Missouri River Basin
Total Maximum Daily Load

Lower Big Sioux River, Little Sioux River, and Rock River Watersheds

MINNESOTA POLLUTION CONTROL AGENCY

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TMDL Summary Table

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303(d) Listing Information	*See Section 1*	16
Applicable Water Quality Standards	TSS: *See Section 2.1* Bacteria: *See Section 2.2* Lake Nutrients: *See Section 2.3*	24 24 25
Loading Capacity (expressed as daily load)	TSS: *See Section 4.4.1* Bacteria: *See Section 4.5.1* Lake Nutrients: *See Section 4.6.1*	53 73 105
Wasteload Allocation	TSS: *See Section 4.4.2* Bacteria: *See Section 4.5.2* Lake Nutrients: *See Section 4.6.2*	54 74 107
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Public Participation	*See Section 9* Public Comment Period: September 25, 2017-October 25, 2017 Comments received: One	131

Acronyms

AF	Anoxic factor
AUID	Assessment Unit ID
BMP	Best Management Practice
CAFO(s)	Concentrated Animal Feeding Operation(s)
cfu	colony-forming unit
Chl-*a*	Chlorophyll-*a*
DMR	Discharge Monitoring Report
DNR	Minnesota Department of Natural Resources
DO	Dissolved Oxygen
BWSR	Board of Water and Soil Resources
EPA	Environmental Protection Agency
EQuIS	Environmental Quality Information System
HSPF	Hydrologic Simulation Program-Fortran
IBI	Index of Biotic Integrity
LA	Load Allocation
LC	Loading Capacity
Lb	pound
m	meter
MAWQCP	Minnesota Agricultural Water Quality Certification Program
mg/L	milligrams per liter
mg/m^2-day	milligram per square meter per day
mL	milliliter
MOS	Margin of Safety
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer Systems
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resource Conservation Service
NRS	Nutrient Reduction Strategy
SDS	State Disposal System
SWCD	Soil and Water Conservation District
SONAR	Statement of Need and Reasonableness
SSTS	Subsurface Sewage Treatment Systems
SWPPP	Stormwater Pollution Prevention Plan
TDLC	Total Daily Loading Capacity
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSS	Total Suspended Solid
WLA	Wasteload Allocation
WWTP	Wastewater Treatment Plant
WRAPS	Watershed Restoration and Protection Strategy

Executive Summary

Missouri River Basin Watershed Approach

Intensive watershed monitoring and stressor Identification were completed in 2014 for the Upper Big Sioux River Watershed (10170202), Lower Big Sioux River Watershed (10170203), Little Sioux River Watershed (10230003), and Rock River Watershed (10170204), which are located in the Missouri River Basin (MPCA 2014a). Ninety-three river/stream reaches were assessed for their ability to support aquatic life and/or aquatic recreation. Of the assessed river/stream reaches, three were considered to be fully supporting of aquatic life and one is fully supporting aquatic recreation. The Little Sioux River Watershed is the only watershed that had lakes assessed, and all of the nine lakes that were assessed are impaired by nutrients. There are currently 21 turbidity (total suspended solids (TSS)) impaired river/stream reaches, 32 bacteria impaired river/stream reaches, 46 macroinvertebrates Index of Biotic Integrity (IBI) impaired river/stream reaches, 34 fish IBI impaired river/stream reaches, and one dissolved oxygen (DO) impaired river/stream reach within the Missouri River Basin. For the remainder of this Total Maximum Daily Load (TMDL) report, the river/stream reach(es) will be referred to as just "reach(es)".

Overview of this TMDL

This TMDL is a continuation of previously completed TMDL studies in the Lower Big Sioux River, Little Sioux River, and Rock River watersheds approved by the Environmental Protection Agency (EPA). In the Lower Big Sioux River Watershed, the Pipestone Creek Fecal Coliform and Turbidity TMDL (MPCA 2008) was approved in 2008. In the Rock River Watershed, the Fecal Coliform and Turbidity TMDL Assessment for the Rock River Watershed (Minnesota State University 2008) was approved in 2008. In the Little Sioux River Watershed, a turbidity and algae TMDL for Little Spirit Lake was completed by the Iowa Department of Natural Resources (IDNR) and approved by the EPA Region 7 in 2004 (IDNR 2004). At the time of this TMDL study, it was assumed that the Turbidity and Algae of Little Spirit Lake TMDL was applicable to Minnesota. However, during the preliminary review of this TMDL report, EPA Region 5 determined that the Turbidity and Algae of Little Spirit Lake TMDL is not applicable to Minnesota because Minnesota and Iowa have different nutrient criteria. According to EPA Region 5, Little Spirit Lake will require a TMDL. Due to this recent development, a nutrient TMDL for Little Spirit Lake will be deferred in the next 10-year watershed approach cycle and is not part of this TMDL report.

This TMDL focuses on impairments of those three major watersheds (Lower Big Sioux, Little Sioux River, and the Rock River) in the Minnesota portions of the Missouri Basin. Biotic (IBI) impairments in the Upper Big Sioux Watershed, as well as the other three major watersheds, were not addressed in this TMDL and will be deferred because the water quality chemistry data was insufficient for TMDLs to be completed at this time. However, these reaches will be addressed through implementation of the Missouri River Basin Watersheds of Minnesota Watershed Restoration and Protection Strategies (WRAPS) report and local water planning efforts.

This TMDL addresses 15 turbidity (TSS) impaired reaches, 28 bacteria impaired reaches, and 8 nutrient impaired lakes in the Lower Big Sioux River, Little Sioux River, and Rock River Watersheds. Forty-six macroinvertebrate IBI impaired reaches, 34 fish IBI impaired reaches, and 1 DO impaired reach will be deferred because the water quality chemistry data was insufficient or because multiple stressors that cannot be quantified were identified. Addressing multiple impairments in this TMDL is consistent with

Minnesota's Water Quality Framework that seeks to develop watershed-wide protection and restoration strategies rather than focus on individual reach impairments.

Turbidity (TSS) Impairments

Hydrologic Simulation Program – Fortran (HSPF) simulated flow and TSS output were used to establish load duration curves (LDCs) for the 15 turbidity (TSS) impairments covered in this TMDL. The curve displays the Class 2B TSS standard of 65 mg/L. A TMDL, which includes the wasteload allocations (WLAs), load allocations (LAs), and Margin of Safety (MOS) were established for five flow zones along the flow duration curve: very high, high, mid, low, and very low flow conditions. Sediment sources were assessed for the turbidity (TSS) impaired reaches and indicate loading is primarily driven by upland erosion and bank erosion within the larger river reaches. Implementation activities will include upland best management practices (BMPs) to reduce soil erosion in highly erodible cropland areas and restoring and increasing water storage opportunities throughout the watersheds to decrease peak discharge rates.

Bacteria (E. coli) Impairments

HSPF simulated flow and monitored bacteria data for the 28 bacteria impaired reaches were used to establish LDCs. The curves were set to meet the *E. coli* standard of no more than 126 organisms per 100 mL. TMDLs that include WLAs, LAs, and MOS for each bacteria impaired reach were established for the five flow zones described in the previous paragraph. A bacteria source assessment exercise indicates livestock is by far the largest producer of bacteria in all of the bacteria impaired reaches covered in this TMDL. However, some of the reaches contained exceedances during low-flow conditions, suggesting failing subsurface treatement systems (SSTS) and/or livestock animals in the stream corridors are important sources during certain hydrologic conditions. Implementation activities will need to focus on feedlot and pasture management BMPs, livestock exclusion from waterways, and SSTS upgrades.

Lake Nutrient Impairments

Nutrient budgets and lake response models were developed for the eight nutrient impaired lakes in the Little Sioux River Watershed covered in this TMDL. The HSPF model was used along with in-lake monitoring data to develop nutrient budgets for each lake and set up the lake response models and TMDL equations. Pollutant source assessment for these lakes indicates nearly all of the lakes require phosphorus reductions from both internal, and external (watershed) sources. For some of the lakes, internal load is a significant source of phosphorus and in-lake efforts will be important to achieve water quality standards. However, any improvements to water quality derived from in-lake efforts will be temporary if external sources are not better controlled so as to reduce the build-up of internal phosphorus. First, implementation activities will need to focus on upland BMPs to prevent phosphorus sources from getting in to the lake. Once upland sources have been addressed, in-lake management activities such as rough fish management, alum treatment, aquatic plant management, and various others are options to decrease phosphorus loading from the lake sediments. If external sources can be controlled, the internal load will reduce itself over time.

1. Project Overview

1.1 Purpose

This TMDL addresses 15 turbidity/TSS impairments and 28 bacteria (fecal coliform and *E. coli*) impairments on several main stem and tributary reaches in the Lower Big Sioux River, Little Sioux River, and Rock River Watersheds. This TMDL also addresses nutrient (phosphorus) impairments for eight lakes in the Little Sioux River Watershed. The watershed boundaries of the impaired reaches and lakes presented in this TMDL covers portions of six counties in Minnesota: Lincoln, Pipestone, Murray, Rock, Nobles, and Jackson. The TMDLs calculated in this report apply only to lakes and reaches within Minnesota.

The goal of this TMDL is to quantify the pollutant reductions needed to meet state water quality standards for TSS, bacteria and phosphorus for the reaches and lakes listed in Tables 1 and 2 and shown in Figures 1 through 3. This TMDL is established in accordance with Section 303(d) of the Clean Water Act and provides WLAs and LAs for the watershed areas as appropriate.

There have been three TMDL studies completed and approved by the EPA in the Missouri River Basin prior to this TMDL study. The Pipestone Creek Fecal Coliform Bacteria and Turbidity TMDL Report (MPCA 2008), approved by the EPA Region 5, covered three bacteria and three turbidity impaired reaches (10170203-527, 514, and 501) in the Lower Big Sioux River Watershed. The Fecal Coliform and Turbidity TMDL Assessment for the Rock River Watershed (Minnesota State University 2008), approved by the EPA Region 5, covered three turbidity impairments (10170204-501, 509, and 519) and one fecal coliform impairment (10170204-501) in the Rock River Watershed. Finally, the Turbidity and Algae of Little Spirit Lake TMDL (IDNR 2004), developed by the IDNR, covered one lake impairment (32-0024-00), approved by the EPA Region 7 in 2004, in the Little Sioux River Watershed. At the time of this TMDL study, it was assumed that the Turbidity and Algae of Little Spirit Lake TMDL was applicable to Minnesota. However, during the preliminary review of this TMDL report, it was determined that the Turbidity and Algae of Little Spirit Lake TMDL is not applicable to Minnesota because Minnesota and Iowa have different nutrient criteria. Little Spirit Lake will require a TMDL. Due to this recent development, a nutrient TMDL for Little Spirit Lake will be deferred in the next 10-year watershed approach cycle and is not part of this TMDL report. Information on these TMDL studies can be found in the provided links in Section 10 - Literature Cited of this TMDL report.

Forty-six macroinvertebrate IBI impaired reaches, 34 fish IBI impaired reaches, and 1 DO impaired reach will be deferred because the water quality chemistry data was insufficient for TMDLs to be completed at this time. However, these impairments will be addressed through implementation of the Missouri River Basin Watersheds of Minnesota WRAPS Report and local water planning efforts.

1.2 Identification of Waterbodies

The TSS/turbidity impaired reaches were placed on the state of Minnesota's 303(d) list of impaired waters in 2008, 2010, and 2014. The bacteria impaired reaches were placed on the 303(d) list in 2010 and 2014. The impaired reaches addressed in this TMDL are Class 2B or 2C waters (warm water). The Nutrient Eutrophication impaired lakes were placed on the state of Minnesota's 303(d) list of impaired waters in 2008, 2010, and 2014. See Tables 1 and 2 for a list of impairments.

Table 1. Reach impairments addressed in this TMDL.

Major Watershed	Major Subwatershed (HUC-10)	Reach Name	AUID#	Impairment	Class	Beneficial Use[1]	Year Listed
Little Sioux River	West Fork Little Sioux River	Little Sioux River, West Fork	10230003-508	*E. coli*	2C	AQR	2014
		Judicial Ditch 13 (Skunk Creek)	10230003-511	*E. coli*	2C	AQR	2010
				Turbidity (TSS)	2C	AQL	2010
		Little Sioux River West Fork	10230003-509	*E. coli*	2C	AQR	2014
	Headwaters Little Sioux River	Little Sioux River	10230003-514	*E. coli*	2C	AQR	2014
		Unnamed Creek	10230003-516	*E. coli*	2B	AQR	2014
		Little Sioux River	10230003-515	*E. coli*	2C	AQR	2014
				Turbidity (TSS)	2C	AQL	2014
Lower Big Sioux River	Flandreau Creek	Flandreau Creek	10170203-502	*E. coli*	2C	AQR	2014
	Pipestone Creek	Pipestone Creek	10170203-505	*E. coli*	2B	AQR	2014
	Split Rock Creek	Split Rock Creek	10170203-512	*E. coli*	2C	AQR	2014
				Turbidity (TSS)	2C	AQL	2010
	Beaver Creek	Beaver Creek	10170203-522	*E. coli*	2C	AQR	2010
				Turbidity (TSS)	2C	AQL	2010
Rock River	Mud Creek	Mud Creek	10170204-525	*E. coli*	2C	AQR	2014
				Turbidity (TSS)	2C	AQL	2008
	Headwaters Rock River	Rock River, T107 R44W S30, east line to Chanarambie Cr	10170204-504	*E. coli*	2C	AQR	2014
				Turbidity (TSS)	2C	AQL	2014
		Chanarambie Creek	10170204-522	*E. coli*	2B	AQR	2014
				Turbidity (TSS)	2B	AQL	2014
		Poplar Creek	10170204-523	*E. coli*	2B	AQR	2014
				Turbidity (TSS)	2B	AQL	2014
		Rock River, Poplar Cr to Unnamed Cr	10170204-506	*E. coli*	2C	AQR	2014
				Turbidity (TSS)	2C	AQL	2014
		Unnamed Creek, Unnamed Cr to Rock R	10170204-545	*E. coli*	2B	AQR	2014
		Unnamed Creek, Headwaters to Rock R	10170204-521	*E. coli*	2B	AQR	2014
		Rock River, Unnamed cr to Champepadan Cr	10170204-508	*E. coli*	2C	AQR	2014

Major Watershed	Major Subwatershed (HUC-10)	Reach Name	AUID#	Impairment	Class	Beneficial Use[1]	Year Listed
				Turbidity (TSS)	2C	AQL	2014
		Mound Creek	10170204-551	*E. coli*	2C	AQR	2014
	Champepadan Creek – Rock River	Champepadan Creek	10170204-520	*E. coli*	2B	AQR	2014
		Elk Creek	10170204-519	*E. coli*	2B	AQR	2014
	Kanaranzi Creek	Kanaranzi Creek, Headwaters to E Br Kanaranzi Cr	10170204-515	*E. coli*	2C	AQR	2014
		Kanaranzi Creek, East Branch	10170204-514	*E. coli*	2B	AQR	2010
				Turbidity (TSS)	2B	AQL	2014
		Norwegian Creek	10170204-518	*E. coli*	2B	AQR	2010
		Kanaranzi Creek, Norwegian Cr to MN/IA border	10170204-517	*E. coli*	2C	AQR	2010
				Turbidity (TSS)	2C	AQL	2010
	Little Rock River	Little Rock Creek	10170204-511	*E. coli*	2B	AQR	2014
				Turbidity (TSS)	2B	AQL	2014
		Little Rock River, Headwaters to Little Rock Cr	10170204-512	*E. coli*	2C	AQR	2014
				Turbidity (TSS)	2C	AQL	2014
		Little Rock River, Little Rock Cr to MN/IA border	10170204-513	*E. coli*	2C	AQR	2010
				Turbidity (TSS)	2C	AQL	2008

[1] Beneficial use abbreviations: AQL = aquatic life; AQR = aquatic recreation.

Table 2. Lake impairments addressed in this TMDL.

Major Watershed	Major Subwatershed (HUC-10)	Lake Name	Lake ID	Impairment	Year Listed
Little Sioux River	Ocheyedan River	Okabena Lake	53-0028-00	Nutrients	2010
		Ocheda Lake (West Basin)	53-0024-01	Nutrients	2010
		Bella Lake	53-0045-00	Nutrients	2014
	West fork Little Sioux River	Indian Lake	53-0007-00	Nutrients	2014
		Iowa Lake	32-0084-00	Nutrients	2014
		Round Lake	32-0069-00	Nutrients	2014
	Milford Creek	Clear Lake	32-0022-00	Nutrients	2008
		Loon Lake	32-0020-00	Nutrients	2008

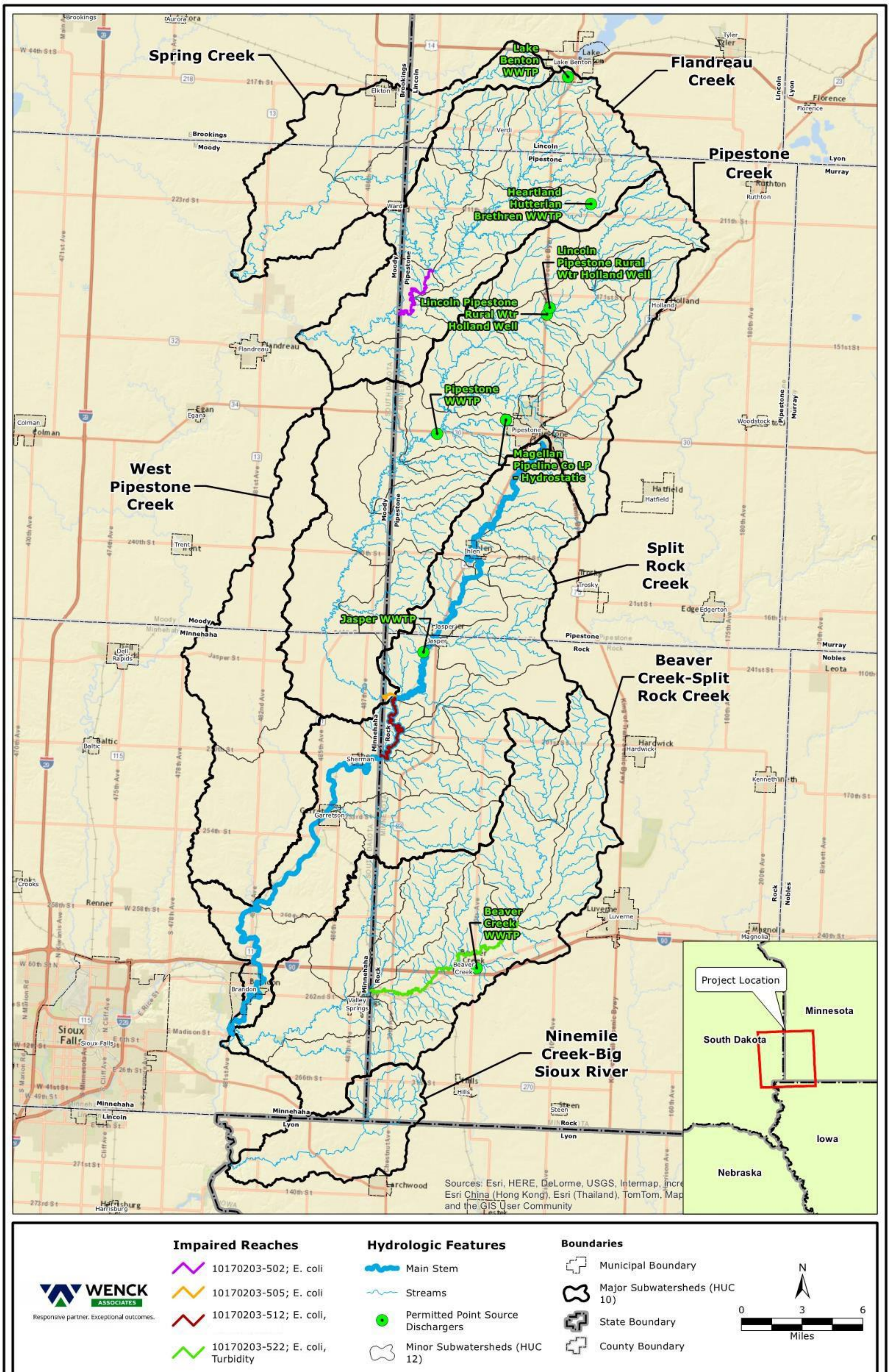

Figure 1. Lower Big Sioux River Watershed impairments addressed in this TMDL.

