-
TOTAL IN	**3.2**	**100%**	**345.6**	**100%**	**109**
Evaporation	0.4	13.0%	-	-	-
Retention	-	-	-	-	-
Advective Outflow	2.8	87.0%	168.3	48.7%	61
Net Diffusive Outflow	-	-	177.2	51.3%	-
TOTAL OUT	**3.2**	**100%**	**345.6**	**100%**	**126**

B.5.4.2 South Bay

Parameter	Flow (hm^3/yr)	% Flow	TP load (kg/yr)	% TP load	TP concentration (µg/L)
Segment mass balance: <u>Baseline</u>					
Silver Lake Loading	12.7	81.3%	994.6	51.8%	79
Watershed Loading	0.1	0.5%	8.3	0.4%	119
Precipitation	0.1	0.4%	1.6	0.1%	24
Internal Loading	-	-	-	-	-
Advective Inflow	2.8	17.8%	389.5	20.3%	142
Net Diffusive Inflow	-	-	526.3	27.4%	-
TOTAL IN	**15.5**	**100%**	**1920.3**	**100%**	**124**
Evaporation	0.1	0.4%	-	-	-
Retention	-	-	-	-	-
Advective Outflow	15.4	99.6%	1920.3	100.0%	125
TOTAL OUT	**15.5**	**100%**	**1920.3**	**100%**	**-**
Segment mass balance: <u>Target</u>					
Silver Lake Loading	12.6	81.3%	503.6	58.9%	40
Watershed Loading	0.1	0.5%	4.2	0.5%	55
Precipitation	0.1	0.4%	1.6	0.2%	24
Internal Loading	-	-	-	-	-
Advective Inflow +	2.8	17.8%	168.3	19.7%	60
Net Diffusive Inflow +	-	-	177.2	20.7%	-
TOTAL IN	**15.4**	**100.0%**	**855.0**	**100.0%**	**-**
Evaporation	0.1	0.4%	-	-	-
Retention	-	-	-	-	-
Advective Outflow	15.4	99.6%	855.0	100.0%	60
TOTAL OUT	**15.5**	**100%**	**855.0**	**100%**	**-**

+ Advective and net diffusive inflows to South Bay are attributed to direct inflows from the North Bay.

B.5.5 Millstone Lake

Global Variables	Averaging period (yrs.)	1
	Precipitation and Evaporation (m/yr)	0.708
	Atmospheric TP Load (mg/m^2-yr)	26.8
Model Options	P model and P calibration	Settling Velocity, Decay Rates
Model Coefficients	TP Coefficient	1
Segment	Surface Area (km^2), Mean & Mixed Layer Depths (m)	0.81, 1.3, 1.3
	Observed and Target TP (µg/L)	223, 60
	Internal Loading (mg/mg^2-day)	0.595 (Baseline), 0.096 (TMDL)
	Hydraulic residence time (yr), Overflow rate (m/yr)	2.15, 0.6
Watershed and Tributary Inputs*	Watershed Loading: flow (hm^3/yr), TP (µg/L)	0.49, 187

*Total watershed area for Millstone Lake is 710 acres including the lake.

Parameter	Flow (hm^3/yr)	% Flow	TP load (kg/yr)	% TP load	TP concentration (µg/L)
Segment mass balance: <u>Baseline</u>					
Watershed Loading	0.5	46.1%	91.6	31.7%	187
Precipitation	0.6	53.9%	21.7	7.5%	38
Internal Loading	-	-	176.0	60.8%	-
TOTAL IN	**1.1**	**100%**	**289.4**	**100%**	**272**
Evaporation	0.6	53.9%	-	-	-
Retention	-	-	180.3	62.3%	-
Outflow	0.5	46.1%	109.1	37.7%	223
TOTAL OUT	**1.1**	**100%**	**289.4**	**100%**	**-**
Segment mass balance: <u>Target</u>					
Watershed Loading	0.5	46.1%	29.4	37.8%	60
Precipitation	0.6	53.9%	21.7	27.9%	38
Internal Loading	-	-	26.6	34.3%	
TOTAL IN	**1.1**	**100%**	**77.7**	**100%**	**73**
Evaporation	0.6	53.9%	-	-	-
Retention	-	-	48.4	62.3%	-
Outflow	0.5	46.1%	23.9	37.7%	60
TOTAL OUT	**1.1**	**100%**	**77.7**	**100%**	**-**