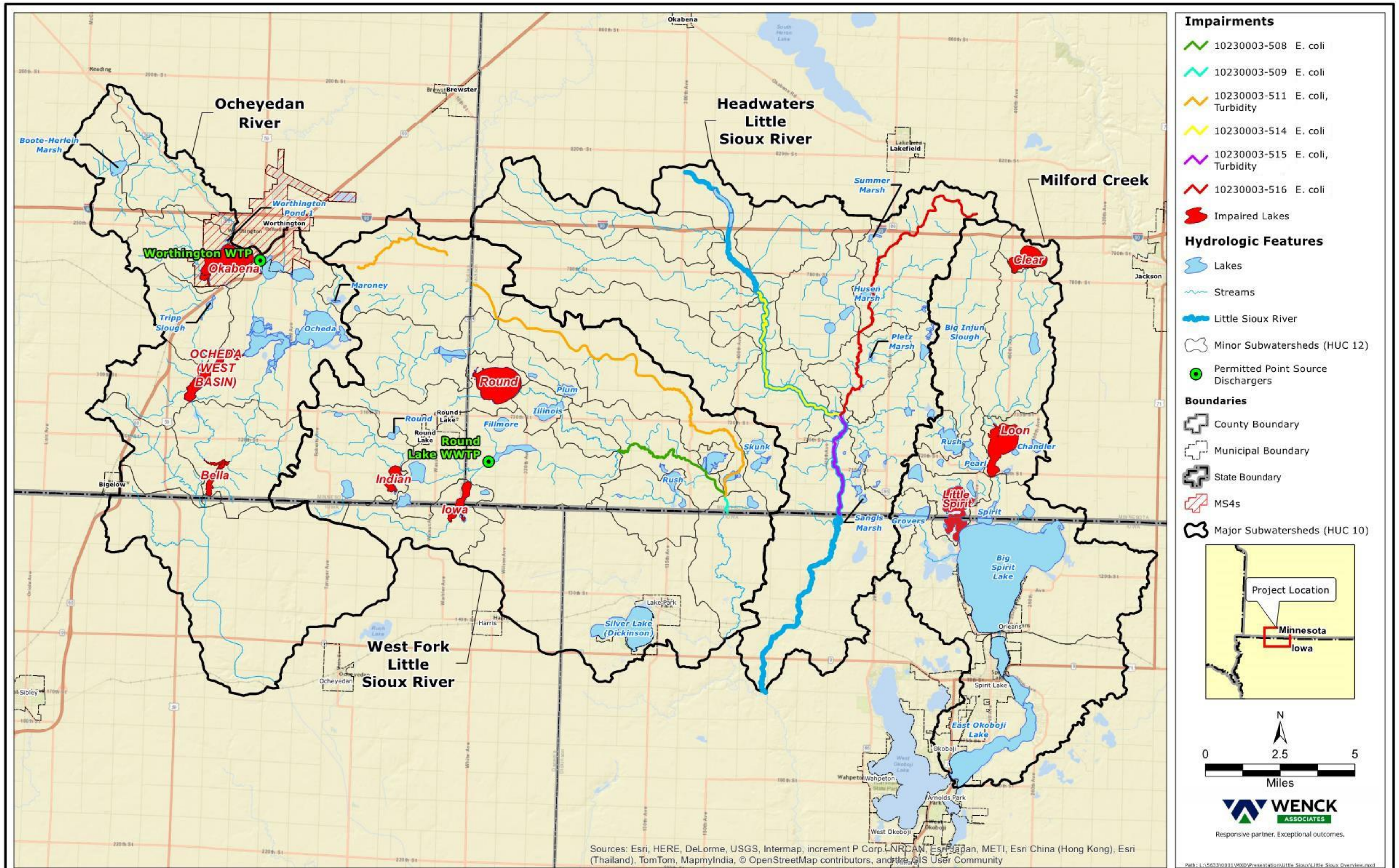

Figure 2. Little Sioux River Watershed impairments addressed in this TMDL.

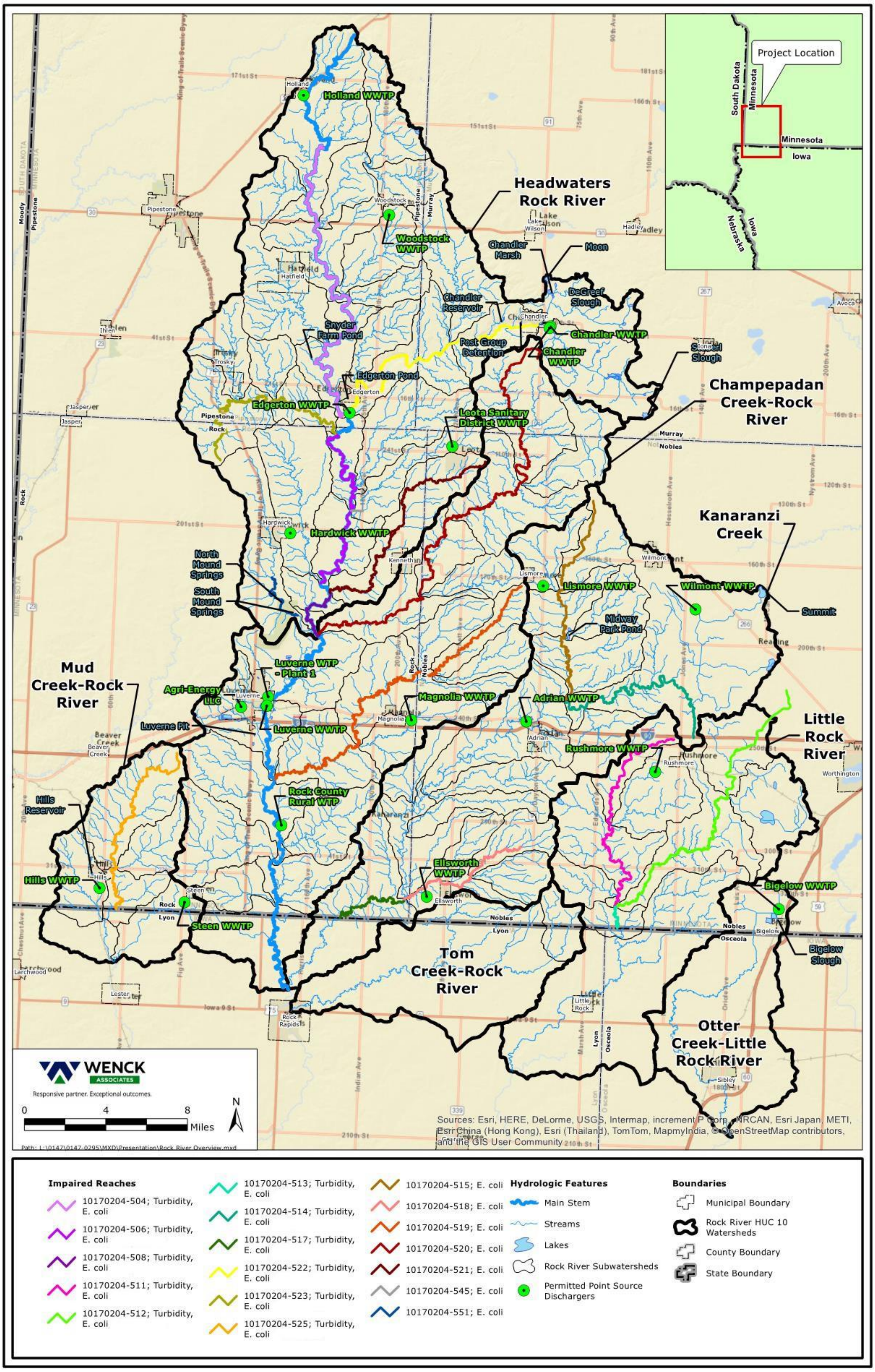

Figure 3. Rock River Watershed impairments addressed in this TMDL.

Several impaired reaches within the Missouri River Basin flow across the Minnesota state border into South Dakota or Iowa. See Figures 1-3 for maps of the watersheds. TMDLs are being calculated to Minnesota state water quality standards. The MPCA's TMDL process calculates TMDL endpoints to attain water quality standards at the most downstream endpoint of the impaired reach. For a segment which crosses a state border, this is typically the state border. One should assume that compliance with TMDLs mean that Minnesota water quality standards are being met at the state border, and that waters originating within its boundaries will not cause or contribute to impairments downstream.

Minnesota / South Dakota Border Waterbodies

Flandreau Creek is impaired by *E. coli* in both Minnesota and South Dakota. The impaired reach (10170203-502) in Minnesota has a very small portion of its watershed located in South Dakota, consisting of agricultural land and intermittent grassed waterways. This small portion drains across the border into Minnesota and eventually flows into Flandreau Creek. Flandreau Creek flows southwest across Minnesota and crosses the state border. Flandreau Creek has an impaired reach (SD-BS-R-FLANDREAU_01) listed for *E. coli* in South Dakota. The Minnesota standard for *E. coli* (geomean of 126 cfu/100mL) for Flandreau Creek is more restrictive and protective compared to South Dakota's Limited Contact Recreation standard (SDDENR 2017a) for *E. coli* (geomean of 630 cfu/100mL). If the standard is met for the reach in Minnesota, it should not contribute to the impaired reach downstream in South Dakota.

Pipestone Creek is impaired by *E. coli* in both Minnesota and South Dakota. The creek starts in Minnesota, flows into South Dakota, and then flows back into Minnesota. The impaired reach (10170203-505) in Minnesota is the small section of Pipestone Creek in Minnesota starting at the South Dakota/Minnesota border and ending where it enters as a tributary to Split Rock Creek. Both states have the same numeric standard for *E. coli* (126 cfu/100mL) for this reach. If South Dakota's Immersion Recreation standard (SDDENR 2017b) is met for the reach in South Dakota, it should not contribute to the downstream impaired reach in Minnesota.

Split Rock Creek is impaired by *E. coli* and TSS in both Minnesota and South Dakota. The impaired reach (10170203-512) in Minnesota ends at the border where the creek flows into South Dakota. The fecal coliform bacteria standard in South Dakota for Split Rock Creek is 400 cfu/100mL (which calculates to 252 cfu/100mL *E. coli* using the MPCA's fecal coliform to *E. coli* conversion ratio of 0.63). The *E. coli* standard for Split Rock Creek in Minnesota is 126 cfu/100mL. If the *E. coli* standard is met for the reach in Minnesota, it should not contribute to the impaired reach in South Dakota. The TSS standard for Split Rock Creek in Minnesota is 65 mg/L. The TSS standard for Split Rock Creek in South Dakota is 158 mg/L. If the TSS standard is met for the reach in Minnesota, it should not contribute to the impaired reach in South Dakota.

Minnesota / Iowa Border Waterbodies

Mud Creek (10170204-525), Rock River (10170204-508), and the Little Rock River (10170204-513) are all impaired by both TSS and *E. coli* in Minnesota, but are only listed as impaired by *E. coli* in Iowa. Both Minnesota and Iowa have the same standard for *E. coli* (126 cfu/100mL). If the standard is met for the reaches in Minnesota, they should not contribute to any downstream *E. coli* impairments.

Kanaranzi Creek is impaired by both TSS and *E. coli* in Minnesota, but is not impaired by either in Iowa. Since there are no known impairments for Kanaranzi Creek in Iowa, the impaired reach in Minnesota cannot currently be considered an upstream contributor.

Two reaches of the Little Sioux River (10230003-508, 10230003-509) are impaired by *E. coli* in Minnesota. Both reaches have watershed areas in Minnesota and Iowa. Both Minnesota and Iowa have the same standard for *E. coli* (126 cfu/100mL). If the standard is met for the reaches in Minnesota, they should not contribute to any downstream *E. coli* impairments in Iowa.

Currently, Iowa does not have a standard for TSS. Since there are no TSS impairments in Iowa, any impaired reaches in Minnesota cannot be considered upstream contributors.

Iowa has several IBI impairments downstream of Minnesota TSS impaired reaches. The MPCA recently developed TSS criteria to replace the previous turbidity standard. These TSS criteria are regional in scope and based on a combination of both biotic sensitivity to TSS concentrations and reference streams/least impacted streams as data allowed. The results of the TSS criteria development were published by the MPCA in 2011, and proposed a 65 mg/L TSS standard for Class 2B waters in the Southern River Nutrient Region, that may not be exceeded more than 10% of the time from April through September over a multiyear data window (MPCA 2011). The TSS standard technical support document was placed on public notice in November 2013, and the rules were adopted at the June 24, 2014, meeting of the MPCA Citizen's Board. The rules were approved by the EPA in January 2015. If the standard is met for the impaired reaches in Minnesota, then those reaches should not contribute to any downstream IBI impairments.

Iowa (32-0084-00), Bella (53-0045-00), and Indian (53-0007-00) lakes are impaired by nutrient eutrophication. Iowa Lake is located on the border in both Minnesota and Iowa. The majority of Iowa Lake's watershed and approximately half the lake is in Iowa. Currently, Iowa Lake is not listed as impaired in the State of Iowa. All three lakes have watershed areas in Iowa that drain into Minnesota. All Lake TMDL calculations were factored for the entire lake and lakeshed, however, the TMDLs apply only to areas within Minnesota.

1.3 Priority Ranking

The MPCA's schedule for TMDL completions, as indicated on the 303(d) impaired waters list, reflects Minnesota's priority ranking of this TMDL. The MPCA has aligned our TMDL priorities with the watershed approach and our WRAPS cycle. The schedule for TMDL completion corresponds to the WRAPS report completion on the 10-year cycle. The MPCA developed a state plan Minnesota's TMDL Priority Framework Report to meet the needs of EPA's national measure (WQ-27) under EPA's Long-Term Vision for Assessment, Restoration and Protection under the Clean Water Act Section 303(d) Program. As part of these efforts, the MPCA identified water quality impaired segments that will be addressed through TMDLs by 2022. The Missouri River Basin waters addressed by this TMDL are part of that MPCA prioritization plan to meet the EPA's national measure.

2. Applicable Water Quality Standards

2.1 Turbidity and TSS

Turbidity is a measure of the cloudiness or haziness of water caused by suspended and dissolved substances in the water column. Turbidity can be caused by increased suspended soil or sediment particles, phytoplankton growth, and dissolved substances in the water column. Excess turbidity can degrade aesthetic qualities of water bodies, increase the cost of treatment for drinking water or food processing uses, and harm aquatic life. Adverse ecological impacts caused by excessive turbidity include hampering the ability of aquatic organisms to visually locate food, negative effects on gill function, and smothering of spawning beds and benthic organism habitat.

The 15 reaches of the Lower Big Sioux River, Little Sioux River, and Rock River Watersheds listed as impaired by turbidity are class 2B warm water streams. The class 2B turbidity standard (Minn. R. 7050.0222) that was in place at the time of the assessment for these reaches was 25 nephelometric turbidity units (NTUs). This standard, which had been in place since the late 1960s, had several weaknesses, including being a statewide standard that does not account for regional differences. Also, because turbidity is a measure of light scatter and absorption, it is not a mass unit measurement, and therefore not directly amenable to TMDLs and other load-based studies. Other issues with the previous turbidity standard included having too much variation in measurement because of particle composition in water, variation among turbidity meters, and poor quantitative documentation of what a turbidity unit is.

As a result, a committee of MPCA staff across several divisions met for over a year to develop TSS criteria to replace the previous turbidity standard. These TSS criteria are regional in scope and based on a combination of both biotic sensitivity to TSS concentrations and reference streams/least impacted streams as data allow. The results of the TSS criteria development were published by the MPCA in 2011, and proposed a 65 mg/L TSS standard for Class 2B waters in the Southern River Nutrient Region that may not be exceeded more than 10% of the time from April through September over a multiyear data window (MPCA 2011). The TSS standard technical support document was placed on public notice in November 2013, and the rules were adopted at the June 24, 2014, meeting of the MPCA Citizen’s Board. The rules were approved by the EPA in January 2015. For the purpose of this TMDL report, the 65 mg/L TSS standard for Class 2B waters will be used to develop the turbidity TMDL and allocations for the Lower Big Sioux River, Little Sioux River, and Rock River Watershed turbidity impaired reaches.

2.2 Bacteria

With the revisions of Minnesota’s water quality rules in 2008, the State changed from a fecal coliform based standard to an *E. coli* based standard because it is a superior potential illness indicator and costs for lab analysis are less (MPCA 2007b). The revised standards now state:

> “*E. coli* concentrations are not to exceed 126 organisms per 100 milliliters 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.”

The *E. coli* concentration standard of 126 organisms per 100 mL was considered reasonably equivalent to the previous fecal coliform standard of 200 organisms per 100 milliliters from a public health protection standpoint. The SONAR (Statement of Need and Reasonableness) section that supports this rationale uses a log plot that shows a good relationship between these two parameters. The following regression equation was deemed reasonable to convert any data reported in fecal coliform to *E. coli* equivalents:

$$E\ coli \text{ concentration (equivalents)} = 1.80 \times (\text{Fecal Coliform Concentration})^{0.81}$$

It should also be noted that most analytical laboratories report *E. coli* in terms of colony forming units per 100 milliliters (cfu/100 mL), not organisms per 100 milliters. This TMDL report will present *E. coli* data in cfu/100 mL since all of the monitored data collected for this TMDL was reported in these units. Bacteria TMDLs were written to achieve the bacteria water quality standard of 126 orgs/100 mL.

2.3 Nutrients

Under Minn. R. 7050.0150 and 7050.0222, subp. 4, the lakes addressed in this TMDL are shallow lakes located within the Western Cornbelt Plain (WCBP) Ecoregion. Minnesota water quality standards for total phosphorus (TP), chlorophyll-a (Chl-*a)* and Secchi disk transparency are listed in Table 3.

In addition to meeting TP limits, Chl-*a* and Secchi depth standards must also be met for the resource to be considered "fully supporting" its designated use. In developing the lake nutrient standards for Minnesota lakes (Minn. R. 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 disk transparency. Based on these relationships it is expected that by meeting the TP target in each lake, the Chl-*a* and Secchi standards will likewise be met.

Table 3. Standards for shallow lakes in the WCBP Ecoregion.

Parameter	WCBP Ecoregion Standards (shallow lakes[1])
Total Phosphorus [µg/L]	90
Chlorophyll-a [µg/L]	30
Secchi Disk Transparency [meters]	0.7

[1] Shallow lakes are defined as lakes with a maximum depth of 15 feet or less, or with 80% or more of the lake area shallow enough to support emergent and submerged rooted aquatic plants (littoral zone).

3. Watershed and Waterbody Characterization

The Upper Big Sioux River, Lower Big Sioux River, Little Sioux River, and Rock River watersheds are major HUC-8 watersheds of the greater Missouri River Basin, which covers the southwest corner of Minnesota. Collectively, the Lower Big Sioux River, Little Sioux River, and Rock River Watersheds included in this TMDL cover approximately 2,258 square miles or 1,445,270 acres total. There are approximately 1,118,901 acres in Minnesota, 211,407 acres in South Dakota, and 114,962 acres in Iowa. The major subwatersheds (HUC-10s) of the three major watersheds covered in this TMDL are shown in Figures 1 through 3. Smaller, individual subwatersheds (HUC 12s and DNR catchments) for the impaired reaches and lakes are also shown on these maps and were determined using the Minnesota Department of Natural Resources (DNR) GIS catchment file. The three major watersheds encompass all or parts of Lincoln, Pipestone, Murray, Rock, Nobles, and Jackson Counties. Lakes are not a prominent feature of the Missouri River Basin. All the natural lakes are in the Little Sioux River Watershed.

There are seven major HUC-10 subwatersheds in the Lower Big Sioux River Watershed: Spring Creek, Flandreau Creek, Pipestone Creek, West Pipestone Creek, Split Rock Creek, Beaver Creek – Split Rock Creek, and Ninemile Creek – Big Sioux River (Figure 1). The streams and tributaries that make up these major subwatersheds generally flow in a westerly direction into South Dakota.

In the Little Sioux River Watershed, there are four major HUC-10 subwatersheds: Ocheyedan River, West Fork Little Sioux River, Headwaters Little Sioux River, and Milford Creek (Figure 2). The streams and tributaries in these subwatersheds generally flow south toward Iowa.

The Rock River is the largest river in the Minnesota portion of the Missouri River Basin. There are seven major HUC-10 subwatersheds in the Rock River Watershed: Mud Creek – Rock River, Headwaters Rock River, Champepadan Creek – Rock River, Kanaranzi Creek, Tom Creek – Rock River, Little Rock River, and Otter Creek – Little Rock River (Figure 3). These subwatersheds flow south into the Big Sioux River in Iowa before entering the Missouri River.

3.1 Streams

The six impaired reaches in the Little Sioux River Watershed (10230003) addressed in this TMDL cover approximately 52 stream miles and drain over 140,000 acres of land across Nobles and Jackson Counties, Minnesota (Table 4). Two (2) of the impaired reaches (508 and 509) include watershed area in both Minnesota and Iowa. No reach impairments have been addressed in the Minnesota portions of the Little Sioux River Watersheds prior to this TMDL.

Table 4. Little Sioux River Watershed reach impairments, locations, and drainage areas.

Reach Name	Impaired Reach AUID#	Impairment(s)	Reach Length [miles]	Direct Drainage[1] [acres]	Total Drainage[2] [acres]
West Fork Little Sioux River	10230003-508	*E. coli*	6.3	4,527	MN: 34,722 IA: 6,512 Total: 41,234
Judicial Ditch 13 (Skunk Creek)	10230003-511	*E. coli* & TSS	20.9	19,924	MN: 28,962 IA: 0 Total: 28,962

Reach Name	Impaired Reach AUID#	Impairment(s)	Reach Length [miles]	Direct Drainage[1] [acres]	Total Drainage[2] [acres]
West Fork Little Sioux River	10230003-509	*E. coli*	0.7	467	MN: 64,175 IA: 6,512 Total: 70,687
Little Sioux River	10230003-514	*E. coli*	7.2	6,115	MN: 39,952 IA: 0 Total: 39,952
Unnamed Creek	10230003-516	*E. coli*	12.3	12,234	MN: 12,233 IA: 0 Total: 12,233
Little Sioux River	10230003-515	*E. coli*, TSS	4.1	4,770	MN: 63,045 IA: 0 Total: 63,045

[1] Includes only area draining directly to impaired reach
[2] All area draining to impaired reach

Collectively, the four impaired reaches in the Lower Big Sioux River Watershed (10170203) addressed in this TMDL span approximately 33 stream miles and drain over 300,000 acres of land in Minnesota and South Dakota (Table 5). The impaired reach watersheds include land in Pipestone and Rock Counties in Minnesota, and Minnehaha and Moody Counties in South Dakota. There are three reaches (501, 514, and 527) in the Lower Big Sioux River Watershed impaired by turbidity and fecal coliform that were covered under a previous TMDL (MPCA 2008). All three of these reaches are located in the Pipestone Creek Subwatershed, which is a major tributary to the Lower Big Sioux River.