B.6 BATHTUB Modeling References

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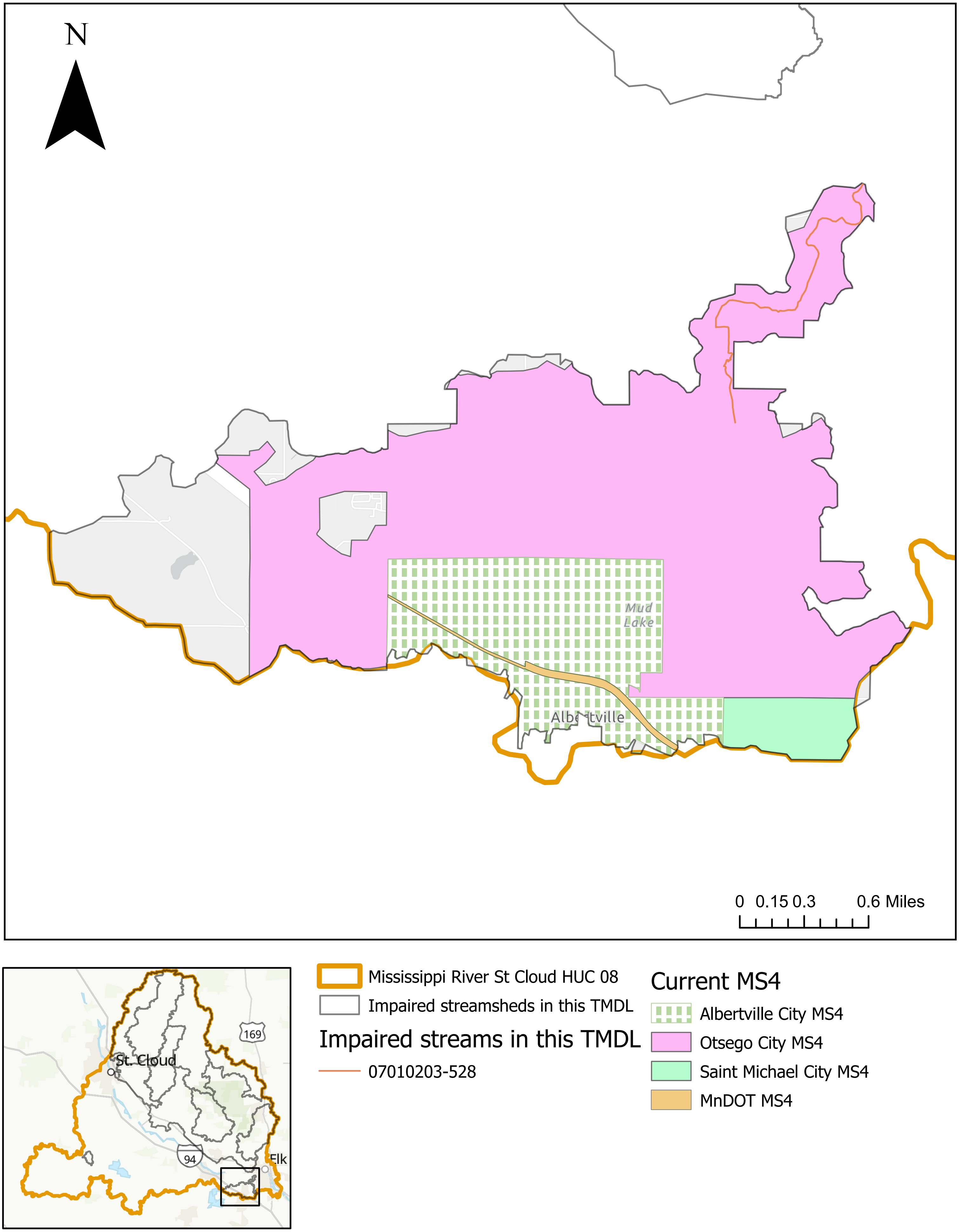
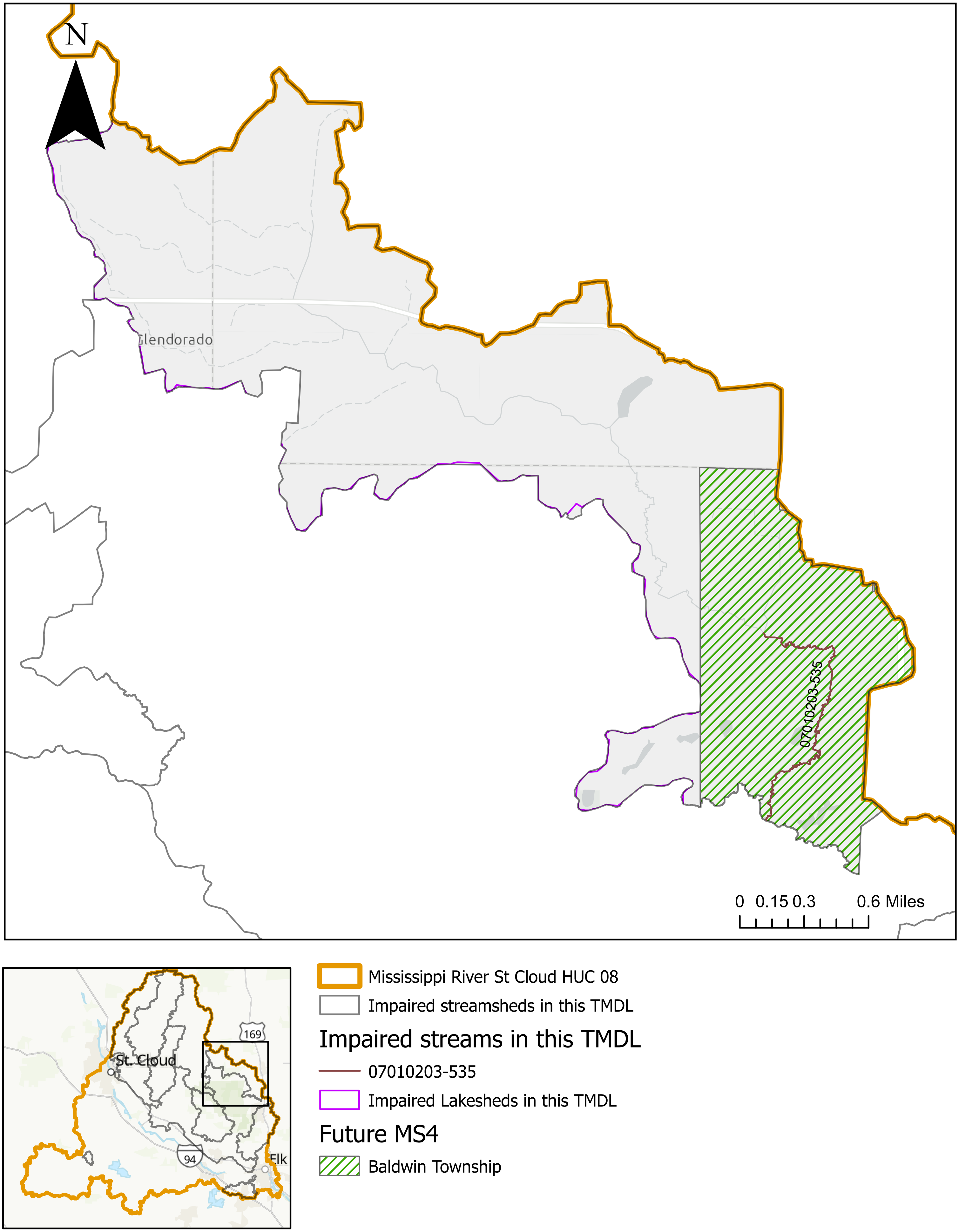
Appendix C. Impaired Streamshed Series

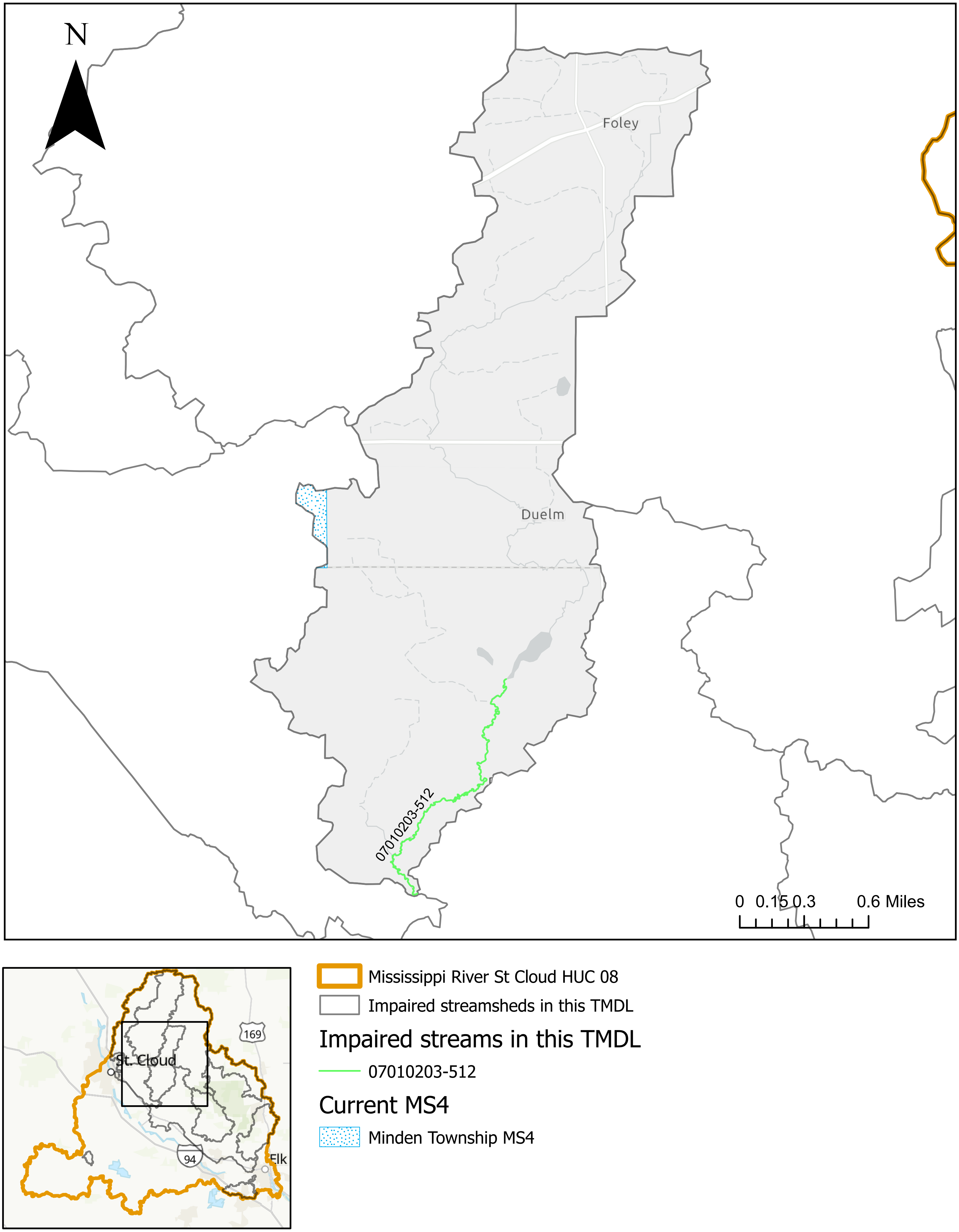
Unnamed Creek (Otsego) 07010203-528



Battle Brook 07010203-535



Rice Creek 07010203-512



Mississippi River St Cloud HUC 08

Impaired streamsheds in this TMDL