Table 5. Lower Big Sioux River Watershed reach impairments, locations, and drainage areas.

Reach Name	Impaired Reach AUID#	Impairment(s)	Reach Length [miles]	Direct Drainage[1] [acres]	Total Drainage[2] [acres]
Flandreau Creek	10170203-502	*E. coli*	7.7	4,050	MN: 59,457 SD: 1,194 Total: 60,651
Pipestone Creek	10170203-505	*E. coli*	1.1	379	MN: 97,310 SD: 44,358 Total: 141,668
Split Rock Creek	10170203-512	*E. coli*, TSS	6.8	3,198	MN: 168,243 SD: 45,111 Total: 213,354
Beaver Creek	1070203-522	*E. coli*, TSS	17.7	19,886	MN: 54,835 SD: 0 Total: 54,835

[1] Includes only area draining directly to impaired reach
[2] All area draining to impaired reach

The 18 impaired reaches in the Rock River Watershed (10170204) addressed in this TMDL span approximately 294 stream miles and drain approximately 450,000 acres of land across four Minnesota counties: Pipestone, Rock, Murray, and Nobles (Table 6). The two most downstream reaches of the Rock River, reaches 501 and 509, along with one major tributary reach (Elk Creek reach 519) were covered as part of a previous turbidity and fecal coliform TMDL (Minnesota State University 2008).

Table 6. Rock River Watershed reach impairments, locations, and drainage areas.

Reach Name	Impaired Reach AUID#	Impairment(s)	Reach Length [miles]	Direct Drainage[1] [acres]	Total Drainage[2] [acres]
Mud Creek	10170204-525	*E. coli*, TSS	16.33	14,240	MN: 19,043 Total: 19,043
Rock River, T107 R44W S30, east line to Chanarambie Cr	10170204-504	*E. coli*, TSS	31.77	32,010	MN: 72,719 Total: 72,719
Chanarambie Creek	10170204-522	*E. coli*, TSS	20.51	15,749	MN: 47,915 Total: 47,915
Poplar Creek	10170204-523	*E. coli*, TSS	19.18	13,273	MN: 22,364 Total: 22,364
Rock River, Poplar Cr to Unnamed Cr	10170204-506	*E. coli*, TSS	15.7	12,394	MN: 178,159 Total: 178,159
Unnamed Creek, Unnamed Cr to Rock R	10170204-545	*E. coli*	0.57	6,307	MN: 6,307 Total: 6,307
Unnamed Creek, Headwaters to Rock R	10170204-521	*E. coli*	18.37	11,907	MN: 11,907 Total: 11,907
Rock River, Unnamed Cr to Champepadan Cr	10170204-508	*E. coli*, TSS	4.35	9,274	MN: 197,623 Total: 197,623
Mound Creek	10170204-551	*E. coli*	4.07	11,111	MN: 11,111 Total: 11,111
Champepadan Creek	10170204-520	*E. coli*	37.98	37,444	MN: 7,749 Total: 7,749
Elk Creek	10170204-519	*E. coli*	31.43	24,818	MN: 41,220 Total: 41,220
Kanaranzi Creek, Headwaters to E Br Kanaranzi Cr	10170204-515	*E. coli*	16.42	18,862	MN: 29,367 Total: 29,367
Kanaranzi Creek, East Branch	10170204-514	*E. coli*, TSS	17.15	31,246	MN: 36,444 Total: 36,444
Norwegian Creek	10170204-518	*E. coli* & TSS	9.79	10,798	MN: 14,932 Total: 14,932
Kanaranzi Creek, Norwegian Cr to MN/IA border	10170204-517	*E. coli*, TSS	6.77	8,744	MN: 124,503 Total: 124,503
Little Rock Creek	10170204-511	*E. coli*, TSS	17.37	15,276	MN: 26,934 Total: 26,934
Little Rock River, Headwaters to Little Rock Cr	10170204-512	*E. coli*, TSS	23.67	22,227	MN: 30,982 Total: 30,982
Little Rock River, Little Rock Cr to MN/IA border	10170204-513	*E. coli*, TSS	2.22	2,039	MN: 59,955 Total: 59,955

[1] Includes only area draining directly to impaired reach

[2] All area draining to impaired reach

3.2 Lakes

Collectively, the eight impaired lakes in the Little Sioux River Watershed presented in this TMDL include approximately 3,883 acres of open water and drain over 76,000 acres of land (Table 7). Three of the impaired lake watersheds (Bella, Indian, and Iowa) include area in both Minnesota and Iowa. Little Spirit, an impaired border lake in the Little Sioux River Watershed, has a completed TMDL (IDNR 2004), developed by the IDNR and approved by the EPA Region 7. At the time of this TMDL study, it was assumed that the Turbidity and Algae of Little Spirit Lake TMDL was applicable to Minnesota. However, during the preliminary review of this TMDL report, it was determined that the Turbidity and Algae of Little Spirit Lake TMDL is not applicable to Minnesota because Minnesota and Iowa have different nutrient criteria. Little Spirit Lake will require a TMDL. Due to this recent development, a nutrient TMDL for Little Spirit Lake will be deferred in the next 10-year watershed approach cycle and is not part of this TMDL report. Lake morphometry and watershed information for each impaired lake in the Little Sioux River Watershed is also presented in Table 7 for this TMDL.

Table 7. Little Sioux River Watershed impaired lake watershed areas and lake morphometry.

Lake Name	Surface Area [acres]	Ave. Depth [ft]	Max Depth [ft]	Volume [acre-ft]	Littoral Area [acres]	Littoral Area [%]	Direct Drainage[1] [acres]	Total Drainage[2] [acres]
Okabena Lake	780	6.6	15.0	5,150	780	100	MN: 10,011	MN: 10,011
Ocheda Lake (West Basin)	464	4.0	5.0	1,856	464	100	MN: 21,366	MN: 31,377
Bella Lake	164	5.0	14.0	820	164	100	MN: 6,839 IA: 462	MN: 38,216 IA: 462
Indian Lake	182	4.2	7.0	775	182	100	MN: 7,063 IA: 661	MN: 7,063 IA: 661
Iowa Lake	220	3.0	5.0	660	220	100	MN: 766 IA: 3,550	MN: 766 IA: 3,550
Round Lake	930	4.6	9.0	4,229	930	100	MN: 5,708	MN: 5,708
Clear Lake	434	7.2	9.0	3,116	434	100	MN: 1,343	MN: 1,343
Loon Lake	709	5.0	6.0	3,764	709	100	MN: 19,155	MN: 20,498

3.3 Land Use

Uninterrupted prairie originally covered a majority of the three major watersheds in this TMDL report. Like most areas across the Midwest, these watersheds have been converted from mostly a range of tallgrass prairie and a small amount of wet prairies to a matrix of intensive agricultural uses. This conversion has resulted in various changes throughout the watersheds, such as increases in overland flow, decreases in groundwater infiltration/subsurface recharge, and increases in the nonpoint source transport of sediment, nutrients, agricultural and residential chemicals, and feedlot runoff.

Current land use within each of the three major watersheds is dominated by agriculture (mostly row crops,) followed by rangeland, developed land, wetlands, open water and forest/shrubland (Table 8; Figures 4 through 6). Row crops throughout the watersheds are predominately planted in corn, forage for livestock, and soybeans (MDA 2009 and 2010a). Rangeland typically follows stream corridors, which is a large reason for less channelization of the streams than in similar regions of Minnesota. The Little Sioux River Watershed has less rangeland and more channelization due to more intensive crop farming.

While all three watersheds are predominantly rural, there are several cities and small municipalities located throughout each watershed (Table 9). The city of Worthington (MS400257) is located in the Little Sioux River Watershed and is the largest city and the only community within the three major watersheds subject to the MPCA's Municipal Separate Stormwater System (MS4) Permit program (see Section 4.5).

Table 8. Land cover (MRLC 2006) **in the Lower Big Sioux River, Little Sioux River, and Rock River Watersheds.**

Land use	Lower Big Sioux River Watershed [Percent of total]	Little Sioux River Watershed [Percent of total]	Rock River Watershed [Percent of total]
Cropland	77.3%	82.7%	80.6%
Rangeland	15.3%	3.4%	10.9%
Developed	5.9%	6.2%	6.2%
Forest/Shrubland	0.6%	1.3%	0.8%
Open Water	0.1%	3.6%	0.2%
Wetlands	0.7%	2.7%	1.2%
Barren/Mining	<0.1%	<0.1%	0.1%

Table 9. Minnesota Cities in the Little Sioux River, Lower Big Sioux River, and Rock River Watersheds (Minnesota Department of Administration 2015).

City Name	Major Watershed	County	Population	Sewered	MS4
Pipestone	Lower Big Sioux	Pipestone	4,200	Yes	No
Lake Benton	Lower Big Sioux	Lincoln	675	Yes	No
Jasper	Lower Big Sioux	Pipestone & Rock	611	Yes	No
Beaver Creek	Lower Big Sioux	Rock	291	Yes	No
Holland	Lower Big Sioux	Pipestone	172	Yes	No
Ihlen	Lower Big Sioux	Pipestone	54	Yes	No
Worthington	Little Sioux	Nobles	13,208	Yes	Yes
Round Lake	Little Sioux	Nobles	378	Yes	No
Luverne	Rock	Rock	4,707	Yes	No
Adrian	Rock	Nobles	1,230	Yes	No
Hills	Rock	Rock	687	Yes	No
Ellsworth	Rock	Nobles	461	Yes	No
Rushmore	Rock	Nobles	343	Yes	No
Wilmont	Rock	Nobles	341	Yes	No
Chandler	Rock	Murray	261	Yes	No
Bigelow	Rock	Nobles	235	Yes	No
Lismore	Rock	Nobles	230	Yes	No
Magnolia	Rock	Rock	215	Yes	No
Hardwick	Rock	Rock	191	Yes	No
Steen	Rock	Rock	185	Yes	No
Woodstock	Rock	Pipestone	110	Yes	No
Trosky	Rock	Pipestone	74	No	No
Kenneth	Rock	Rock	61	Yes	No
Hatfield	Rock	Pipestone	46	Yes	No

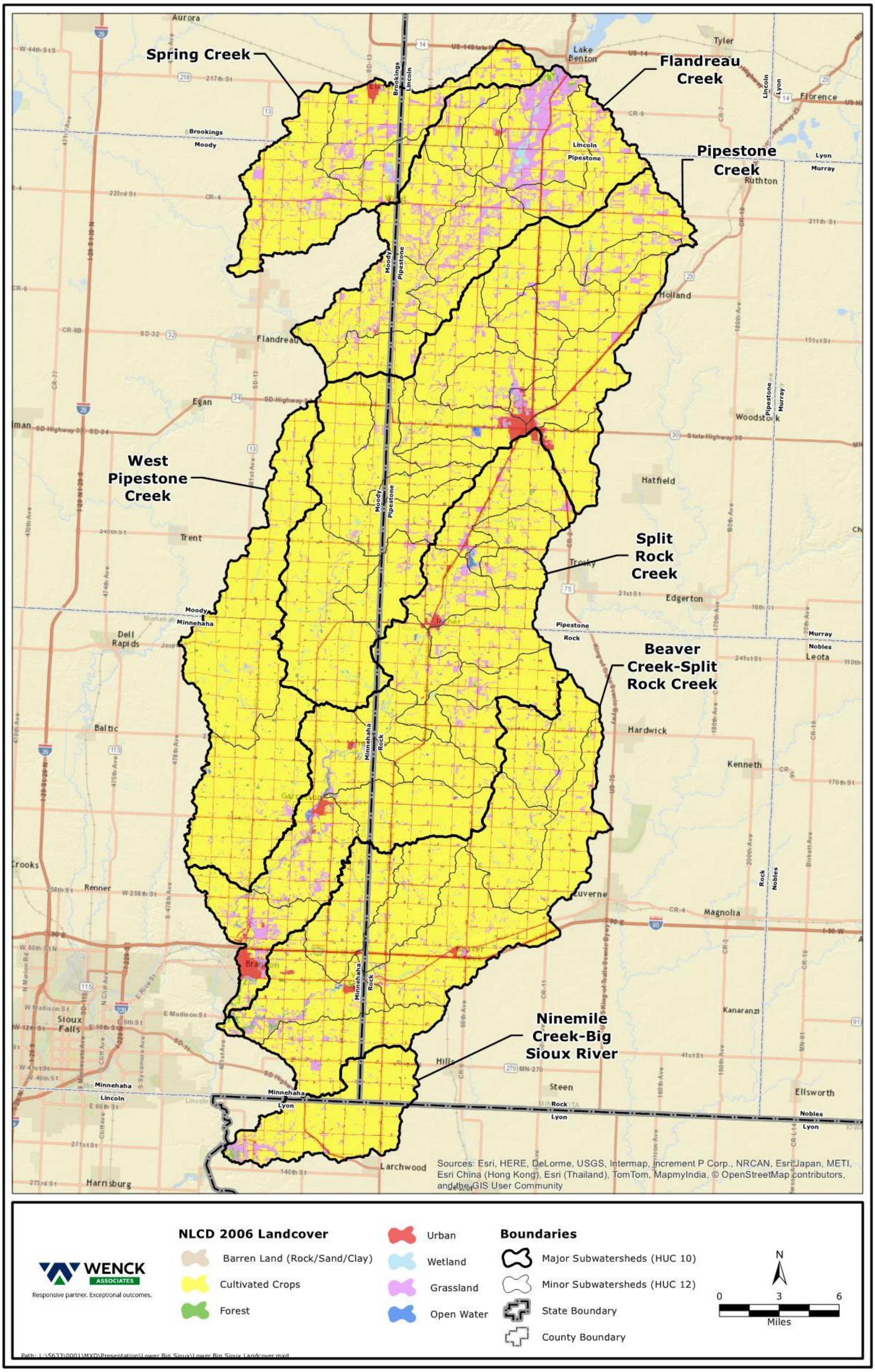

Figure 4. Land cover (MRLC 2006) in the Lower Big Sioux River Watershed.

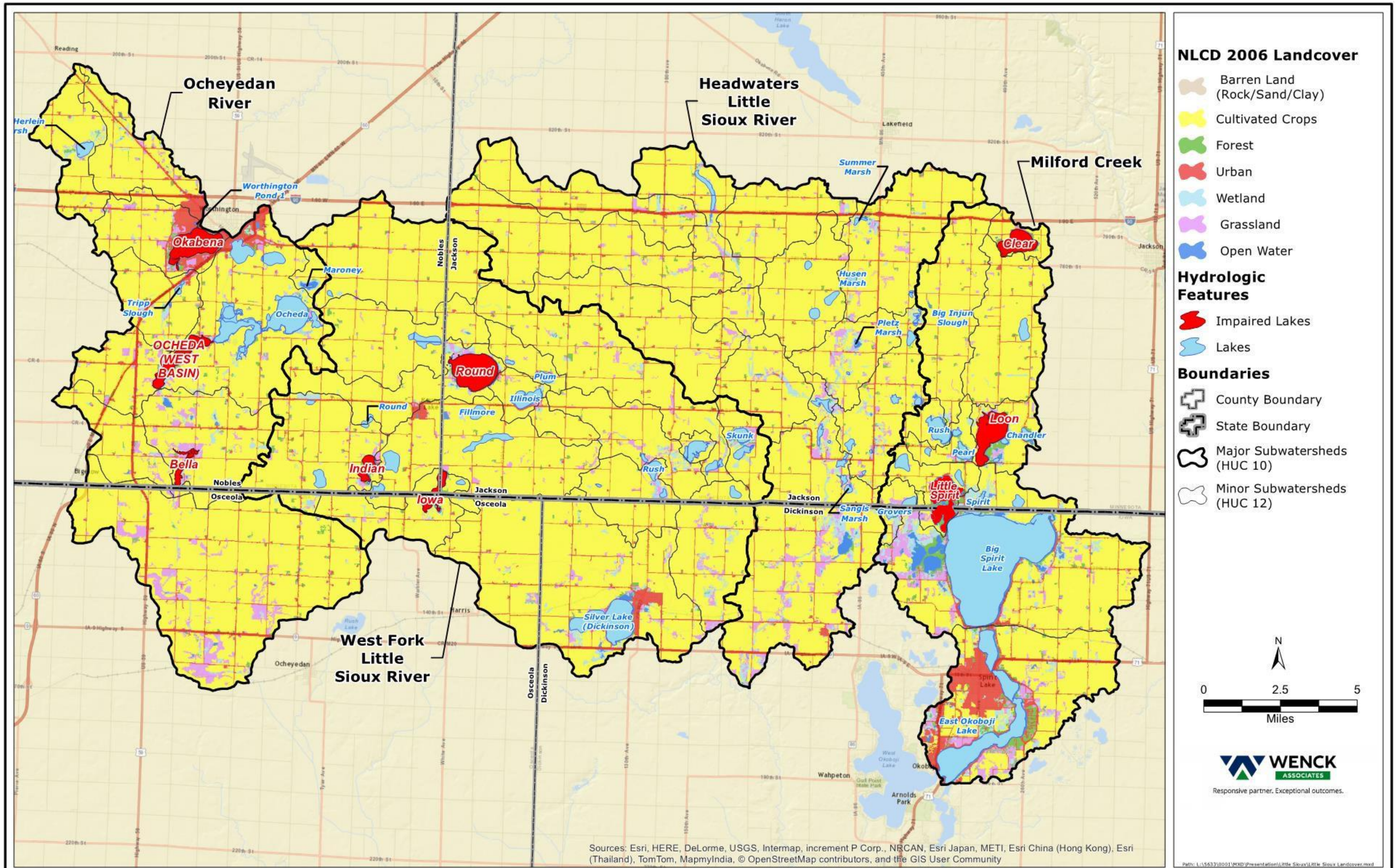

Figure 5. Land cover (MRLC 2006) in the Little Sioux River Watershed.

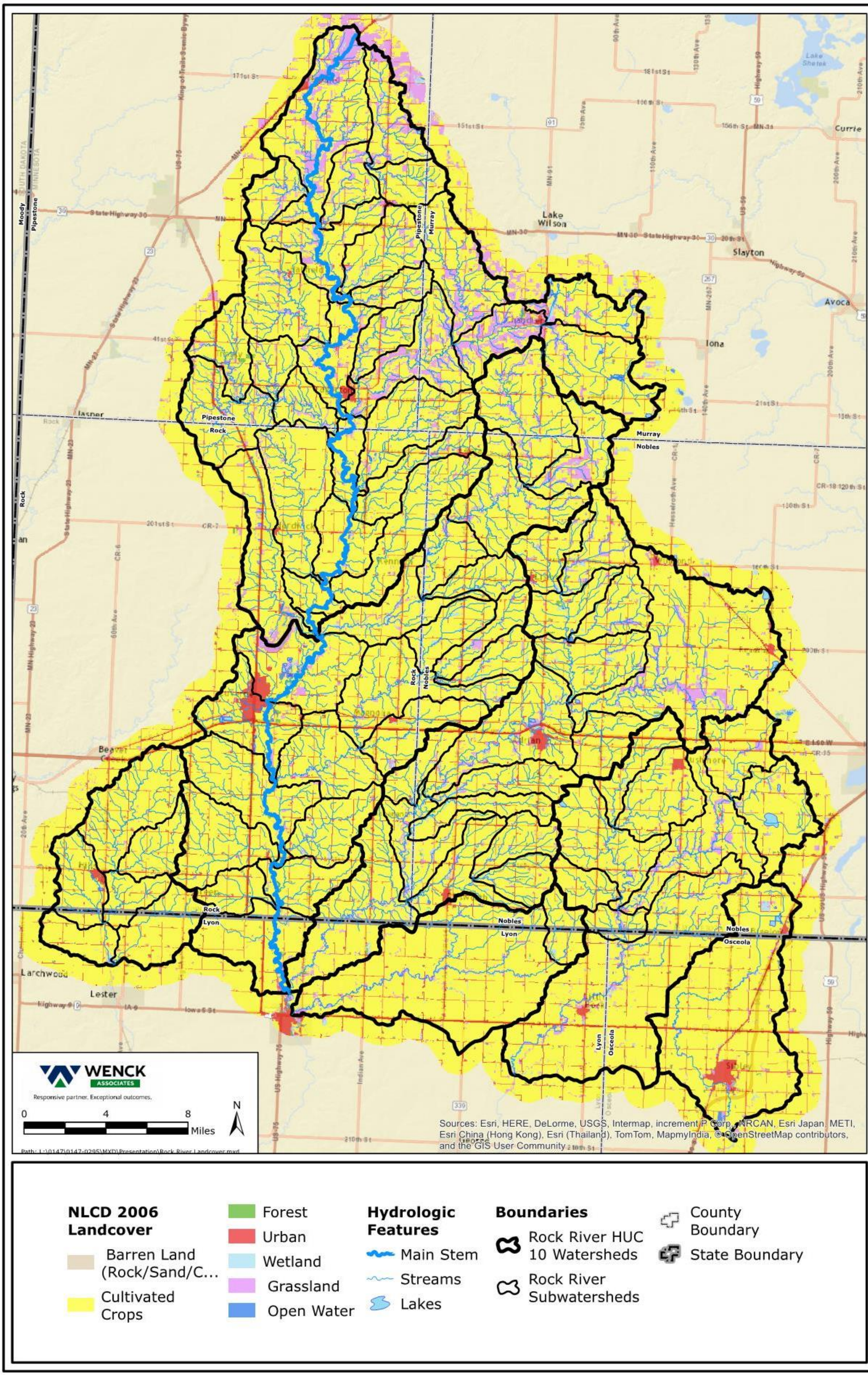

Figure 6. Land cover (MRLC 2006) in the Rock River Watershed.