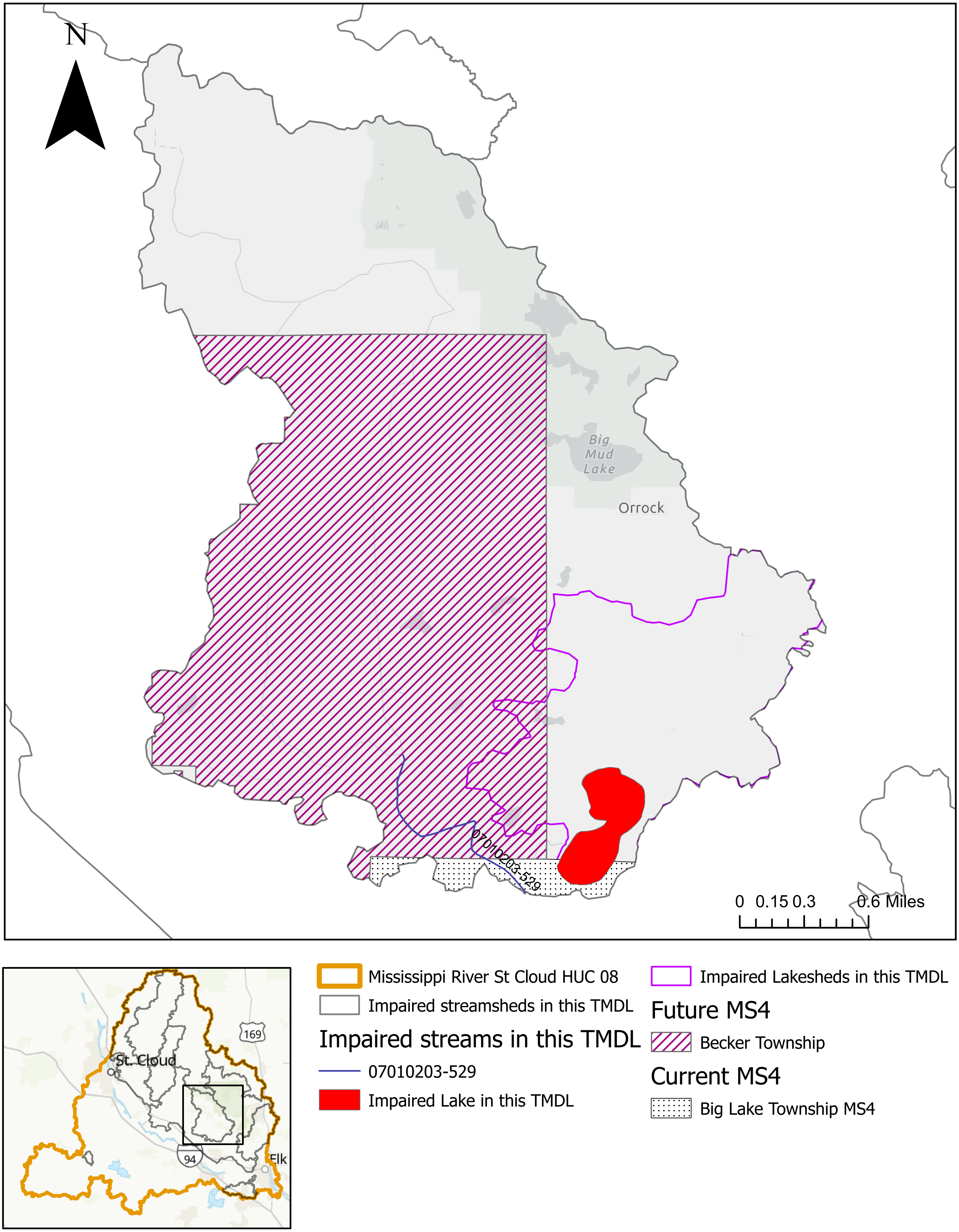
Impaired streams in this TMDL

07010203-512

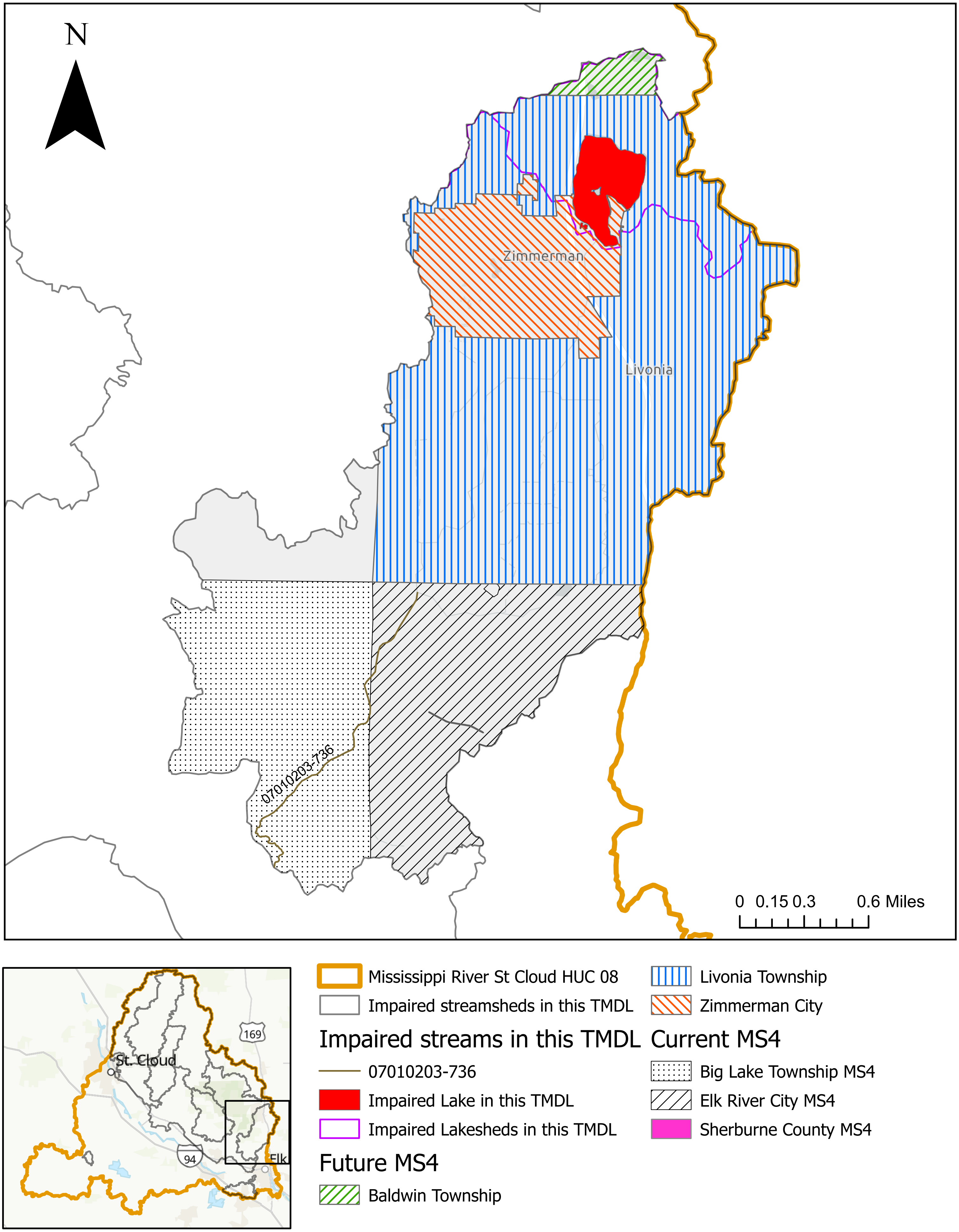
Current MS4

Minden Township MS4

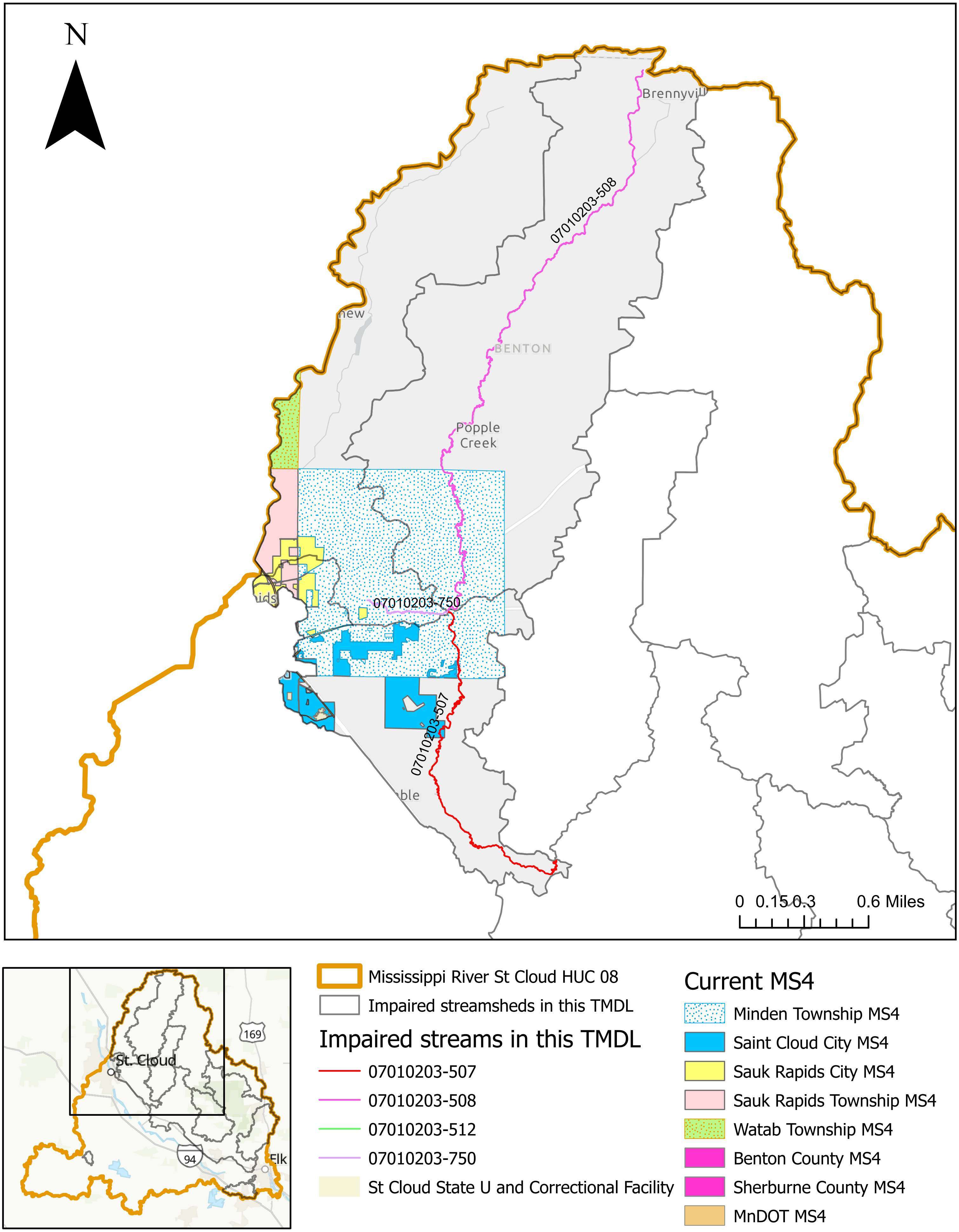
Snake River 07010203-529



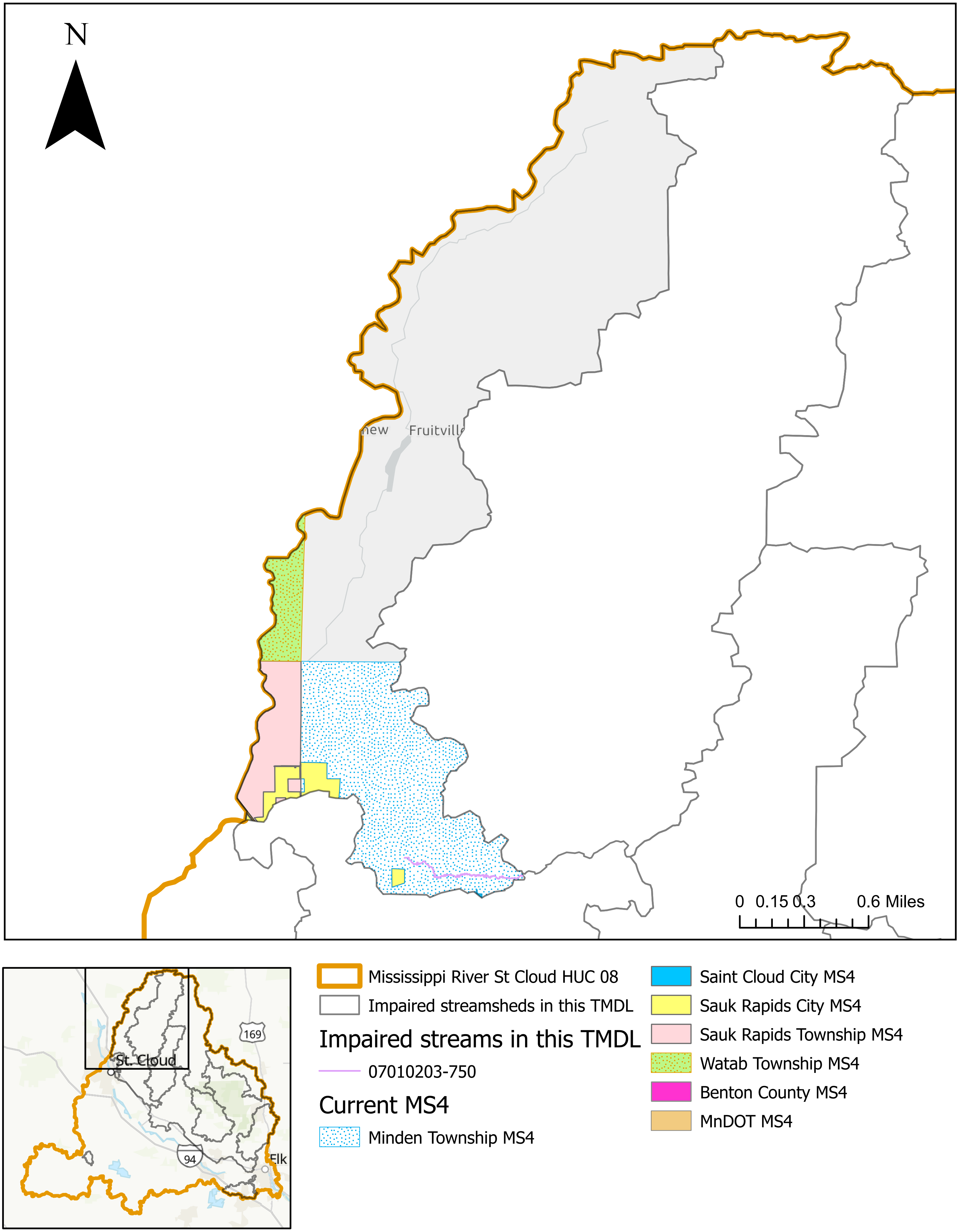
Tibbets Brook 07010203-736



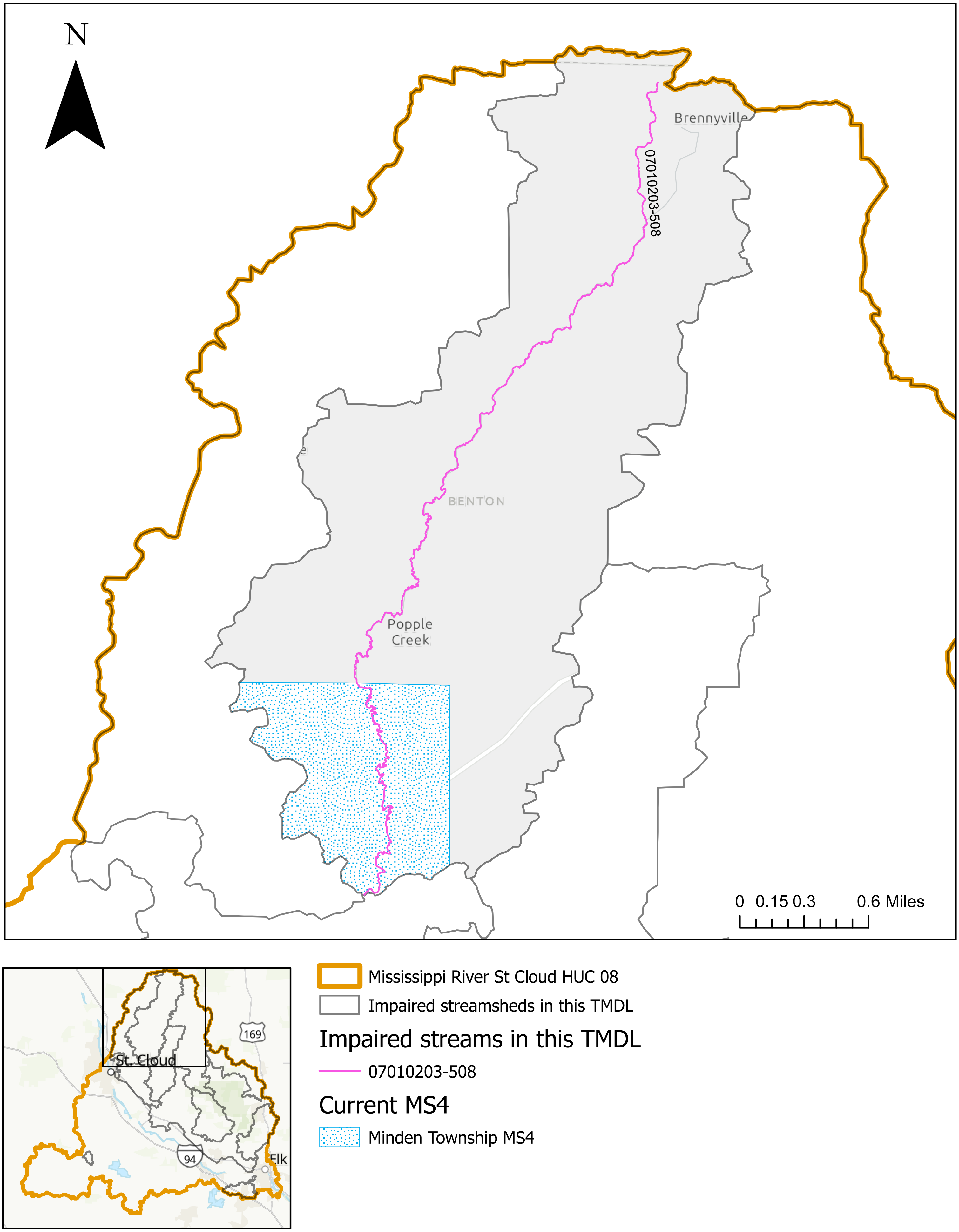
Elk River 07010203-507



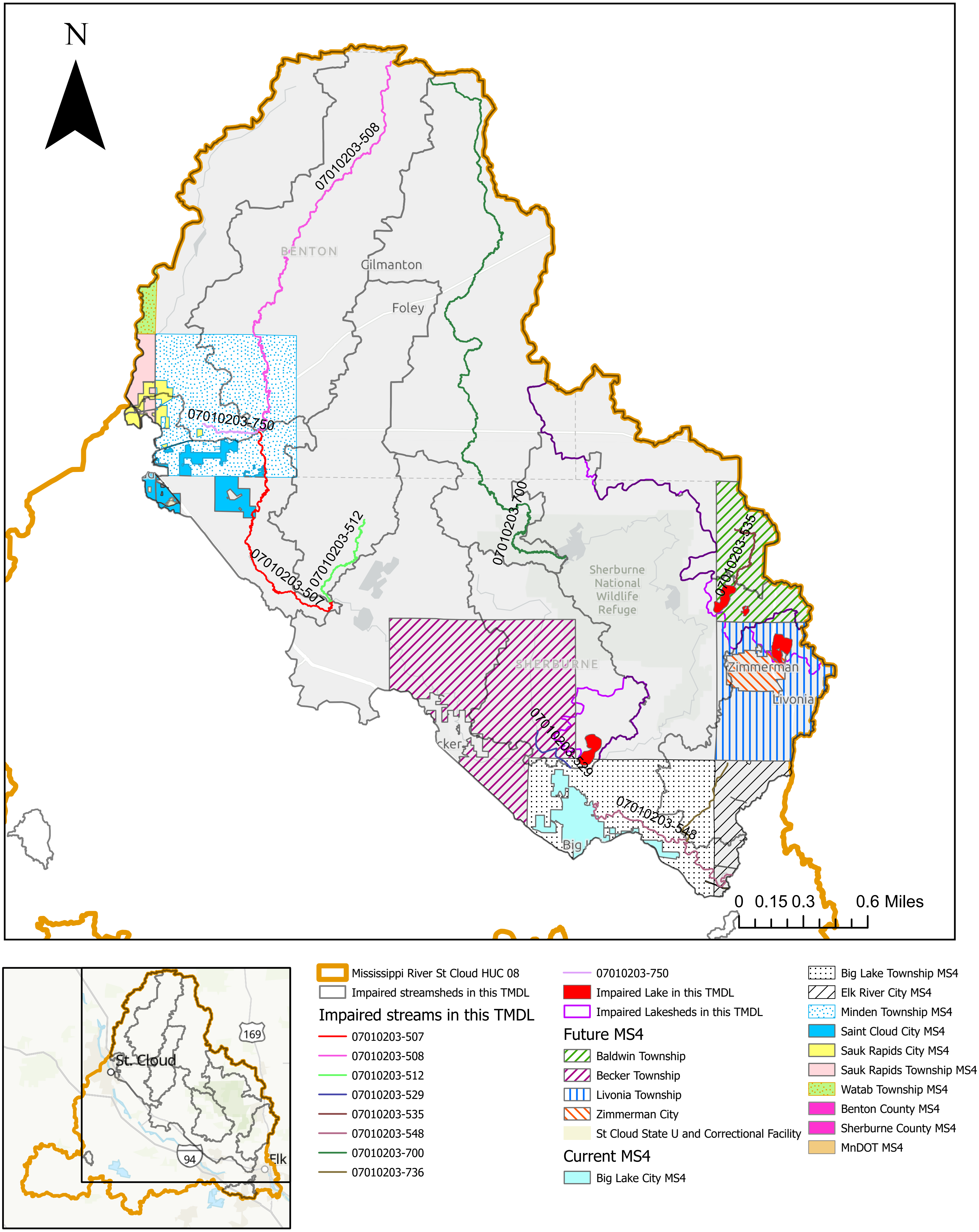
Mayhew Creek 07010203-750