3.4 Current/Historic Water Quality

All data used in the development of this TMDL were collected between 2000 and 2015 by various agencies and local partners, including the MPCA, area Soil and Water Conservation Districts (SWCDs), local watershed districts, and volunteer monitoring programs. Although data prior to 2000 exists in each of the major watersheds, the more recent data represent current conditions. Only data available through the MPCA's Environmental Quality Information System (EQuIS) website were used in this TMDL.

3.4.1 TSS and Turbidity

TSS, turbidity, and transparency data were summarized by site for each turbidity impaired reach in the Lower Big Sioux River, Little Sioux River, and Rock River Watersheds using all data from 2000 to 2015 (Table 10). The turbidity TMDLs presented in this TMDL are based upon the current TSS standard for the Southern River Nutrient Region of 65 mg/L. Turbidity and transparency data are also presented in Table 10 since these measurements are also used by the MPCA in assessing turbidity impairments when TSS data is not available. Figures 10 through 24 in Section 4.4.6 show the variability of TSS by flow condition for each TSS impaired reach since these reaches were assessed using these criteria.

3.4.2 Bacteria

A reach is placed on the Clean Water Act Section 303(d) Impaired Waters List if the geometric mean (or "geomean") of the aggregated monthly *E. coli* concentrations for one or more months exceed the chronic standard of 126 cfu/100 mL. A water body is also considered impaired if more than 10% of the individual samples during any calendar year exceed the 1,260 cfu/100 mL acute standard.

Table 11 shows April through October monthly *E. coli* geometric means for the 28 bacteria impaired reaches in the Lower Big Sioux River, Little Sioux River, and Rock River Watersheds addressed in this TMDL. Geometric means are often used to describe bacteria data over arithmetic means as the geometric mean normalizes the ranges being averaged, using the following equation:

$$Geometric\ mean = \sqrt[n]{x_1 *\ x_2 * \ldots . x_n}$$

Older records for bacteria samples in the three watersheds were analyzed for fecal coliform and more recently *E. coli*. Fecal coliform data were converted to *E. coli* equivalents using the equation described in Section 2.2. Table 10 shows monthly geometric means and acute exceedances for sampling stations located within each impaired reach. Results indicate all impaired reaches exceeded the 126 cfu/100 mL chronic *E. coli* standard for at least one month during the April through October index period. Additionally, individual samples exceed the 1,260 cfu/100 mL acute standard at least 10% of the time in several reaches during the April through October index period.

Table 10. Observed TSS, turbidity, and transparency data for the turbidity impaired reaches in the Lower Big Sioux River, Little Sioux River, and Rock River Watersheds.

Major Watershed	Reach (AUID)	Reach Name	Station(s)	TSS [1]				Turbidity [2,3]				Transparency [4]			
				Year(s) [5]	Measurements [6]	Exceedances	Percent	Year(s) [5]	Measurements [6]	Exceedances	Percent	Year(s) [5]	Measurements [6]	Exceedances	Percent
Lower Big Sioux River	512	Split Rock Creek	S004-528	2008-2015	180	67	37%	2008-2015	180	97	54%	2008-2014	147	84	57%
			S006-579	2011-2011	11	3	27%		0	0		2011-2012	20	16	80%
Lower Big Sioux River	522	Beaver Creek	S004-811	2008-2012	89	50	56%	2008-2012	78	56	72%	2008-2012	88	63	72%
Lower Big Sioux River	521	Unnamed to Beaver Creek	S007-389	2013-2013	6	1	17%	--	0	--	--	2013-2013	5	1	20%
Lower Big Sioux River	505 [7]	Pipestone Creek	S006-580	2011-2011	11	3	27%	--	0	--	--	2011-2012	19	13	68%
Lower Big Sioux River	501 [8]	Pipestone Creek	S000-099	2000-2009	41	7	17%	2000-2008	9	4	44%	2000-2009	32	8	25%
			S000-510	2011-2014	59	20	34%	2013-2014	48	21	44%	2011-2014	60	31	52%
Lower Big Sioux River	514 [8]	Pipestone Creek, North Branch	S001-904	2002-2004	47	5	11%	2002-2004	46	16	35%	2002-2014	282	154	55%
Lower Big Sioux River	506 [7]	Pipestone Creek	S007-394	2013-2013	11	3	27%	--	0	--	--	2013-2013	10	3	30%
Lower Big Sioux River	509 [7]	Split Rock Creek	S000-652	2013-2013	7	1	14%	--	0	--	--	2013-2013	7	4	57%
Lower Big Sioux River	507 [7]	Split Rock Creek	S001-139	2013-2013	6	1	17%	--	0	--	--	2013-2013	5	3	60%
Lower Big Sioux River	527 [8]	Main Ditch	S000-646	2002-2013	218	18	8%	2007-2007	22	2	9%	2002-2014	421	47	11%
Little Sioux River	508 [9]	Little Sioux River, West Fork	S004-924	2008-2009	21	6	29%	2008-2009	21	12	57%	2008-2009	36	18	50%
Little Sioux River	509 [9]	Little Sioux River, West Fork	S000-100	2011-2012	29	12	41%	2001-2012	66	31	47%	2002-2012	73	38	52%
Little Sioux River	511	Skunk Creek (JD13)	S004-923	2008-2009	21	2	10%	2008-2009	21	7	33%	2008-2009	36	14	39%
Little Sioux River	515	Little Sioux River	S004-219	2011-2012	34	9	26%	2001-2012	80	41	51%	2002-2012	64	37	58%
			S006-549	2011-2011	8	1	13%	--	0	--	--	2011-2012	18	11	61%
Little Sioux River	514 [10]	Little Sioux River	S004-922	2008-2009	19	3	16%	2008-2009	19	11	58%	2008-2009	32	12	38%
Little Sioux River	516 [10]	Unnamed Creek	S004-921	2008-2009	14	0	0%	2008-2009	14	0	0%	2008-2009	25	0	0%
Rock River	525	Mud Creek	S004-391	2007-2014	57	16	28%	--	0	--	--	--	0	--	--
Rock River	508	Unnamed Cr to Champepadan Cr	S004-390	2007-2014	57	13	23%	--	0	--	--	--	0	--	--
Rock River	551 [11]	Mound Creek	S006-168	2010-2013	60	11	18%	2012-2013	39	26	67%	2010-2013	73	44	60%
Rock River	521 [11]	Unnamed Creek to Rock River	S006-169	2010-2012	52	27	52%	2012-2012	31	22	71%	2010-2012	71	38	54%
Rock River	506	Rock River, Poplar Cr to Unnamed Cr	S000-147	2007-2014	47	8	17%	--	0	--	--	--	0	--	--
Rock River	571 [12]	Unnamed Creek to AUID 506	S007-376	2013-2013	7	1	14%	--	0	--	--	2013-2013	6	1	17%
Rock River	545 [12]	Unnamed Creek to Rock River	S007-046	2012-2013	17	4	24%	2012-2013	16	6	38%	2012-2013	17	9	53%
Rock River	523	Poplar Creek	S006-578	2011-2013	48	4	8%	2012-2013	38	16	42%	--	0	--	--
Rock River	588 [13]	Unnamed Creek	S007-371	2013-2013	5	0	0%	--	0	--	--	2013-2013	5	2	40%
Rock River	504	Rock River, T107 R44W S30, east line to Chanarambie Cr	S006-577	2011-2012	47	16	34%	2011-2012	37	22	59%	2011-2012	53	35	66%

Major Watershed	Reach (AUID)	Reach Name	Station(s)	TSS [1]				Turbidity [2,3]				Transparency [4]			
				Year(s) [5]	Measurements [6]	Exceedances	Percent	Year(s) [5]	Measurements [6]	Exceedances	Percent	Year(s) [5]	Measurements [6]	Exceedances	Percent
Rock River	530 [14]	Rock River, East Branch	S007-049	2012-2013	46	1	2%	2012-2013	39	6	15%	2012-2013	45	5	11%
Rock River	593 [14]	Unnamed Creek to AUID 504	S007-048	2012-2013	39	1	3%	2012-2013	39	5	13%	2012-2013	38	11	29%
Rock River	522	Chanarambie Creek	S006-576	2011-2013	48	15	31%	2012-2013	38	22	58%	--	0	--	--
Rock River	559 [15]	Unnamed Creek to AUID 522	S007-377	2013-2013	7	0	0%	--	0	--	--	2013-2013	6	1	17%
Rock River	517	Kanaranzi Creek, Norwegian Cr to MN/IA border	S004-717	2008-2012	78	40	51%	2008-2012	73	47	64%	--	0	--	--
Rock River	516 [16]	Unnamed Creek to AUID 517	S007-380	2013-2013	7	2	29%	--	0	--	--	2013-2013	7	2	29%
Rock River	518 [16]	Norwegian Creek	S001-016	2008-2009	42	1	2%	2008-2009	42	19	45%		0	0	
Rock River	515 [16]	Kanaranzi Creek, Headwaters to E Br Kanaranzi Cr	S006-904	2011-2011	10	2	20%	--	0	--	--	2011-2012	13	3	23%
Rock River	514	Kanaranzi Creek, East Branch	S004-927	2008-2011	52	8	15%	2008-2009	45	16	36%	2008-2012	53	18	34%
Rock River	513	Little Rock River, Little Rock Cr to MN/IA border	S004-928	2011-2012	41	24	59%	2011-2012	36	28	78%	--	0	--	--
Rock River	512	Little Rock River, Headwaters to Little Rock Cr	S006-272	2011-2013	16	7	44%	--	0	--	--	--	0	--	--
Rock River	511	Little Rock Creek	S006-271	2011-2011	10	1	10%	--	0	--	--	--	0	--	--

[1] TSS exceedances based on the newly adopted 65 mg/L criteria for Southern River Nutrient Region class 2B waters
[2] Turbidity exceedances based on the [previous] 25 NTU standard for class 2B waters
[3] Turbidity measurements for Reach 512 (Split Rock Creek, station S004-528) were reported in NTRU. Turbidity measurements for all other reaches and stations were reported in NTU
[4] Transparency exceedances based on the [previous] 20 cm standard for class 2B waters
[5] Measurements prior to 2000 were not included in this table
[6] Only measurements collected from April 1 through October 30 are included in this table
[7] Reaches 505, 506, 507, and 509 (Lower Big Sioux River) are currently not impaired for turbidity. Data for these reaches were included in this table because it is located upstream of impaired Reach 512 (Lower Big Sioux River).
[8] Reaches 501, 514 and 527 (Lower Big Sioux River) are upstream of Reaches 505 and 512 and were covered in a previous TMDL (MPCA 2008)
[9] Reaches 508 and 509 (Little Sioux River) are currently not impaired for turbidity. Data for this reach were included in this table because it is located downstream of impaired Reach 511 (Little Sioux River).
[10] Reaches 514 and 516 (Little Sioux River) are currently not impaired for turbidity. Data for this reach were included in this table because it is located upstream of impaired Reach 515 (Little Sioux River).
[11] Reaches 521 and 551(Rock River) are currently not impaired for turbidity. Data for this reach were included in this table because it is located upstream of impaired Reach 508 (Rock River).
[12] Reaches 545 and 571 (Rock River) are currently not impaired for turbidity. Data for this reach were included in this table because it is located upstream of impaired Reach 506 and therefore 508 (Rock River).
[13] Reach 588 (Rock River) is currently not impaired for turbidity. Data for this reach were included in this table because it is located upstream of impaired Reach 523 (Rock River).
[14] Reaches 530 and 593 (Rock River) are currently not impaired for turbidity. Data for this reach were included in this table because it is located upstream of impaired Reach 504 (Rock River).
[15] Reach 559 (Rock River) is currently not impaired for turbidity. Data for this reach were included in this table because it is located upstream of impaired Reach 522 (Rock River).
[16] Reach 515, 516, and 518 (Rock River) are currently not impaired for turbidity. Data for this reach were included in this table because it is located upstream of impaired Reach 517 (Rock River).

Table 11. Monthly geometric mean of *E. coli* values for the Lower Big Sioux River, Little Sioux River, and Rock River Watershed bacteria impaired reaches, and major upstream reaches.

					April			May			June			July			August			September			October			All Months		
Major Watershed	Reach (AUID)	Reach name	Station(s)	Year(s)	n	Geo	%n > 1,260	n	Geo	%n > 1,260	n	Geo	%n > 1,260	n	Geo	%n > 1,260	n	Geo	%n > 1,260	n	Geo	%n > 1,260	n	Geo	%n > 1,260	n	Geo	%n > 1,260
Little Sioux River	508	West Fork Little Sioux River	S004-924	2008-2009	5	21	0%	5	106	0%	5	254	20%	5	465	0%	5	310	0%	5	637	20%	5	394	0%	35	214	6%
Little Sioux River	509	West Fork Little Sioux River	S000-100	2003-2012	1	5	0%	9	199	0%	21	296	5%	16	434	6%	14	239	0%	9	581	0%	6	311	17%	76	303	5%
Little Sioux River	511	Skunk Creek (JD13)	S004-923	2008-2009	5	47	0%	5	125	20%	5	318	20%	5	1189	40%	5	568	20%	5	789	20%	5	759	40%	35	358	23%
Little Sioux River	514	Little Sioux River	S004-922	2008-2009	5	63	0%	5	88	0%	5	779	40%	5	1128	20%	5	801	0%	1	1,300	100%	5	739	40%	31	393	19%
Little Sioux River	515	Little Sioux River	S004-219	2001-2012	3	44	0%	17	128	0%	18	160	11%	10	230	0%	11	362	0%	9	293	0%	7	319	14%	75	188	4%
Little Sioux River	516	Little Sioux River	S004-921	2008-2009	5	22	0%	5	91	0%	5	182	0%	5	509	0%	2	2420	10%	0	NA	NA	2	510	50%	24	170	13%
Lower Big Sioux River	502	Flandreau Creek	S006-581	2011-2012	0	--	--	0	--	--	5	1,667	60%	5	1076	60%	5	593	20%	0	--	--	0	--	--	15	1021	47%
Lower Big Sioux River	505	Pipestone Creek	S006-580	2011-2012	0	--	--	0	--	--	5	396	20%	5	81	0%	5	337	20%	0	--	--	0	--	--	15	221	13%
Lower Big Sioux River	522	Beaver Creek	S004-811	2008-2012	7	27	0%	18	423	22%	20	1,287	50%	14	1034	50%	12	1042	50%	8	775	38%	6	525	33%	85	591	38%
Lower Big Sioux River	512	Split Rock Creek	S006-579	2011-2012	0	--	--	0	--	--	5	513	20%	5	153	0%	5	333	0%	0	--	--	0	--	--	15	297	7%
Lower Big Sioux River	501 [1]	Pipestone Creek	S000-099	2000-2008	8	42	13%	4	108	0%	4	476	0%	4	195	0%	7	389	0%	6	686	17%	8	686	13%	41	206	7%
			S000-510	2011-2012	0	--	--	0	--	--	5	713	20%	6	465	17%	6	328	0%	0	--	--	0	--	--	17	466	12%
Lower Big Sioux River	514 [1]	Pipestone Creek, North Branch	S001-904	2002-2004	9	56	0%	13	96	15%	15	373	13%	17	509	12%	17	360	12%	10	561	30%	1	561	0%	82	251	13%
Lower Big Sioux River	527 [1]	Main Ditch	S000-646	2002-2004	10	97	30%	13	113	23%	15	157	20%	18	430	17%	17	370	18%	10	514	30%	1	514	0%	84	222	21%
Rock River	504	Rock River	S006-577	2011-2012	3	105	0%	11	768	36%	15	1,040	40%	8	170	0%	7	325	0%	3	223	0%	0	--	--	47	443	21%
Rock River	522	Chanarambie Creek	S006-576	2011-2013	6	77	0%	5	822	60%	10	1,264	40%	11	2,157	82%	10	1,221	60%	5	1,363	80%	6	243	0%	53	821	49%
Rock River	523	Poplar Creek	S006-578	2011-2013	6	145	0%	5	3,021	60%	10	999	50%	11	120	0%	10	115	0%	5	52	0%	6	23	0%	53	189	15%
Rock River	545	Unnamed Creek	s007-046	2012-2013	5	20	0%	4	2,388	75%	5	1,114	40%	2	562	0%	0	--	--	0	--	--	0	--	--	16	355	31%
Rock River	521	Unnamed Creek	S006-169	2010-2012	5	169	0%	4	2,609	100%	12	1,965	83%	14	1,649	64%	11	1,480	73%	4	3,802	75%	5	864	0%	55	1,412	62%
Rock River	506	Rock River	S000-147	2007-S2014	11	26	0%	13	61	8%	12	338	17%	12	439	25%	12	359	8%	8	508	25%	5	185	0%	73	179	12%

					April			May			June			July			August			September			October			All Months		
Major Watershed	**Reach (AUID)**	**Reach name**	**Station(s)**	**Year(s)**	n	Geo	%n > 1,260	n	Geo	%n > 1,260	n	Geo	%n > 1,260	n	Geo	%n > 1,260	n	Geo	%n > 1,260	n	Geo	%n > 1,260	n	Geo	%n > 1,260	n	Geo	%n > 1,260
Rock River	551	Mound Creek	S006-168	2010-2013	6	20	0%	5	1,748	60%	10	144	20%	11	154	9%	9	48	0%	5	96	0%	6	47	0%	52	104	12%
Rock River	508	Rock River	S004-390	2007-2014	11	22	0%	13	87	8%	15	374	13%	16	358	13%	17	382	12%	8	525	0%	5	357	0%	85	213	8%
Rock River	520	Champepadan Creek	S005-809	2009-2010	1	124	0%	0	--	--	3	802	33%	6	529	33%	7	278	14%	5	583	20%	3	174	0%	25	391	20%
			S006-167	2010-2013	6	100	0%	6	458	33%	7	746	29%	9	378	0%	9	147	0%	5	263	0%	6	49	0%	48	226	8%
Rock River	519	Elk Creek	S001-360	2011-2013	6	214	1%	6	1,137	67%	7	2,149	71%	8	3,302	75%	8	3,759	88%	5	3,781	80%	6	1,437	50%	46	1,754	67%
			S006-606	2011-2012	3	344	0%	12	2,585	67%	10	1,943	80%	2	1,852	100%	1	1,300	100%	2	337	0%	0	--	--	30	1451	67%
Rock River	515	Kanaranzi Creek	S006-904	2011-2012	0	--	--	0	--	--	2	517	0%	3	1,831	33%	4	829	25%	2	940	50%	0	--	--	11	966	27%
Rock River	514	Kanaranzi Creek, East Branch	S004-927	2008-2012	6	67	0%	6	211	17%	8	1,021	25%	9	1,208	56%	10	489	20%	8	614	13%	6	477	17%	53	478	23%
Rock River	519	Norwegian Creek	S001-016	2008-2009	6	30	0%	6	207	17%	6	1,089	33%	6	1,249	50%	6	1553	67%	6	1,794	100%	6	659	33%	42	552	43%
Rock River	517	Kanaranzi Creek	S004-717	2008-2012	8	178	0%	14	1,485	57%	17	2,376	88%	11	1,826	73%	12	1,231	58%	11	1,637	55%	6	2,023	67%	79	1,310	62%
Rock River	525	Mud Creek	S004-391	2007-2014	12	9	0%	15	75	20%	19	1,228	53%	21	1,599	67%	19	875	37%	7	1,436	57%	5	427	20%	98	419	40%
Rock River	512	Little Rock River	S006-272	2010-2011	0	--	--	0	--	--	3	1,078	33%	5	984	20%	5	2,011	80%	2	1999	50%	0	--	--	15	1,398	47%
Rock River	511	Little Rock Creek	S006-271	2010-2011	0	--	--	0	--	--	3	1,929	33%	5	1,036	20%	5	644	0%	2	1084	50%	0	--	--	15	1,008	20%
Rock River	513	Little Rock River	S004-928	2008-2012	6	90	0%	15	1150	47%	14	1,433	71%	8	1,087	38%	5	632	40%	5	755	20%	2	497	0%	55	739	44%
Rock River	530 [2]	Rock River, East Branch	S007-049	2012-2013	6	26	0%	5	553	40%	5	163	0%	7	185	0%	5	760	0%	5	902	20%	6	207	33%	39	231	13%
Rock River	528 [2]	Unnamed Creek	S007-048	2012-2013	6	43	0%	5	585	40%	5	567	20%	7	335	14%	5	361	0%	5	276	0%	6	91	0%	39	226	10%

Notes:
Red values = monthly geomean values greater than 126 cfu/100mL
n = number of samples
Geo = Geometric mean in cfu/100 mL
%n > 1,260 = Percent of samples greater than 1,260 cfu/100 mL
-- no available data
[1] Reaches 501, 514 and 527 (Lower Big Sioux River) are upstream of Reaches 505 and 512 and were covered in a previous TMDL (MPCA 2008)
[2] Reaches 528 and 530 (Rock River) are not listed as impaired for *E. coli* at this time but are upstream of Reach 504 (Rock River)
* Rock River Reaches 509 and 501 (not shown in table) are directly downstream of Reaches 508 and 519 and were covered in a previous TMDL (Minnesota State University, Mankato Water Resources Center 2008)

3.4.3 Nutrients

In general, historical in-lake water quality data collected from 2005 through 2015 was reviewed for use in this TMDL. Table 12 lists the June through September averages for TP, Chl-*a*, and Secchi depth for each impaired lake. The table also lists the data years which were used to calculate the "average" condition for this TMDL. All lakes indicate average summer TP, Chl-a and/or Secchi depth are not meeting ecoregion-defined state standards.