Elk River 07010203-508

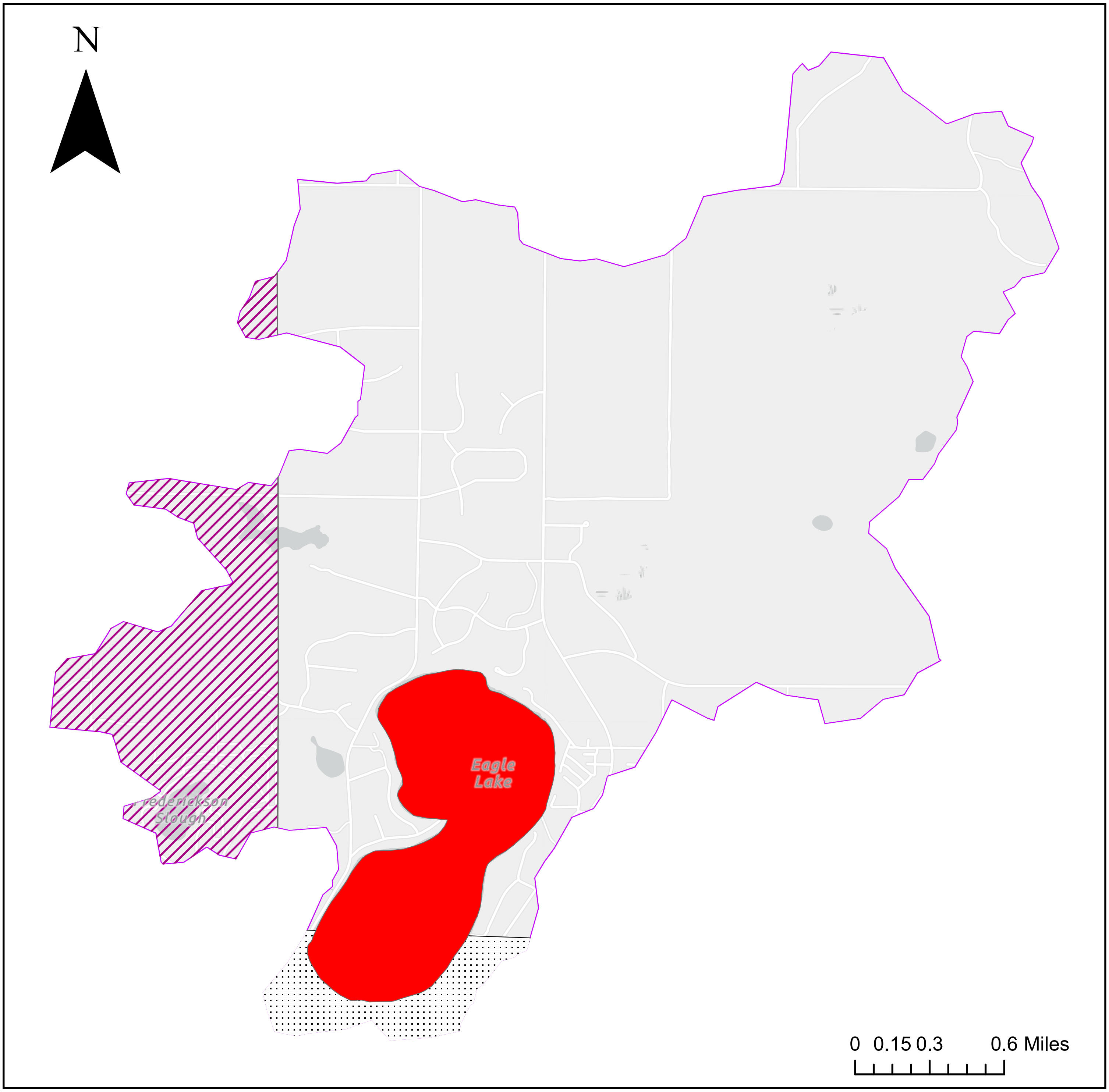


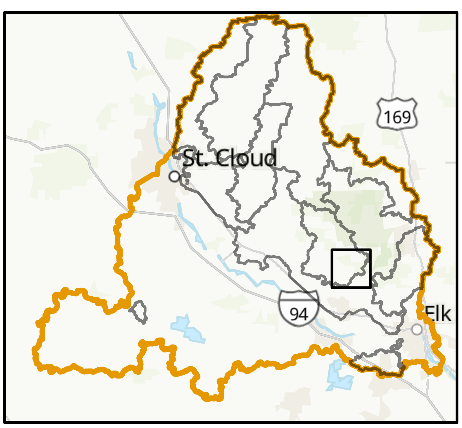
Elk River 07010203-548



Appendix D. Impaired Lakeshed Series

Eagle Lake





Mississippi River St Cloud HUC 08