Table 12. Summer growing season averages for each water quality parameter.

		In-Lake "Average" Condition [Calculated June – September]		
Lake Name	**"Average" Condition Calculation Years**	**TP Concentration [µg/L]**	**Chl-*a* Concentration [µg/L]**	**Secchi Depth [m]**
WCBP Ecoregion Shallow Lake Standards		**90**	**30**	**0.7**
Loon Lake	2005 - 2010	309	104	0.5
Clear Lake	2005 - 2010	108	52	0.6
Round Lake	2008 - 2010	117	16	0.5
Iowa Lake	2010 - 2011	221	75	0.2
Indian Lake	2009 - 2011	213	61	1.1
Ocheda Lake (West Basin)	2007 - 2008	228	133	0.2
Okabena Lake	2000 - 2014	151	25	0.5
Bella Lake	2008 - 2009	176	111	0.4

3.5 Pollutant Source Summary

3.5.1 TSS

Turbidity source assessments generally focus on TSS, not turbidity, since TMDL development is based on the TSS standard. When assessing the TSS in streams, the first step is to evaluate the external and internal sources.

Potential external sources include sediment loading from permitted sources outside the stream; construction, industrial, and municipal stormwater runoff, wastewater effluent, and overland erosion. Potential Internal sources of sediment and turbidity include bank erosion and in-channel algal production. This TMDL used available monitoring and GIS data/information to assess each of these potential sources. Table 13 below provides a reach by reach summary of the sediment source assessment data/information compiled for this TMDL.

Stormwater

Although the city of Worthington is a MS4, it doesn't discharge to a turbidity/TSS impaired reach, therefore, there are no permitted MS4s in any of the TSS impaired reach watersheds covered in this TMDL.

Wastewater Treatment Facilities

There are five active permitted wastewater dischargers in the Lower Big Sioux River TSS impaired reach watersheds and 12 facilities in the Rock River impaired reach watersheds (see Section 4.4.2.1). There are no active industrial or municipal wastewater dischargers in the Little Sioux River TSS impaired reach watersheds. Permitted TSS concentration limits for all of the permitted facilities in the Lower Big Sioux River and Rock River Watersheds are either 30 mg/L or 45 mg/L (see Table 19) and are therefore protective of the 65 mg/L standard for class 2B streams. Discharge Monitoring Reports (DMRs) for each facility were downloaded through the MPCA's database and TSS effluent concentrations were reviewed for this TMDL (Appendix A). Results show that individual monthly exceedances of each facility's concentration limit are rare and occur less than 10% of the time.

Overland Erosion

External sediment loads can also come from non-permitted sources such as sediment erosion from upland fields, tile drainage (Schottler 2012), gully erosion, and livestock pastures in riparian zones. Upland nonpoint sources of sediment were evaluated using the Revised Universal Soils Loss Equation (RUSLE). The RUSLE provides an assessment of existing soil loss from upland field sources and predicts the long term average annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, land use and management practices. Detailed methodology and results of the RUSLE analysis are provided in Appendix B.

Bank Erosion

The Channel Condition and Stability Index (CCSI) (MPCA 2009) was used to assess whether streambanks are a potential source of sediment to the TSS impaired reaches (see Appendix B for discussion). The CCSI score in Little Sioux River Reach 515 indicate streambanks are severely unstable while CCSI scores for five other reaches indicate streambanks are moderately unstable.

In-channel Algal Production

Chl-*a* data for each impaired reach was reviewed to determine whether algae growth is a potential source of turbidity (Appendix B). Algae growth in the water column can increase turbidity. Only two of the impaired reaches have Chl-*a* data (Table 13). Concentration in these reaches occasionally exceed the State's eutrophication criteria of 35 µg/L for streams in the South River Nutrient Region, suggesting algae may be a source of turbidity/TSS. Most of these exceedances occurred during late summer (August and September) low flow conditions. More data will need to be collected to fully assess algal turbidity in the TSS impaired reaches.

Table 13. TSS source assessment summary for all TSS impaired reaches in the Lower Big Sioux River, Little Sioux River, and Rock River Watersheds.

Major Watershed	Major Subwatershed (HUC-10)	Impaired Reach	Monitored TSS [percent reduction]					Average RUSLE Potential Soil Loss [tons/acre/yr]	CCSI Score	Chlorophyll-a Exceedances [percent]	Upstream TSS (as presented in Table 10)
			Very High	High	Mid	Low	Very Low				
Lower Big Sioux River	Split Rock Creek	Split Rock Creek Reach 512	85%	64%	11%	12%	3%	2.76 Moderate	51 Moderately Unstable	55%	Upstream Reaches 505, 506, 507, and 509 have little TSS data (all <11 samples) but all have >10% exceedance
	Beaver Creek	Beaver Creek Reach 522	90%	59%	64%	0%	2%	4.32 High	64 Moderately Unstable	NA	NA
Little Sioux River	West Fork Little Sioux River	Judicial Ditch 13 Reach 511	0%	0%	0%	56%	NA	1.46 Low	59 Moderately Unstable	NA	NA
	Headwaters Little Sioux River	Little Sioux River Reach 515	0%	44%	32%	NA	0%	3.02 High	89 Severely Unstable	8%	Upstream Reach 514 has little TSS data (19 samples) but has 16% exceedances; Upstream Reach 516 has little TSS data (14 samples) but no TSS exceedances
Rock River	Mud Creek	Mud Creek Reach 525	47%	34%	7%	54%	2%	3.12 High	N/A	NA	NA
	Headwaters Rock River	Rock River Reach 504	69%	8%	0%	0%	NA	2.94 Moderate	43 Fairly Stable	NA	Tributary Reaches 530 and 593 have been monitored extensively for TSS (>39 samples) and show very few exceedances (<3%)
		Chanarambie Creek Reach 522	62%	51%	0%	24%	0%	3.12 High	42 Fairly Stable	NA	Tributary Reach 559 has little TSS data (7 samples) but no TSS exceedances
		Poplar Creek Reach 523	71%	0%	0%	0%	0%	3.01 High	N/A	NA	Tributary Reach 588 has little TSS data (5 samples) but no TSS exceedances
		Rock River Reach 506	64%	0%	0%	0%	0%	2.98 Moderate	77 Moderately Unstable	NA	TSS impaired Reaches 523, 522, and 504 are located upstream and drain to this reach; tributary reaches 545 and 571 have little TSS data but have >10% exceedance
		Rock River Reach 508	70%	38%	0%	0%	0%	2.74 Moderate	74 Moderately Unstable	NA	TSS impaired Reaches 506, 523, 522, and 504 are located upstream and drain to this reach; tributary reaches 521 and 551 have have exceeded the standard 52% and 18% of the time, respectively
	Kanaranzi Creek	Kanaranzi Creek, East Branch Reach 514	56%	0%	0%	0%	0%	2.73 Moderate	N/A	NA	NA
		Kanaranzi Creek Reach 517	82%	53%	26%	0%	4%	2.77 Moderate	45 Fairly Stable	NA	TSS impaired Reach 514 is located upstream and drains to this reach; Reaches 515 and 516 have little TSS data but have >10% exceedances; Reach 518 has shown few exceedances (2%)
	Little Rock River	Little Rock Creek Reach 511	1%	0%	0%	NA	NA	2.50 Moderate	N/A	NA	NA
		Little Rock River Reach 512	70%	20%	0%	36%	NA	3.14 High	N/A	NA	NA
		Little Rock River Reach 513	89%	43%	0%	0%	36%	2.57 Moderate	N/A	NA	TSS impaired Reaches 511 and 512 are located upstream and drain to this reach

3.5.2 Bacteria

An estimate of the total amount of bacteria produced within the three major watersheds was made using available data on livestock, geographic information systems (GIS), human and pet populations, wildlife population, and SSTS, and literature rates from various studies/sources to estimate bacteria production in each watershed. The purpose of this exercise was to compare the number of bacteria generated by each source to aid in focusing implementation activities. Detailed results of the watershed bacteria accounting exercise are presented in Appendix C. Livestock animals were by far the biggest bacteria producer in each of the assessed watersheds (99% of total in all reaches). Failing SSTS, while not a major bacteria producer in terms of total production numbers (less than 1% in all reaches), may be a critical source to the impaired reaches, particularly during low flow conditions. Below is a general summary of the results of the accounting exercise and a general description of the sources of bacteria in the three major watersheds.

Feedlot Facilities

In Minnesota, animal feedlot operators are required to register with their delegated county if they are 1) an animal feedlot capable of holding 50 or more animal units (AUs), or a manure storage area capable of holding the manure produced by 50 or more AUs; and 2) an animal feedlot capable of holding 10 or more and fewer than 50 AUs, or a manure storage area capable of holding the manure produced by 10 or more and fewer than 50 AUs, that is located within shoreland. Further explanation of registration requirements can be found in Minn. R. ch. 7020.0350.

Concentrated Animal Feeding Operation (CAFO) is an EPA definition that implies not only a certain number of animals but also specific animal types e.g. 2500 swine is a CAFO, 1000 cattle are a CAFO, but a site with 2499 swine and 999 cattle is not a CAFO, according to the EPA definition. The MPCA currently uses the federal definition of a CAFO in its permit requirements of animal feedlots along with the definition of AU. In Minnesota, the following types of livestock facilities are issued, and must operate under, a National Pollutant Discharge Elimination System (NPDES) Permit or a state issued State Disposal System (SDS) Permit (Permit): a) all federally defined CAFOs which have had a discharge, some of which are under 1000 AUs in size; and b) all CAFOs and non-CAFOs that have 1000 or more AUs. These feedlots must be designed to totally contain runoff, and manure management planning requirements are more stringent than for smaller feedlots. 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 with an appropriate mix of field inspections, offsite monitoring and compliance assistance. The number of AUs by animal type registered with the MPCA feedlot database are used in this TMDL.

Livestock can contribute bacteria to the watershed through runoff from feedlot facilities. There are approximately 2,144 active feedlot facilities with over 600,000 livestock AUs throughout the Lower Big Sioux River, Little Sioux River, and Rock River Watersheds (Figures 7 through 9). There are also 52, 36, and 97 CAFOs in Lower Big Sioux River, Little Sioux River, and Rock River Watersheds, respectively (Appendix H).

Facility and livestock numbers by major watershed, based on the MPCA record of registered feedlot facilities, are listed in Table 14. There are 283 feedlots located within 1,000 feet of a lake or 300 feet of a stream or river, an area generally defined as shoreland. 213 of these feedlots in shoreland have open lots. Open lots present a potential pollution hazard if the runoff from the open lots is not treated prior to reaching surface water. The bacteria production exercise presented in Appendix C estimates the amount of bacteria produced by each type of livestock in each major watershed. Manure from these feedlots is typically applied as fertilizer to agricultural fields and is discussed below.

Table 14. Feedlot summary for the three major watersheds.

Description	Lower Big Sioux River Watershed	Little Sioux River Watershed	Rock River Watershed
Total Feedlots	570	301	1,273
Total AUs	173,329	81,411	394,740
Primary Animal Type	Swine 69% Poultry 16% Cows 13%	Swine 56% Poultry 36% Cows 6%	Swine 71% Poultry 6% Cows 17%
CAFOs	52	36	97
Open Lot Feedlots	467 feedlots 78,766 AUs	183 feedlots 21,173 AUs	862 feedlots 184,722 AUs
Feedlots in Shoreland	86 feedlots 19,572 AUs	34 feedlots 7,466 AUs	163 feedlots 40,744 AUs
Open Lot Feedlots in Shoreland	76 feedlots 11,582 AUs	19 feedlots 2,925 AUs	118 feedlots 22,760 AUs

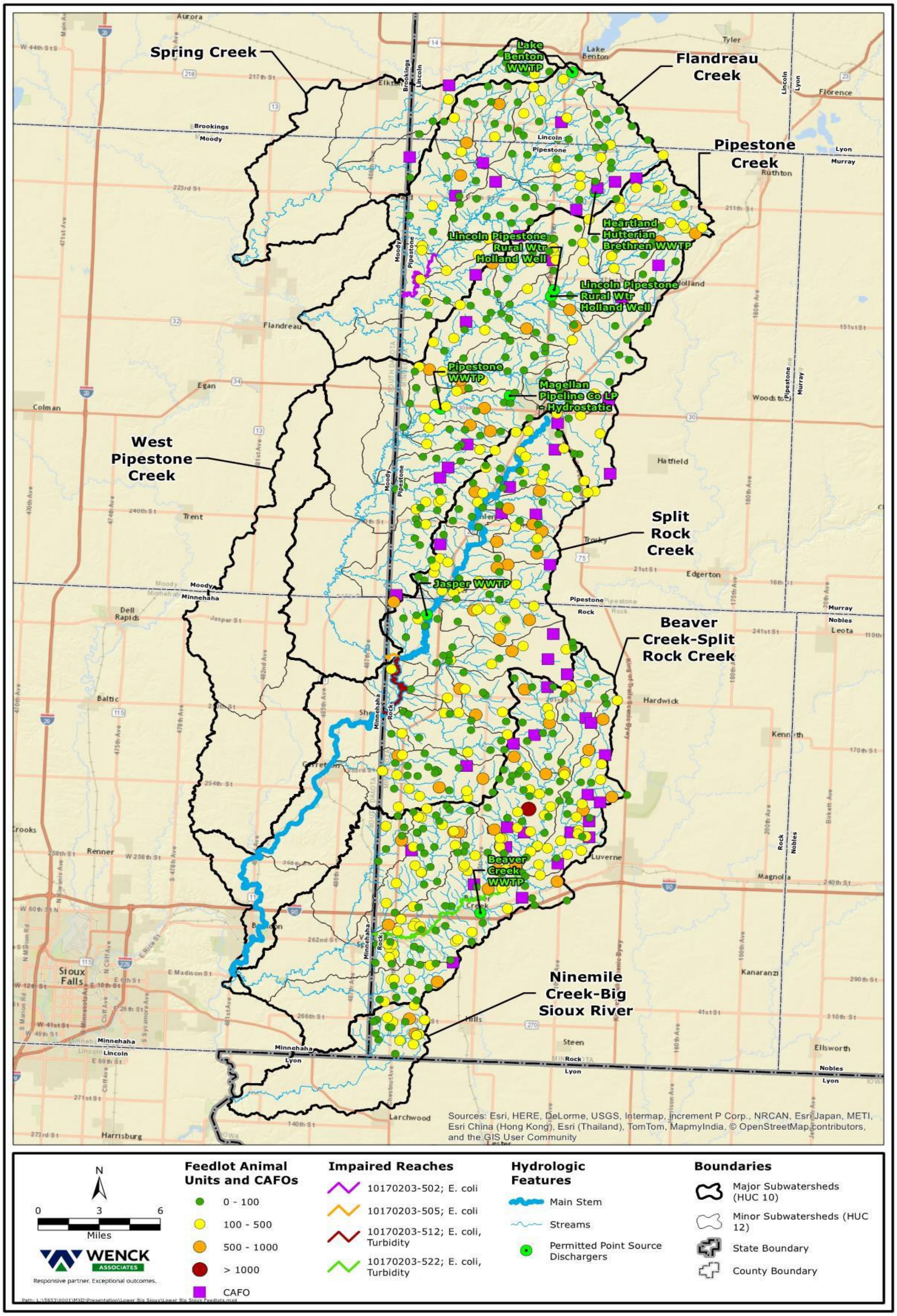

Figure 7. MPCA registered feedots in the Lower Big Sioux River Watershed.

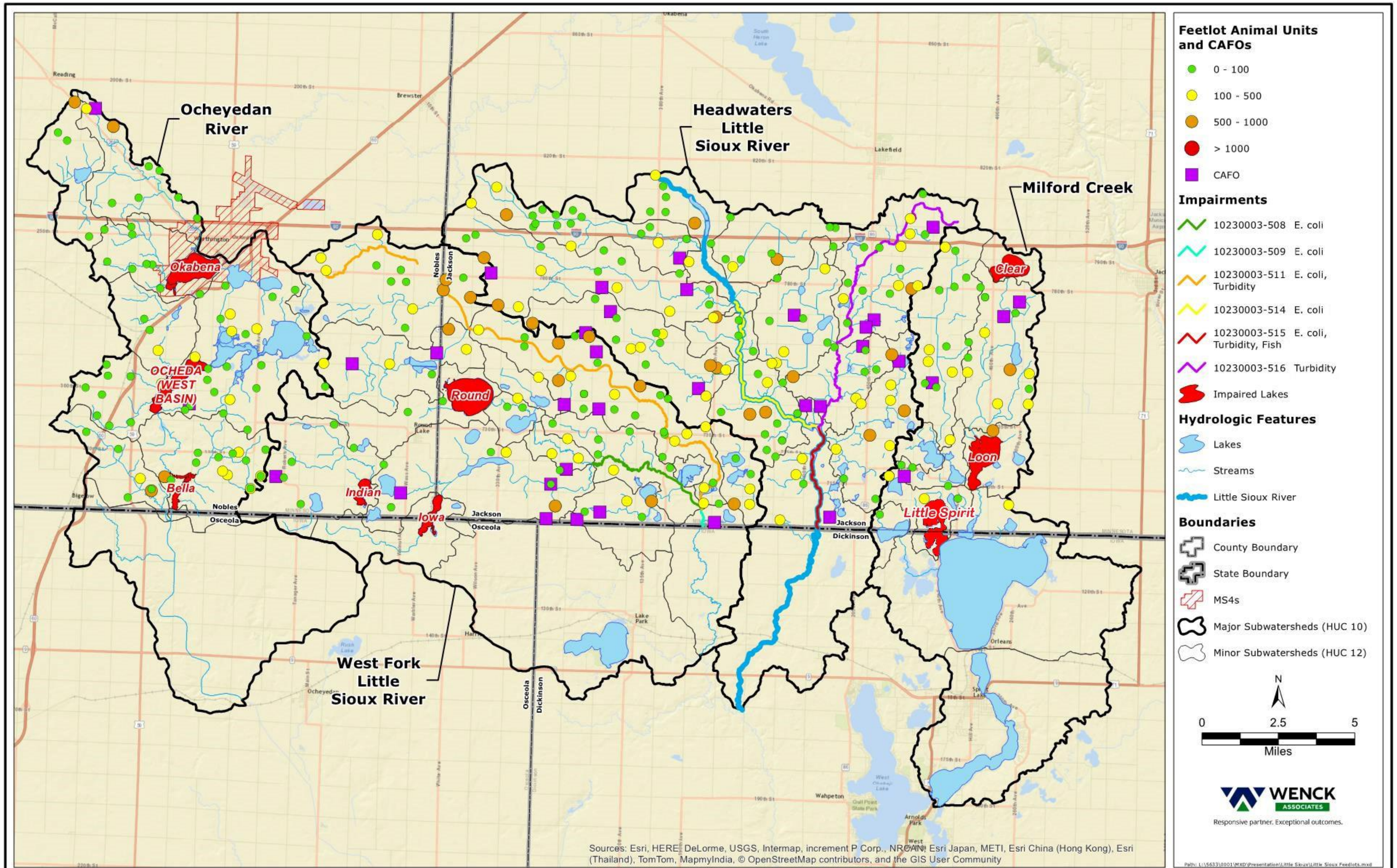

Figure 8. MPCA registered feedlots in the Little Sioux River Watershed.

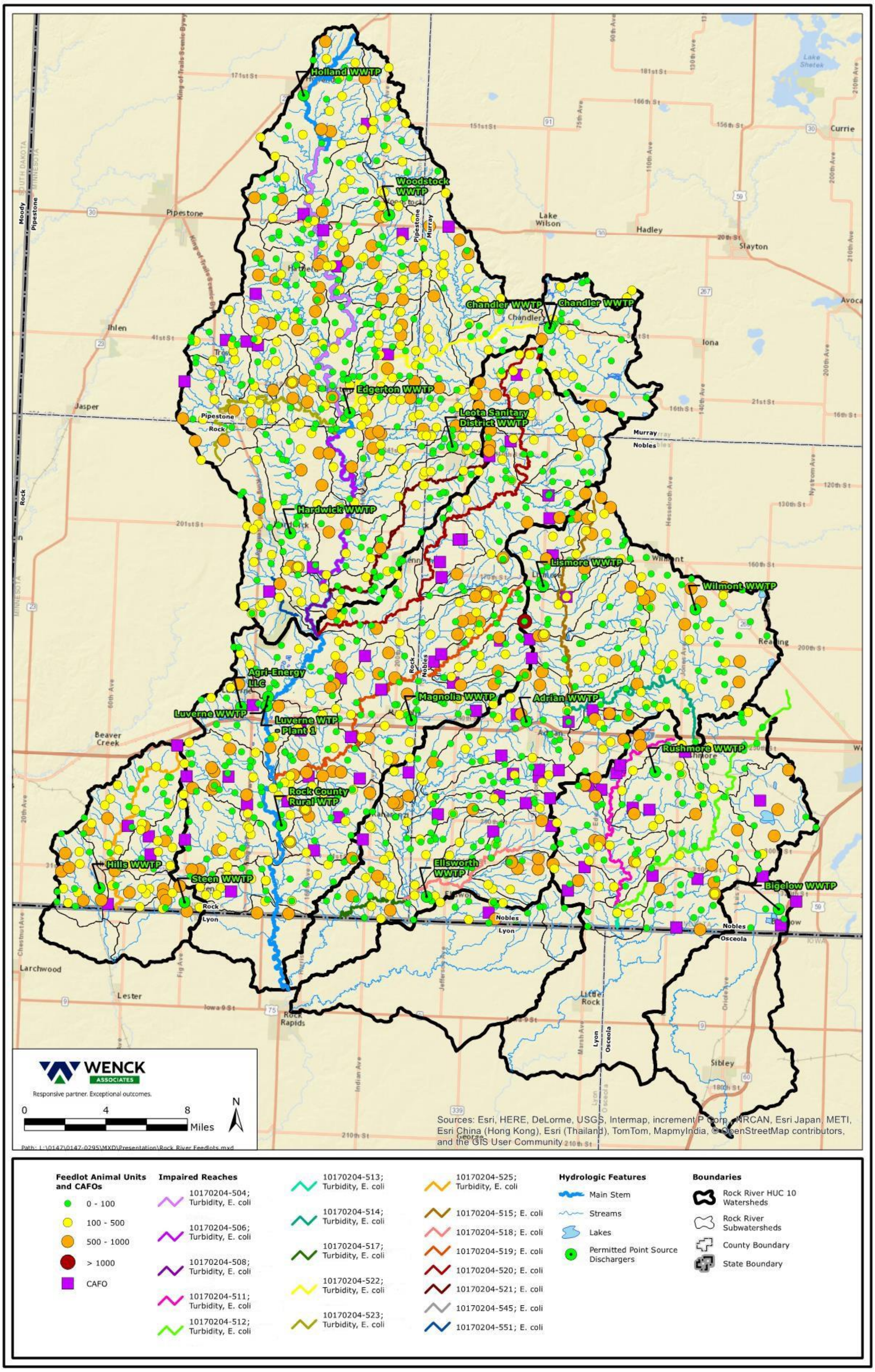

Figure 9. MPCA registered feedlots in the Rock River Watershed.

Manure

Manure is a by-product of animal production and large numbers of animals create large quantities of manure. This manure is usually stockpiled and then spread over agricultural fields to help fertilize the soil. Based on the MPCA feedlot staff analysis of feedlot demographics, knowledge, and actual observations, there is a significant amount of late winter solid manure application (before the ground thaws). During this time the manure can be a source of *E. coli* in rivers and streams, especially during precipitation events. While the results of two surveys (MDA 2010b, 2012) conducted by the Minnesota Department of Agriculture (MDA) are not reported by specific watershed, they indicate very similar results to methods used in the TMDL and WRAPS process.

Short term stockpile sites are defined in Minn. R. ch. 7020 and are considered temporary. Any stockpile kept for longer than a year must be registered with the MPCA and would be identified as part of a feedlot facility. Because of the temporary status of the short term stockpile sites, and the fact they are usually very near or at the land application area, they are included in with the land applied manure.

Incorporating manure is the preferred BMP for land application of manure and should result in less runoff losses. Because land application of manure is only part of the *E. coli* LA there was no attempt to quantify or distinguish between incorporated and non-incorporated manure in the TMDL, instead it was only described as “Manure”. A more detailed source assessment was completed in Section 2.2 in the WRAPS report (MPCA 2017) to help identify specific strategies which could be implemented.

Pasture

Livestock can contribute bacteria to the watershed through runoff from pasture areas in riparian zones as well as direct loading if livestock are allowed access to streams or lakes. Livestock access to streams is a common practice and concern in these watersheds.

SSTS and Unsewered Communities

Failing SSTS near waterways can be a source of bacteria to streams and lakes, especially during low flow periods when these sources continue to discharge and runoff driven sources are not active. The MPCA differentiates between systems that are generally failing and those that are an imminent threat to public health and safety (ITPHS). Generally, failing systems are those that do not provide adequate treatment and may contaminate groundwater. For example, a system deemed failing to protect groundwater may have a functioning, intact tank and soil absorption system, but fails to protect ground water by providing a less than sufficient amount of unsaturated soil between where the sewage is discharged and the ground water or bedrock. Systems considered ITPHS are severely failing or were never designed to provide adequate raw sewage treatment. Examples include SSTS and straight pipe systems that transport raw or partially treated sewage directly to a lake, a stream, a drainage system, or ground surface Minn. Stat. 115.55, subd. 1.

Currently, the exact number and status of SSTS in the Lower Big Sioux River, Little Sioux River, and Rock River Watersheds are unknown. The MPCA’s 2015 SSTS Annual Report (MPCA 2016a) includes some general information regarding the performance of SSTS in the three major watersheds. This TMDL utilizes county annual reports that include estimated failure rates for each county in the state of Minnesota. The bacteria production exercise (Appendix C) utilizes the county failure rates presented in this TMDL to estimate bacteria production from failing SSTS. SSTS failure rates for counties in the Lower Big Sioux River, Little Sioux River, and Rock River Watersheds are summarized in Table 15.

Table 15. SSTS failure rates by county.

County	Total Number of SSTS	Generally Failing SSTS	ITPHS SSTS
Jackson	3,217	50%	15%
Lincoln	2,300	47%	19%
Murray	1,133	9%	37%
Nobles	2,352	38%	20%
Pipestone	1,435	7%	55%
Rock	1,328	40%	18%

Unsewered communities are a group of five or more residencess that lack proper wastewater treatment required by the state of Minnesota. There are four unsewered communities (Kanaranzi, Reading, St. Killian, and Trosky) located in the Rock River Watershed. There are three unsewered communities (Pipestone North Subdivision, Pipestone South Subdivision, and Verdi) located in the Lower Big Sioux River Watershed. There are two unsewered communities (Loon Lake and Round Lake campground) located in the Little Sioux River Watershed.

Wastewater Dischargers

Review of the impaired reaches indicates that there are seven active permitted wastewater dischargers in the Lower Big Sioux River bacteria impaired reach watersheds, one active wastewater discharger in the Little Sioux River impaired reach watersheds, and 13 active wastewater dischargers in the Rock River impaired reach watersheds (Figures 1 through 3; Table 35). DMR summaries for each facility indicate individual monthly exceedances of each facility's bacteria concentration are rare and average monthly effluent concentrations are typically less than 100 cfu/100 mL (see Appendix A).

Urban Runoff

Although the city of Worthington is a MS4, it does not discharge to an *E. coli* impaired reach, therefore, there are no MS4s located in any of the bacteria impaired reach watersheds. There are also no communities likely to become subject to MS4 permit requirements in the near future. There are, however, several non-MS4 communities located throughout the bacteria impaired reach watersheds. These urban areas may contribute bacteria to surface waters from pet waste and wildlife.

Natural Reproduction

It has been suggested that *E. coli* bacteria has the capability to reproduce naturally in water and sediment and therefore should be taken into account when identifying bacteria sources. Two Minnesota studies describe the presence and growth of "naturalized" or "indigenous" strains of *E. coli* in watershed soils (Ishii et al. 2010), and ditch sediment and water (Sadowsky et al. 2015). The latter study, supported with Clean Water Land and Legacy funding, was conducted in the Seven Mile Creek Watershed, an agricultural landscape in south central Minnesota. DNA fingerprinting of *E. coli* from sediment and water samples collected in Seven Mile Creek from 2008 through 2010 resulted in the identification of 1,568 isolates comprised of 452 different *E. coli* strains. Of these strains, 63.5% were represented by a single isolate, suggesting new or transient sources of *E. coli*. The remaining 36.5% of strains were represented by multiple isolates, suggesting persistence of specific *E. coli*. Discussions with the primary author of the Seven Mile Creek study suggest that while 36% might be used as a rough indicator of "background" levels of bacteria at this site during the study period, this percentage is not directly transferable to the concentration and count data of *E. coli* used in water quality standards and TMDLs. Additionally, because the study is not definitive as to the ultimate origins of this bacteria, it would not be appropriate to consider it as "natural" background. Finally, the author cautioned about extrapolating results from the Seven Mile Creek Watershed to other watersheds without further studies.

3.5.3 Nutrients

A key component to developing a nutrient TMDL is understanding the sources contributing to the impairment. This section provides a brief description of the potential permitted and non-permitted sources contributing excess nutrients to the impaired lakes in the Little Sioux River Watershed. Section 4.5 of this TMDL will discuss the major pollutant sources and how they were quantified using monitoring data and water quality modeling. The information presented here and in the upcoming sections together will provide information necessary to both assess the existing contributions of pollutant sources and target pollutant load reductions.

Phosphorus loading from a lake's watershed can come from a variety of sources such as fertilizer, manure, and the decay of organic matter. Wind and water action erode the soil, detaching particles and conveying them in stormwater runoff to nearby water bodies where the phosphorus becomes available for algae growth (Table 16). Organic material such as leaves and grass clippings can leach dissolved phosphorus into standing water and runoff or be conveyed directly to water bodies where biological action breaks down the organic matter and releases phosphorus.

Table 16. Potential permitted stormwater sources of phosphorus.

Permitted Source	Source Description	Phosphorus Loading Potential
Phase II Municipal Stormwater NPDES/SDS General Permit	Municipal Separate Storm Sewer Systems (MS4s)	Potential for runoff to transport sediment, grass clippings, leaves, and other phosphorus-containing materials to surface water through a regulated MS4 conveyance system.
Construction Stormwater NPDES/SDS General Permit	Permits for any construction activities disturbing: 1) One acre or more of soil, 2) Less than one acre of soil if that activity is part of a "larger common plan of development or sale" that is greater than one acre or 3) Less than one acre of soil, but the MPCA determines that the activity poses a risk to water resources.	The EPA estimates a soil loss of 20 to 150 tons per acre per year from stormwater runoff at construction sites. Such sites vary in the number of acres they disturb.
Multi-sector Industrial Stormwater NPDES/SDS General Permit	Applies to facilities with Standard Industrial Classification Codes in 10 categories of industrial activity with significant materials and activities exposed to stormwater.	Significant materials include any material handled, used, processed, or generated that when exposed to stormwater may leak, leach, or decompose and be carried offsite.

Table 17 describes several phosphorus sources that are not regulated by the NPDES program. For many lakes, especially shallow lakes, internal sources can be a significant portion of the TP load. Under anoxic conditions at the lake bottom, weak iron-phosphorus adsorption bonds on sediment particles break, releasing phosphorus into the water column in a form highly available for algal uptake. In many lakes, high internal loading rates are the result of a large pool of phosphorus in the sediment that has accumulated over several decades of watershed loading to the lake. Thus, even if significant watershed load reductions have been achieved through BMPs and other efforts, internal loading from the sediment can remain high and in-lake water quality may not improve. Carp and other rough fish uproot aquatic macrophytes during feeding and spawning and re-suspend bottom sediments, releasing phosphorus and decreasing water clarity. Some aquatic vegetation species such as invasive curly-leaf pondweed can outcompete and suppress native vegetation species. Curly-leaf pondweed begins its growth cycle earlier in the season compared to other species and typically dies back in mid-summer. As a result, lakes with heavy curly-leaf pondweed infestation can have little or no submerged vegetation by late summer. This can cause lower DO levels, increased sediment re-suspension and phosphorus release from sediment. Eurasian watermilfoil, which is present in many lakes throughout Minnesota, is not a phosphorus source, but is an invasive that can also out-compete native vegetation and negatively impact recreational use of lakes.

Table 17. Potential non-permitted sources of phosphorus.

Non-Permitted Source	Source Description
Atmospheric Phosphorus Loading	Precipitation and dryfall (dust particles suspended by winds and later deposited).
Watershed Phosphorus Export	Variety in land use creating both rural and urban stormwater runoff that does not pass through a regulated MS4 conveyance system.
Internal Phosphorus Release	Release from lake bottom sediments during periods of low DO; release from aquatic vegetation during senescence and breakdown; sediment resuspension from rough fish
Failing SSTS	SSTS failures on lakeshore homes can contribute to lake nutrient impairments.

A general summary of the nutrient sources to each impaired lake in the Little Sioux River Watershed is provided in Table 18. Estimates of each source and how they were calculated are discussed in Section 4.6. DNR lake survey reports (if available) were reviewed to assess the vegetation and fish communities for each lake (Appendix D).

Table 18. Nutrient source summary for each of the impaired lakes in the Little Sioux River Watershed.

Major Watershed	Lake Name	Watershed Sources				Internal Sources				Upstream Lake(s)	Notes
		Agriculture	Urban	SSTS	WWTPs	Sediment Release	Historic Impacts (i.e. WWTP discharge)	Aquatic Vegetation	Rough Fish (i.e. Carp)		
Little Sioux River Watershed	Okabena	●	○	○		●		×	Δ		Above average Common Carp total catch observed for similar class lakes. Possible successful recruitment based on recent DNR survey.
	Ocheda (West Basin)	●		○		●		×	Δ	Okabena	Above average Common Carp total catch observed for similar class lakes. Possible successful recruitment based on recent DNR survey.
	Bella	●		○				×	Δ	Ocheda, Okabena	Above average Common Carp observed for similar class lakes.
	Indian	●		○		○		×	Δ		Average Common Carp observed for similar class lakes.
	Iowa	●		○		○		×	×		No fish record. If connected, possible Common Carp spawning habitat.
	Round	●		○		○		Δ	Δ		Curly-leaf pondweed observation. Average Common Carp observed for similar class lakes.
	Clear	●		○		●		×	Δ		Average Common Carp observed for similar class lakes.
	Loon	●		○		●		×	Δ	Clear	Below average Common Carp observed for similar class lakes.

● Primary Source ○ Secondary Source Δ Potential Source (Unknown Level of Impact) × No data/information available

4 TMDL Development

4.1 General Description of a TMDL

A TMDL represents the total mass of a pollutant that can be assimilated by the receiving water without causing that receiving water to violate water quality standards. The TMDL is described as an equation with four different components, as described below:

$$\textbf{TMDL} = \textbf{LC} = \Sigma \textbf{WLA} + \Sigma\ \textbf{LA} + \textbf{MOS} + \textbf{RC}$$

Where:

LC = loading capacity; or the greatest pollutant load a waterbody can receive without violating water quality standards;

WLA = wasteload allocation; or the portion of the TMDL allocated to existing or future permitted point sources of the relevant pollutant;

LA = load allocation, or the portion of the TMDL allocated to existing or future nonpoint sources of the relevant pollutant;

MOS = margin of safety, or an accounting of uncertainty about the relationship between pollutant loads and receiving water quality. The MOS can be provided implicitly through analytical assumptions or explicitly by reserving a portion of loading capacity (EPA 1999).

RC = reserve capacity, an allocation of future growth. This is an MPCA-required element, if applicable (not applicable in this TMDL).

Per Code of Federal Regulations (40 CFR 130.2(1)), TMDLs can be expressed in terms of mass per time, toxicity or other appropriate measures. For this TMDL report, the TMDLs, allocations and margins of safety are expressed in mass/day. Each of the TMDL components is discussed in greater detail in the following sections.

4.1.1 Natural Background Consideration

Natural background was given consideration in the development of LA in this TMDL. Natural background is the landscape condition that occurs outside of human influence. Minn. R. 7050.0150, subp. 4, defines the term “Natural causes” as the multiplicity of factors that determine the physical, chemical, or biological conditions that would exist in a waterbody in the absence of measurable impacts from human activity or influence. Natural background conditions refer to inputs that would be expected under natural, undisturbed conditions. Natural background sources can include inputs from natural geologic processes, such as soil loss from upland erosion and stream development, atmospheric deposition, and loading from forested land, wildlife, etc. Natural background conditions were evaluated, where possible, within the modeling and source assessment. These source assessment exercises indicate natural background inputs are generally low compared to livestock, cropland, streambank, urban stormwater, WWTFs, failing SSTS and other anthropogenic sources.

Based on the MPCA’s waterbody assessment process and the TMDL source assessment exercises, there is no evidence at this time to suggest natural background sources are a major driver of any of the impairments addressed in this TMDL report and/or affect their ability to meet state water quality standards. For all impairments addressed in this TMDL report, natural background sources are implicitly included in the LA portion of the TMDL allocation tables, and TMDL reductions should focus on the major anthropogenic sources identified in the source assessment. Federal law instructs an agency to distinguish between natural and nonpoint source loads "[w]herever possible." 40 C.F.R. § 130.2(g). However, Minnesota law does not compel the MPCA to develop a separate LA for natural background sources, distinct from nonpoint sources (MPCA 2016b).

4.2 Modeling Approach

The HSPF model was used to develop many of the flow and water quality load estimates employed to develop the TMDLs presented in this TMDL. HSPF is a comprehensive watershed model of hydrology and water quality that includes modeling land surface and subsurface hydrologic and water-quality processes, which are linked and closely integrated with corresponding stream, wetland and reservoir processes. HSPF model applications can be used to determine critical environmental conditions (e.g., low/high flows or seasons) for the impaired segments by providing continuous flow and concentration predictions throughout the system.

HSPF models were developed in 2014 for the Lower Big Sioux River, Little Sioux River, and Rock River Watersheds. The HSPF models predict the range of flows that have historically occurred in the modeled area, the load contributions from a variety of point and nonpoint sources in a watershed, and the source contributions when paired flow and concentration data are limited. Multiple memos are available which discuss modeling methodologies, data used, and calibration results for the three major watershed HSPF models [RESPEC 2014a and 2014b; Appendix E].

4.3 Load Duration Curve Approach

Pollutant loading capacity for the impaired stream reaches were developed using LDCs. LDCs incorporate flow and water quality across the reach flow zones, and provide loading capacities and a means of estimating load reductions necessary to meet water quality standards. To develop the LDCs, HSPF simulated average daily flow values from 2000 through 2009 for each reach were multiplied by the appropriate water quality standard and converted to daily loads to create "continuous" LDCs. For the purposes of this TMDL, the baseline year for implementation will be 2005, which represents the mid-range year of the HSPF flow record used to construct the LDCs (See section 8.2). The LDCs presented throughout this TMDL were divided into five flow zones including very high, high, mid, low and very low flow zones. For simplicity, only the median (or midpoint) load of each flow zone is used to show the TMDL equation components in the TMDL tables. However, it should be understood that the entire curve represents the TMDL and is what is ultimately approved by the EPA.

4.4 TSS

4.4.1 Loading Capacity Methodology

LDCs were used to represent the loading capacity for each TSS impaired reach. The flow component of the loading capacity curve is based on the HSPF simulated daily average flows (2000 through 2009), and the concentration component is the TSS concentration criteria of 65 mg/L. TSS LDCs for each impaired reach are shown in Section 4.4.6. On these figures the red curve represents the allowable TSS loading capacity of the reach for each daily flow. The median (or midpoint) load of each flow zone is used to represent the total load capacity in the TMDL tables. Each reach's loading capacity can be compared to current conditions by plotting the measured load during each water quality sampling event (black circles in Figures 10 through 24). Each value that is above the curve represents an exceedance of the water quality standard, while those below the line are below the water quality standard. Also plotted is the 90th percentile monitored TSS load for each flow zone (solid green circles). The difference between the loading capacity line and the monitored 90th percentile load provides a general percent reduction in TSS that will be needed to remove each reach from the impaired waters list.

4.4.2 Wasteload Allocation Methodology

The WLAs for TSS were divided into three categories: NPDES permitted wastewater dischargers, NPDES MS4 stormwater, and NPDES permitted construction and industrial stormwater. The following sections describe how each WLA was assigned. The NPDES permitted livestock CAFOs are zero discharge facilities and are given a WLA of zero, and should not impact water quality in the basin as a point source. Therefore it is not necessary to put them in the TSS TMDL tables 20-34. Straight pipe septic systems are illegal and therefore receive a WLA of zero. Therefore it is not necessary to put them in the TSS TMDL Tables 20 through 34.

4.4.2.1 Permitted Wastewater Dischargers

There are 17 active regulated NPDES wastewater dischargers in the Lower Big Sioux River and Rock River TSS impaired reach watersheds that have been assigned TSS effluent limits. There are no active NPDES wastewater dischargers located in the Little Sioux River TSS impaired reach watersheds. It should also be noted that not all of the facilities presented in Figures 1 through 3 are included in the TMDLs presented in this TMDL since they discharge to impaired reaches covered by previous TMDL studies (see discussion in Section 1.1).

Facility maximum daily effluent TSS loads were established and provided by the MPCA and are a function of the facility design flows and permitted TSS concentration limits (Table 19). WLAs for each facility were calculated by multiplying the TSS effluent limit, permitted facility design flow, and a unit conversion factor. Continuously discharging municipal Wastewater Treatment Plant (WWTP) WLAs were calculated based on the average wet weather design flow, equivalent to the wettest 30-days of influent flow expected over the course of a year. Controlled municipal pond discharge WWTP WLAs were calculated based on the maximum daily volume that may be discharged in a 24-hour period.

Table 19. TSS allocations for permitted point source dischargers in the Lower Big Sioux River, Little Sioux River, and Rock River Watersheds.

Major Watershed	Impaired Reach	Facility Name	NPDES ID#	Facility Type	Effluent Design Flow (MGD)	Permitted TSS Concentration (mg/L)	Permitted Load (pounds/day)
Lower Big Sioux River	522	Beaver Creek WWTP	MNG58005	WWTP	0.37	45	137
	512	Pipestone WWTP	MN0054801	WWTP	6.12*	45	2,297*
	512	Lincoln Pipestone Rural Holland Well	MN0064351	Membrane Filter	0.14	30	30
	512	Lincoln Pipestone Rural Holland Well	MN0064351	Sand Filter	0.04	30	14
	512	Jasper WWTP	MNG58002	WWTP	0.98	45	367
Rock River	504, 506, 508	Woodstock WWTP	MNG580192	WWTP	0.18	45	68
	504, 506, 508	Holland WWTP	MN0021270	WWTP	0.10	45	24
	506, 508, 522	Edgerton WWTP	MNG580011	WWTP	0.73	45	275
	506, 508, 522	Chandler WWTP	MN0039748	WWTP	1.63	45	611
	508	Hardwick WWTP	MNG580194	WWTP	0.31	45	115
	506, 508	Leota Sanitary District WWTP	MNG580219	WWTP	0.33	45	112
	514, 517	Wilmont WWTP	MNG580200	WWTP	0.28	45	107
	517	Ellsworth WWTP	MNG580015	WWTP	0.91	45	342
	517	Adrian WWTP	MNG580001	WWTP	1.72	45	644
	517	Lismore WWTP	MNG580076	WWTP	0.26	45	98
	511, 513	Rushmore WWTP	MNG580201	WWTP	0.95	45	354

* Pipestone's TSS WLA is based on an effluent loading limit which was frozen at pre-expansion levels. The current effluent flow based on 62.37 acres of secondary cells is 10.162 mgd. The TSS limit (and WLA) is based on a 37.6 secondary cell acreage (6.129 mgd)

4.4.2.2 Permitted MS4 Stormwater

There are no MS4s in the Lower Big Sioux River, Rock River, or Little Sioux River TSS/turbidity impaired reach watersheds. Although the city of Worthington is a MS4, they do not discharge to a TSS/turbidity impaired reach.