Impaired Lake in this TMDL

Impaired Lakesheds in this TMDL

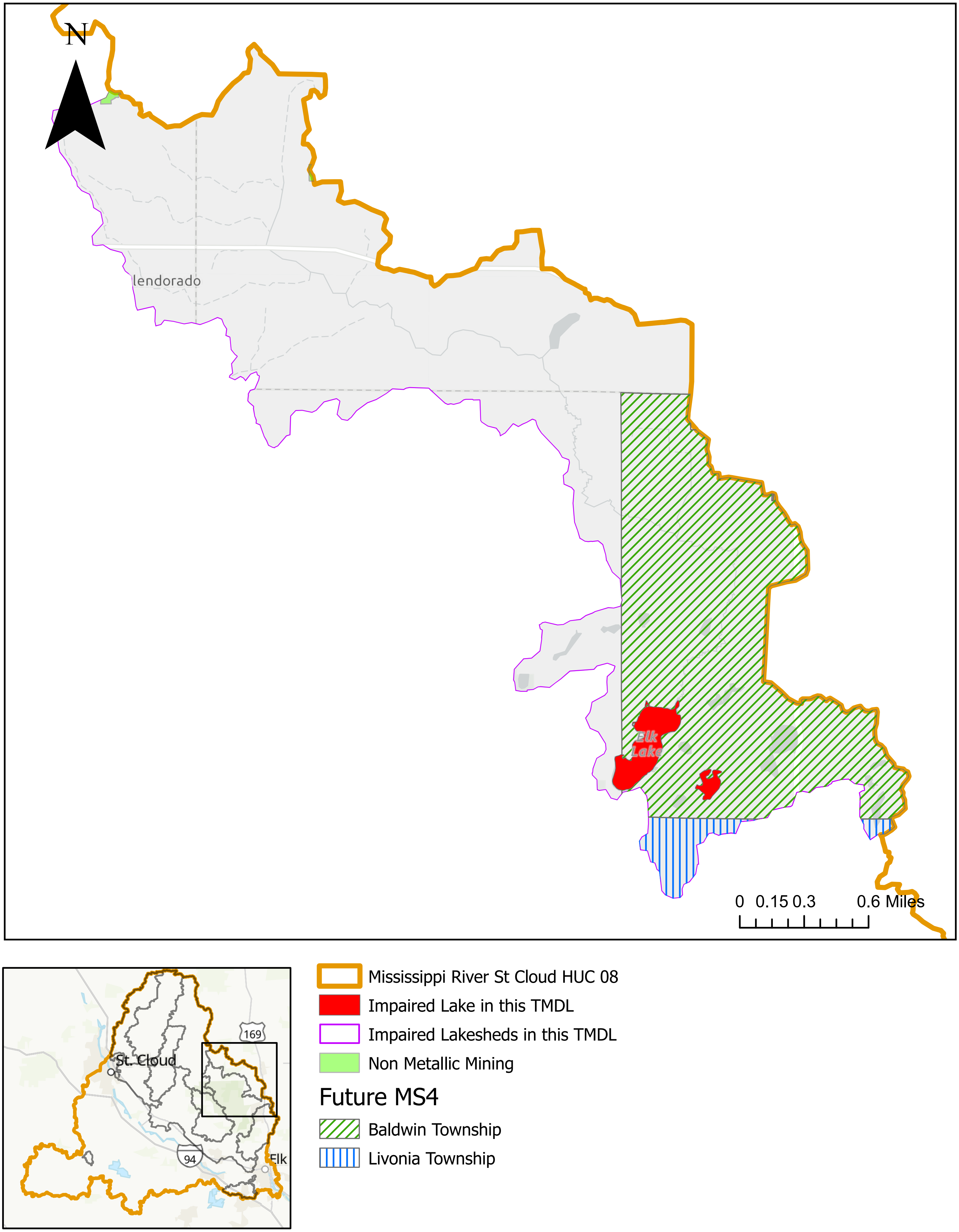
Future MS4

Becker Township

Current MS4

Big Lake Township MS4

Elk Lake



N
lendorado
Elk Lake
0 0.15 0.3 0.6 Miles
St. Cloud
169
94
Elk
Mississippi River St Cloud HUC 08
Impaired Lake in this TMDL
Impaired Lakesheds in this TMDL
Non Metallic Mining
Future MS4
Baldwin Township
Livonia Township

Fremont Lake