4.4.2.3 Permitted Construction and Industrial Stormwater

Construction stormwater is regulated by NPDES Permits for any construction activity disturbing a) one acre or more of soil, b) less than one acre of soil if that activity is part of a "larger common plan of development or sale" that is greater than one acre, or c) less than one acre of soil, but the MPCA determines that the activity poses a risk to water resources. The WLA for stormwater discharges from sites where there are construction activities reflects the number of construction sites expected to be active in the impaired reach watershed at any one time. Industrial stormwater is regulated by NPDES Permits if the industrial activity has the potential for significant materials and activities to be exposed to stormwater discharges.

A categorical WLA was assigned to all construction activity in the watershed. Current acres under Construction and Industrial Stormwater Permit in each major watershed were available through the MPCA's Permit database. The amount of land under Construction and Industrial Stormwater Permit in the three major watersheds was divided by the total area of the watershed to determine the percent of permitted land. Results of this analysis show that approximately 0.2%, 0.3% and 0.5% of land in the Lower Big Sioux River, Little Sioux River, and Rock River Watersheds, respectively, are currently under construction and industrial stormwater permit. To determine the WLAs for these activities, total loading capacity in each flow zone was multiplied by the appropriate construction and industrial coverage percentage.

Loads from construction stormwater are considered to be a small percent of the total WLA and are difficult to quantify. The WLA for stormwater discharges from sites where there are construction activities reflects the number of construction sites with one or more acres 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 the State'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 Appendix A of the Construction General Permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. All local construction stormwater requirements must also be met.

The BMPs and other stormwater control measures that should be implemented at the industrial sites are defined in the State's NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) or facility specific Individual Wastewater Permit or NPDES/SDS General Permit for Construction Sand & Gravel, Rock Quarrying and Hot Mix Asphalt Production facilities (MNG490000). If an industrial facility owner/operator obtains stormwater coverage under the appropriate NPDES/SDS Permit and properly selects, installs and maintains all BMPs required under the permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. All local construction and industrial stormwater management requirements must also be met.

4.4.3 Load Allocation Methodology

As stated in the TMDL equation, the LA is comprised of the nonpoint source load that is allocated to an impaired Assessment Unit ID (AUID) after the WLAs (point sources, construction and industrial stormwater) and MOS were determined and subtracted from the total loading capacity for each reach and flow zone. This residual remaining loading capacity is meant to represent all non-regulated (nonpoint sources) of TSS upstream of the impaired reach (summarized in Section 3.5.1). The LA, also referred to as the watershed LA, includes nonpoint pollution sources that are not subject to NPDES Permit requirements such as wind-blown materials, soil erosion from stream channel and upland areas, and natural background. The LA also includes runoff from agricultural lands and non-NPDES stormwater runoff.

Split Rock Creek (10170203-512), within the Lower Big Sioux River Watershed, has watershed area in both states. See Section 1.2 and Figure 1 for description. For this reach, individual state watershed LAs were assigned by multiplying each state's percent watershed coverage (determined in GIS) by the total watershed LA.

Given the complexity of sediment dynamics and a lack of sufficient historical data in the Missouri River Basin, attempting to allocate a specific natural background load to any river or stream reach would result in a margin of error that in itself may be more than the estimated allocation. As such the LA includes natural background. Schottler et al (2010) and other resources included in Section 3.5.1 discuss this matter further.

4.4.4 Margin of Safety

The MOS is a portion of the TMDL that is set aside to account for the uncertainties associated with achieving water quality standards. The MOS can be either implicitly or explicitly defined as a set-aside amount. An explicit MOS was calculated as 10% of the loading capacity. 10% was considered an appropriate MOS since the LDC approach minimizes a great deal of uncertainty. The LDC calculations are based on TSS target concentrations and modeled flow data that has been calibrated to long-term monitored flow data. Most of the uncertainty with this calculation is therefore associated with the HSPF modeled flow output for each reach. The Missouri River Basin HSPF model was calibrated and validated using 15 years (1995 through 2009) of flow data from gaging stations: 6482610, 6605000, 6605850, 6483290, 6483500, H82042001, H82035001, H82015001, H83027001, H83016001. Calibration results indicate that the HSPF model is a valid representation of hydrological and chemical conditions in the watershed. See Appendix E of this TMDL report for the HSPF model calibration and validation results. The TSS stream LDCs were developed using HSPF modeled daily flow data from April through September. The TSS TMDLs applied a MOS to each flow zone along the duration curves by subtracting 10% of the flow zones loading capacity.

4.4.5 Seasonal Variation

Both seasonal variation and critical conditions are accounted for in this TMDL through the application of LDCs. LDCs evaluate water quality conditions across all flow zones including high flow, runoff conditions where sediment transport tends to be greatest. Seasonality is accounted for by addressing all flow conditions in a given reach.

4.4.6 TSS TMDL Summary

The TMDL allocation tables (Tables 20 through 34) present the total loading capacity (Total Load (TMDL) in tables), the MOS, the WLAs (Wasteload in tables) and the remaining watershed LAs (Load in tables) for the TSS impaired reaches. Allocations for this TMDL were established using the 65 mg/L TSS standard. All load capacities were rounded to the nearest pound. The bottom line of the table shows the estimated load reduction for each flow zone and is calculated based on the difference between the 90th percentile monitored TSS concentration of each flow zone and the 65 mg/L proposed standard. At this time, there is not enough information or data available to estimate or calculate the existing (current conditions) load contribution from each of the WLA and LA sources presented in each table. Thus, the estimated load reduction for each flow zone applies to all sources. The WRAPS report will further investigate which sources and geographical locations within the impaired reach watersheds should be targeted for turbidity/TSS BMPs and restoration activities.

4.4.6.1 Lower Big Sioux River Watershed TSS TMDLs

Split Rock Creek Reach 512 and Beaver Creek Reach 522 are the only TSS impaired reaches in the Lower Big Sioux River Watershed covered in this TMDL. There are three other turbidity impaired reaches in the Lower Big Sioux River Watershed (Reaches 527, 514 and 501) that were covered under the Pipestone Creek Fecal Coliform Bacteria and Turbidity TMDL (MPCA 2008). Split Rock Creek Reach 512 begins at the confluence of Pipestone Creek and Split Rock Creek and therefore encompasses both major subwatersheds. TMDL allocations for both reaches include the entire watershed draining to each impaired reach. For example, allocations for Split Rock Creek Reach 512 includes the watershed draining to Pipestone Creek Reach 505, as well as the watershed draining to non-impaired Reach 507 (Split Rock Creek). Tables 20 and 21 present the TMDL allocations for each reach.

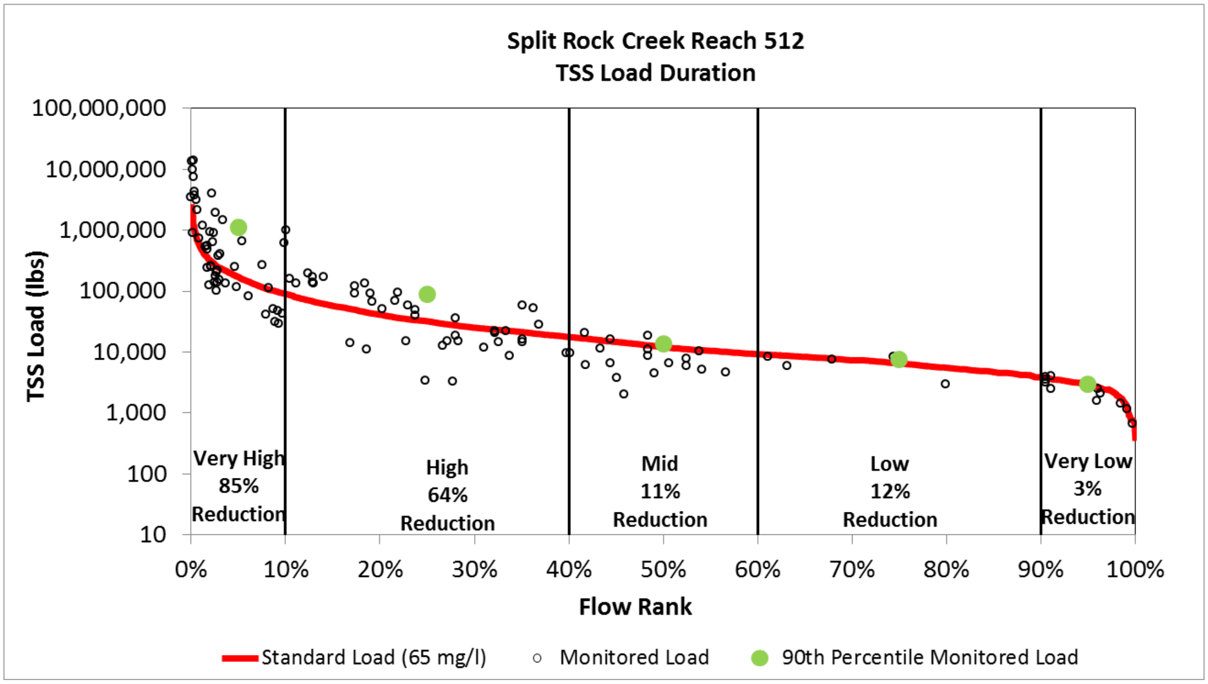

Figure 10. Split Rock Creek Reach 512 TSS load duration and TMDL reductions.

Table 20. Split Rock Creek Reach 512 TSS TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		TSS Load (pounds/day)				
Wasteload	**Total WLA**	**3,080**	**2,778**	**2,734**	**2,722**	**
	Pipestone WWTP	2,297	2,297	2,297	2,297	**
	Lincoln Pipestone Rural Holland Well (Membrane Filter)	30	30	30	30	**
	Lincoln Pipestone Rural Holland Well (Sand Filter)	14	14	14	14	**
	Jasper WWTP	367	367	367	367	**
	Industrial and Construction Stormwater	372	70	26	14	**
Load	**Total LA**	**151,222.3**	**26,346.9**	**8,263.1**	**3,203.6**	**
	MN Watershed Nonpoint Source	119238.78	20774.53	6515.45	2526.03	**
	SD Watershed Nonpoint Source	31983.51	5572.369	1747.645	677.56	**
MOS		**17,144.7**	**3,236.1**	**1,221.9**	**658.4**	**293.5**
TOTAL LOAD (TMDL)		**171,447**	**32,361**	**12,219**	**6,584**	**2,935**
Existing Load (90th percentile of observed data)		1,123,636	89,617	13,724	7,495	3,025
Estimated Reduction (%)		85%	64%	11%	12%	3%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.
** The WLA for the permitted wastewater dischargers (Table 17) are based on facility design flow. The WLA exceeded the very low flow zones total daily loading capacity (minus margin of safety) and is denoted in the table by "**". For this flow zone, the WLA and LAs are determined by the following formula: Allocation = (flow contribution from a given source) X (TSS concentration limit or standard.

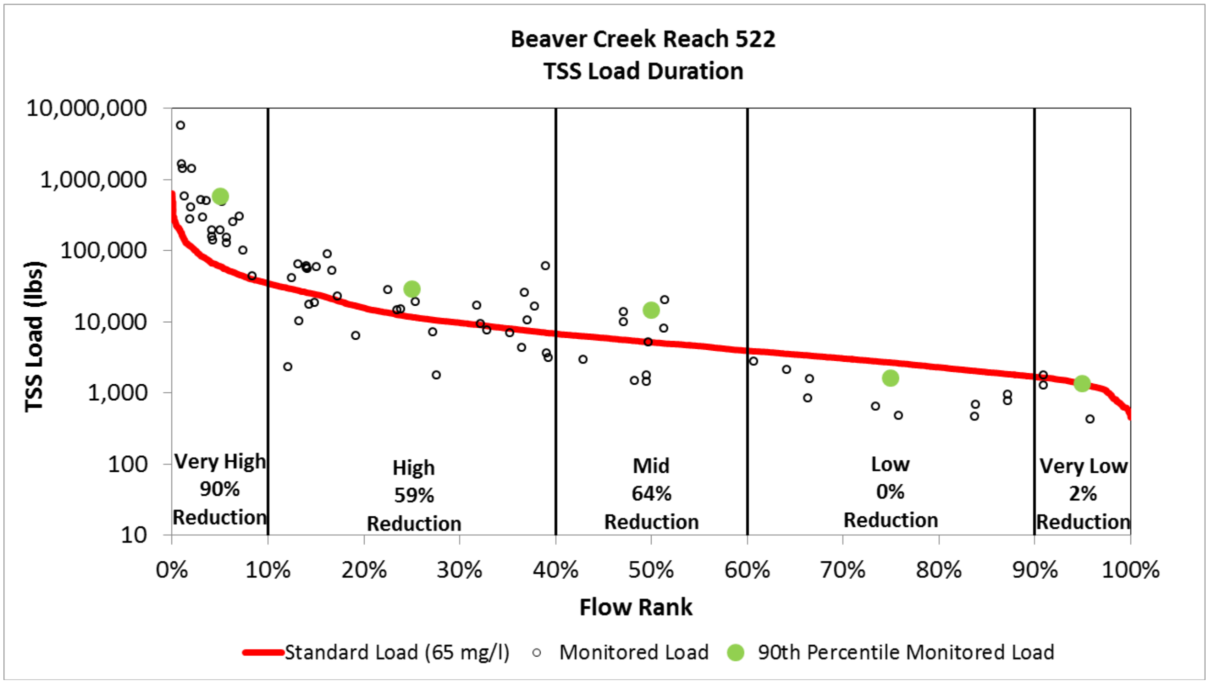

Figure 11. Beaver Creek Reach 522 TSS load duration and TMDL reductions.

Table 21. Beaver Creek Reach 522 TSS TMDL.

		Flow Zone*				
		Very High	High	Mid	Low	Very Low
		TSS Load (pounds/day)				
Wasteload	Total WLA	268	162	148	143	140
	Beaver Creek WWTP	137	137	137	137	137
	Industrial and Construction Stormwater	131	25	11	6	3
Load	Total LA	54,005.6	10,392.3	4,492.4	2,267.2	1,058.8
	MN Watershed Nonpoint Sources	54,005.6	10,392.3	4,492.4	2,267.2	1,058.8
MOS		6,030.4	1,172.7	515.6	267.8	133.2
TOTAL LOAD (TMDL)		60,304	11,727	5,156	2,678	1,332
Existing Load (90th percentile of observed data)		588,200	28,602	14,438	1,647	1,365
Estimated Reduction (%)		90%	59%	64%	0%	2%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

4.4.6.2 Little Sioux River Watershed TSS TMDLs

Little Sioux River Watershed TSS TMDLs for Judicial Ditch 13 (Skunk Creek) Reach 511 and Little Sioux River Reach 515 are the only TSS impaired reaches in the Little Sioux River Watershed. Judicial Ditch 13 Reach 511 is located in the West Fork Little Sioux River major subwatershed while Little Sioux River Reach 515 is located in Headwaters – Little Sioux River major subwatershed. Both reaches are headwater reaches and therefore do not receive flow from any major upstream reaches. Tables 22 and 23 present the TMDL allocations for each reach.

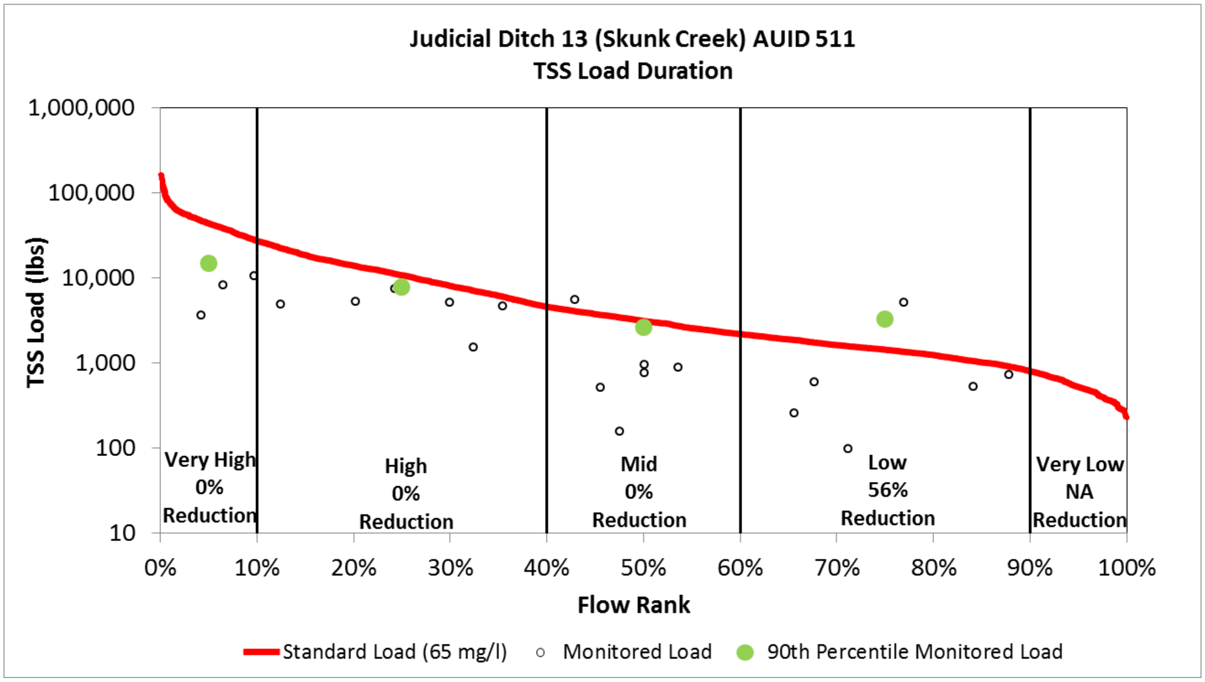

Figure 12. Judicial Ditch 13 (Skunk Creek) Reach 511 TSS load duration and TMDL reductions.

Table 22. Judicial Ditch 13 (Skunk Creek) Reach 511 TSS TMDL.

		Flow Zone*				
		Very High	High	Mid	Low	Very Low
		TSS Load (pounds/day)				
Wasteload	**Total WLA**	**138**	**34**	**10**	**4**	**2**
	Industrial and Construction Stormwater	138	34	10	4	2
Load	**Total LA**	**39,570**	**9,730**	**2,820**	**1,205**	**460**
	MN Watershed Nonpoint Sources	**39,570**	**9,730**	**2,820**	**1,205**	**460**
MOS		**4,412.0**	**1,084.9**	**314.4**	**134.3**	**51.3**
TOTAL LOAD (TMDL)		**44,120**	**10,849**	**3,144**	**1,343**	**513**
Existing Load (90th percentile of observed data)		14,953	7,783	2,671	3,052	NA**
Estimated Reduction (%)		0%	0%	0%	56%	NA**

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

** Not enough data at this time to estimate a reduction.

Figure 13. Little Sioux River Reach 515 TSS load duration and TMDL reductions.

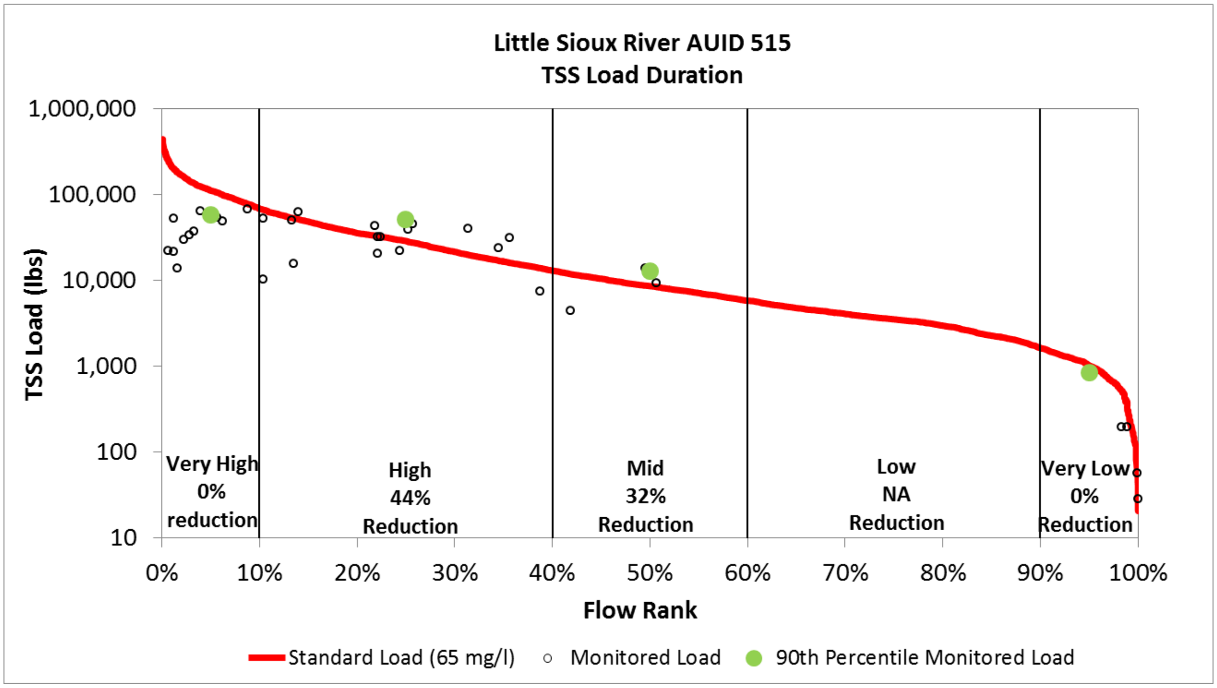

Table 23. Little Sioux River Reach 515 TSS TMDL.

		Flow Zone*				
		Very High	High	Mid	Low	Very Low
		TSS Load (pounds/day)				
Wasteload	**Total WLA**	**351**	**91**	**27**	**11**	**3**
	Industrial and Construction Stormwater	351	91	27	11	3
Load	**Total LA**	**100,622.7**	**25,941.5**	**7,760.7**	**3,175.9**	**915.0**
	MN Watershed Nonpoint Sources	100,622.7	25,941.5	7,760.7	3,175.9	915.0
MOS		**11,219.3**	**2,892.5**	**865.3**	**354.1**	**102**
TOTAL LOAD (TMDL)		**112,193**	**28,925**	**8,653**	**3,541**	**1,020**
Existing Load (90th percentile of observed data)		58,922	51,726	12,791	NA**	844
Estimated Reduction (%)		0%	44%	32%	NA**	0%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.
** Not enough data at this time to estimate a reduction.

4.4.6.3 Rock River Watershed TSS TMDLs

This TMDL covers 11 TSS impaired reaches in the Rock River Watershed located in the following major subwatersheds: Mud Creek (Reach 525), Headwaters – Rock River (Reaches 504, 522, 523, 506, 508), Kanaranzi Creek (Reach 514,517), and Little Rock River (Reaches 511, 512, and 513). There are also three other turbidity impaired reaches in the Rock River Watershed (Reaches 501, 509 and 519) that were covered under the Rock River Fecal Coliform and Turbidity TMDL (Minnesota State University 2008).

TMDL allocations for all impaired reaches include the entire watershed draining to each impaired reach. For example, allocations for Rock River Reach 508 includes the watershed draining directly to the reach, as well as the watersheds draining to Reaches 521, 506, 522, and 504. Tables 24 through 34 contain the TMDL allocations for each impaired reach in the Rock River Watershed, organized upstream to downstream and from east to west throughout the watershed.

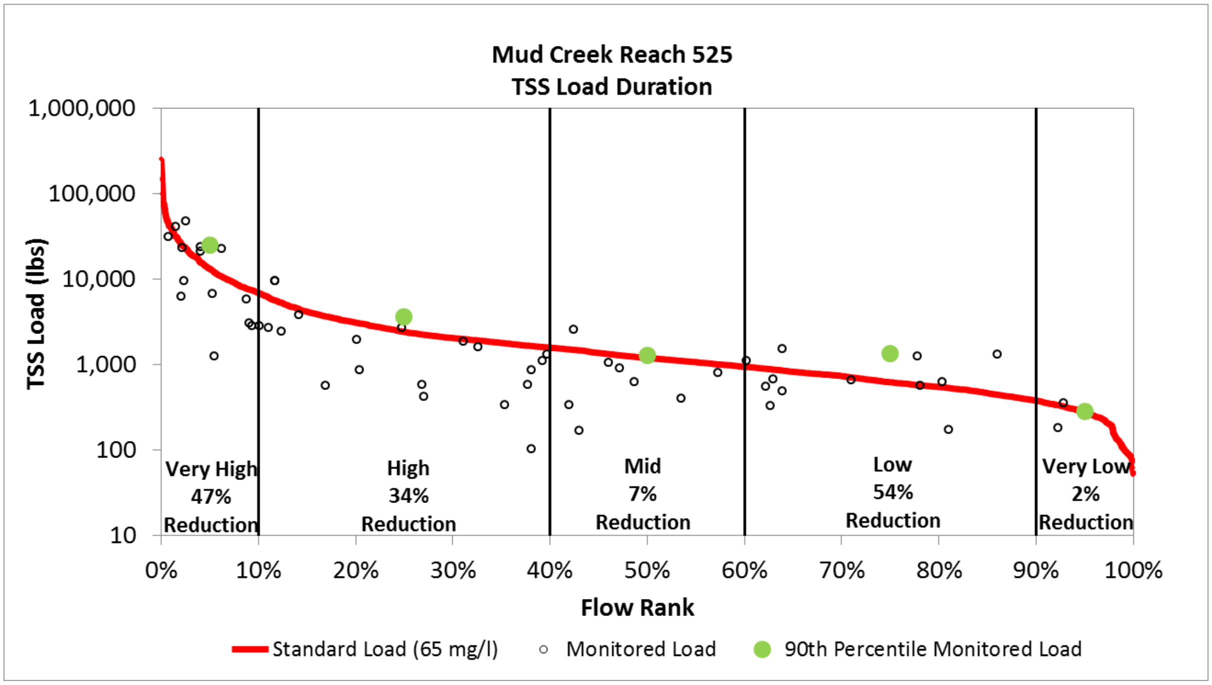

Figure 14. Mud Creek Reach 525 load duration and TMDL reductions.

Table 24. Mud Creek Reach 525 TSS TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		TSS Load (pounds/day)				
Wasteload	**Total WLA**	**72**	**13**	**7**	**3**	**2**
	Construction & Industrial Stormwater	72	13	7	3	2
Load	**Total LA**	**11,827**	**2,174**	**1,078**	**560**	**250**
	MN Watershed Nonpoint Sources	11,827	2,174	1,078	560	250
MOS		**1,322.1**	**243**	**120.6**	**62.5**	**28**
TOTAL LOAD (TMDL)		**13,221**	**2,430**	**1,206**	**625**	**280**
Existing Load (90th percentile of observed data)		25,221	3,665	1,295	1,351	286
Estimated Reduction (%)		47%	34%	7%	54%	2%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

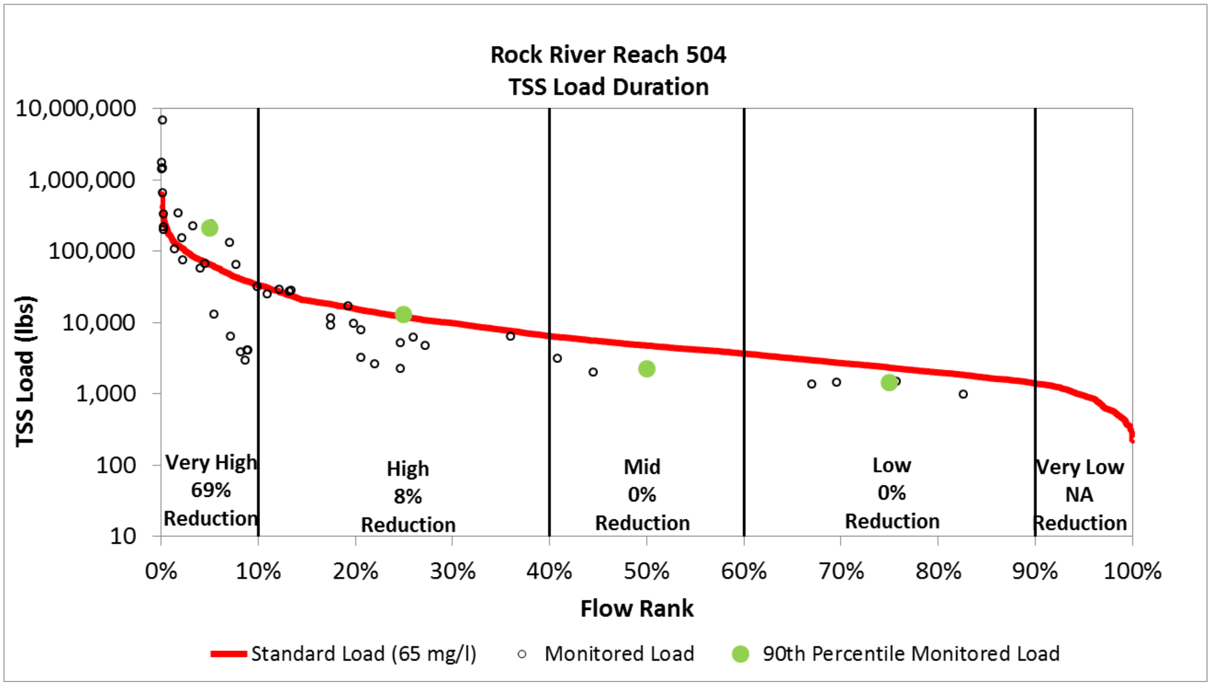

Figure 15. Rock River Reach 504 TSS load duration and TMDL reductions.

Table 25. Rock River Reach 504 TSS TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		TSS Load (pounds/day)				
Wasteload	**Total WLA**	**448**	**157**	**118**	**105**	**97**
	Woodstock WWTP	68	68	68	68	68
	Holland WWTP	24	24	24	24	24
	Construction & Industrial Stormwater	356	65	26	13	5
Load	**Total LA**	**58,632.5**	**10,630.4**	**4,167.8**	**1,991.1**	**752.6**
	MN Watershed Nonpoint Sources	58,632.5	10,630.4	4,167.8	1,991.1	752.6
MOS		**6,564.5**	**1,198.6**	**476.2**	**232.9**	**94.4**
TOTAL LOAD (TMDL)		**65,645**	**11,986**	**4,762**	**2,329**	**944**
Existing Load (90th percentile of observed data)		210,197	13,028	2,284	1,424	NA**
Estimated Reduction (%)		69%	8%	0%	0%	NA**

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.
** Not enough data at this time to estimate a reduction.

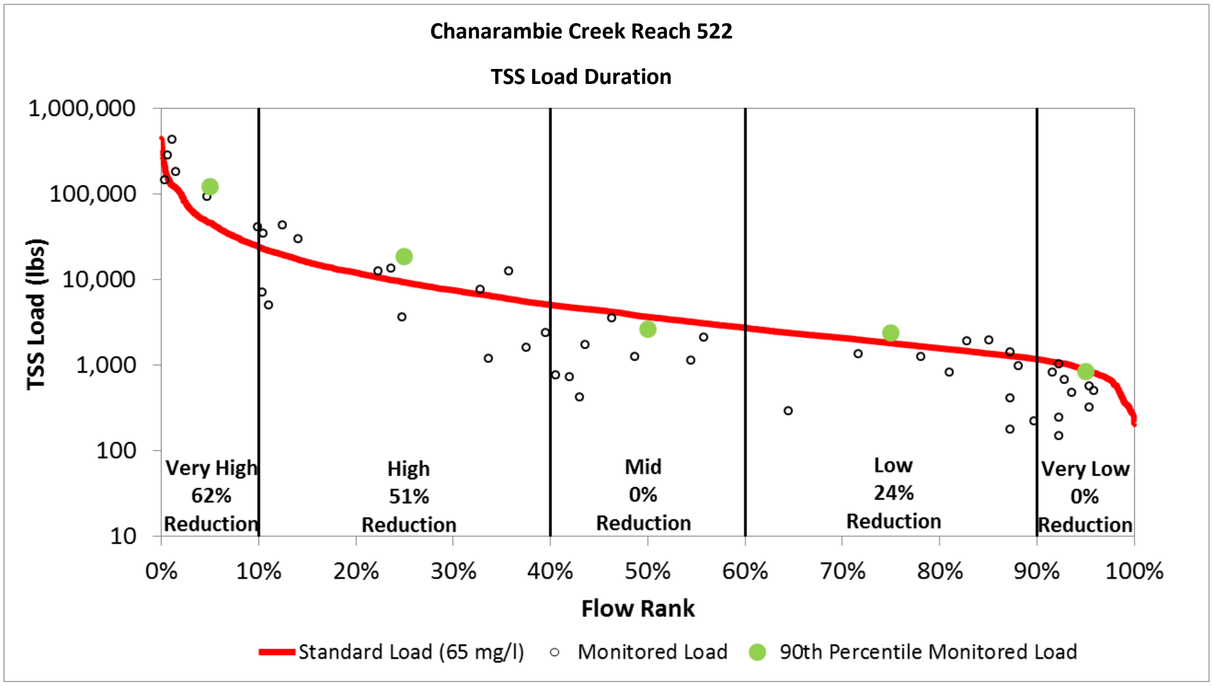

Figure 16. Chanarambie Creek Reach 522 TSS load duration and TMDL reductions.

Table 26. Chanarambie Creek Reach 522 TSS TMDL.

		Flow Zone*				
		Very High	High	Mid	Low	Very Low
		TSS Load (pounds/day)				
Wasteload	**Total WLA**	**1,138**	**937**	**906**	**896**	**
	Edgerton WWTP	275	275	275	275	**
	Chandler WWTP	611	611	611	611	**
	Construction & Industrial Stormwater	252	51	20	10	**
Load	**Total LA**	**40,566.2**	**7,466.3**	**2,406.9**	**742.0**	**
	MN Watershed Nonpoint Sources	40,566.2	7,466.3	2,406.9	742.0	**
MOS		**4,633.8**	**933.7**	**368.1**	**182**	**86.9**
TOTAL LOAD (TMDL)		**46,338**	**9,337**	**3,681**	**1,820**	**869**
Existing Load (90th percentile of observed data)		122,259	18,902	2,678	2,380	845
Estimated Reduction (%)		62%	51%	0%	24%	0%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.
** The WLA for the permitted wastewater dischargers (Table 17) are based on facility design flow. The WLA exceeded the very low flow zones total daily loading capacity (minus margin of safety) and is denoted in the table by “**”. For this flow zone, the WLA and LAs are determined by the following formula: Allocation = (flow contribution from a given source) X (TSS concentration limit or standard.

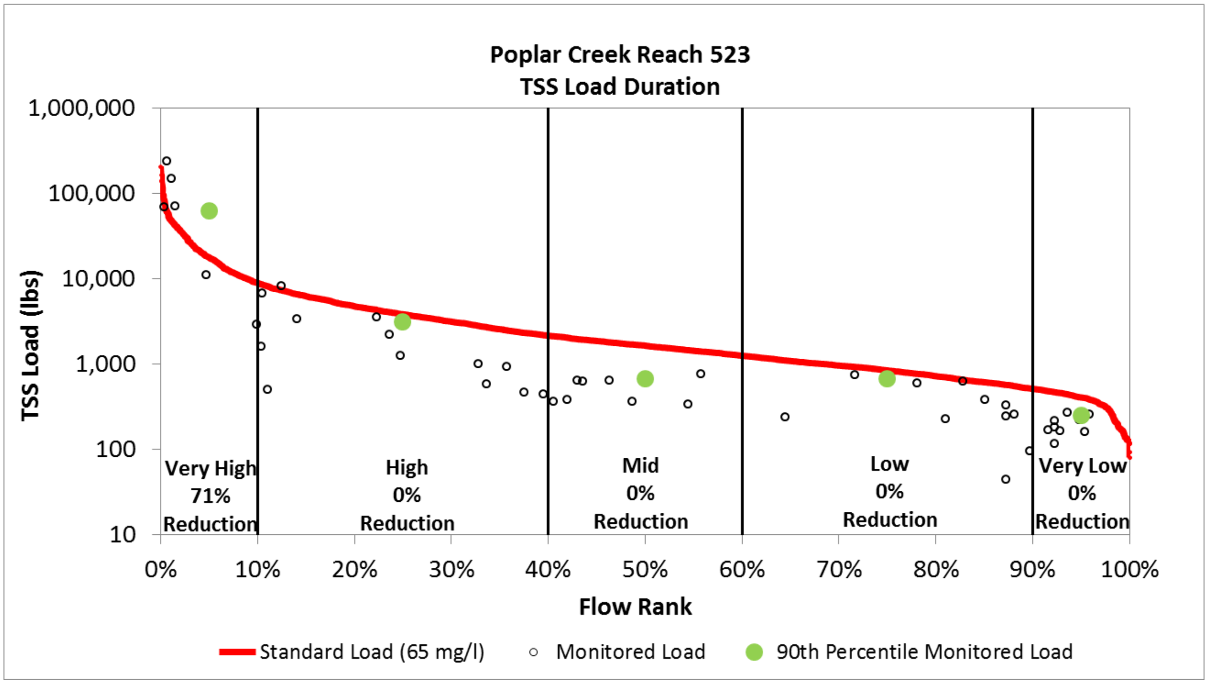

Figure 17. Poplar Creek Reach 523 TSS load duration and TMDL reductions.

Table 27. Poplar Creek Reach 523 TSS TMDL.

		Flow Zone*				
		Very High	High	Mid	Low	Very Low
		TSS Load (pounds/day)				
Wasteload	**Total WLA**	**97**	**21**	**9**	**5**	**2**
	Construction & Industrial Stormwater	97	21	9	5	2
Load	**Total LA**	**15,921.2**	**3,453.9**	**1,483.2**	**759.1**	**365.2**
	MN Watershed Nonpoint Sources	15,921.2	3,453.9	1,483.2	759.1	365.2
MOS		**1,779.8**	**386.1**	**165.8**	**84.9**	**40.8**
TOTAL LOAD (TMDL)		**17,798**	**3,861**	**1,658**	**849**	**408**
Existing Load (90th percentile of observed data)		62,658	3,178	680	680	253
Estimated Reduction (%)		71%	0%	0%	0%	0%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

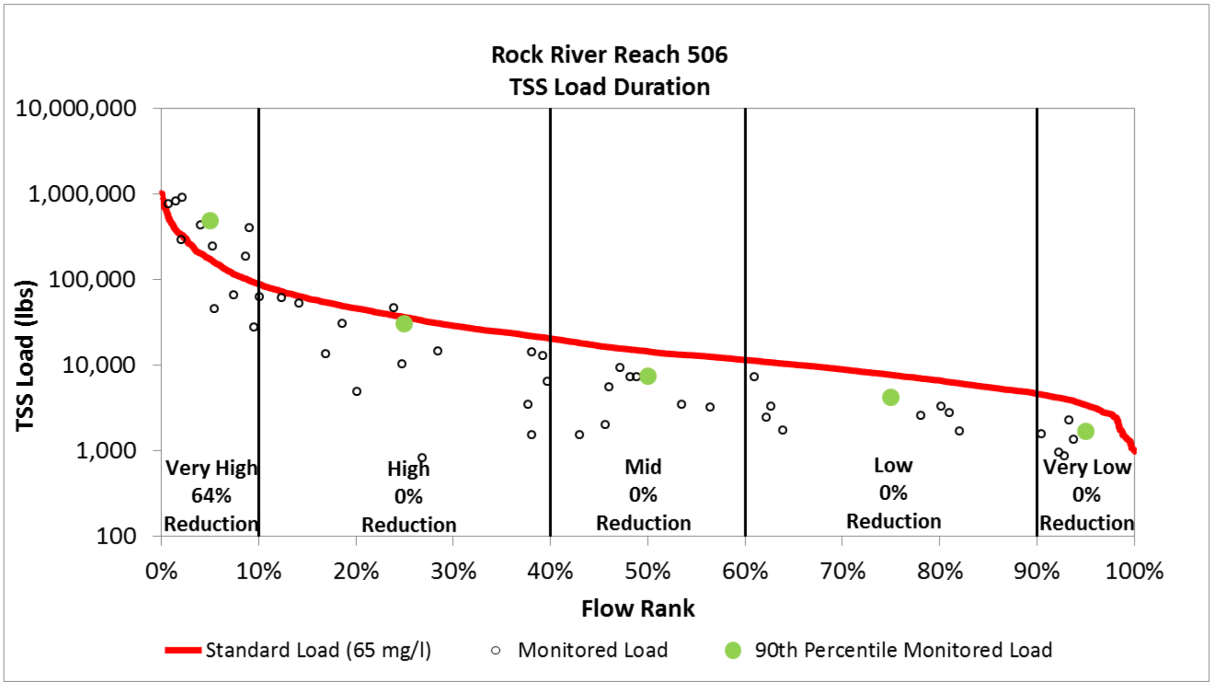

Figure 18. Rock River Reach 506 TSS load duration and TMDL reductions.

Table 28. Rock River Reach 506 TSS TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		TSS Load (pounds/day)				
Wasteload	**Total WLA**	**2,032**	**1,289**	**1,169**	**1,132**	**1,109**
	Construction & Industrial Stormwater	942	199	79	42	19
	Leota Sanitary District WWTP	112	112	112	112	112
	Holland WWTP	24	24	24	24	24
	Edgerton WWTP	275	275	275	275	275
	Chandler WWTP	611	611	611	611	611
	Woodstock WWTP	68	68	68	68	68
Load	**Total LA**	**154,173.8**	**31,686.1**	**11,950.3**	**5,830.4**	**1,985.2**
	MN Watershed Nonpoint Sources	154,173.8	31,686.1	11,950.3	5,830.4	1,985.2
MOS		**17,356.2**	**3,663.9**	**1,457.7**	**773.6**	**343.8**
TOTAL LOAD (TMDL)		**173,562**	**36,639**	**14,577**	**7,736**	**3,438**
Existing Load (90th percentile of observed data)		487,801	30,418	7,575	4,241	1,686
Estimated Reduction (%)		64%	0%	0%	0%	0%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

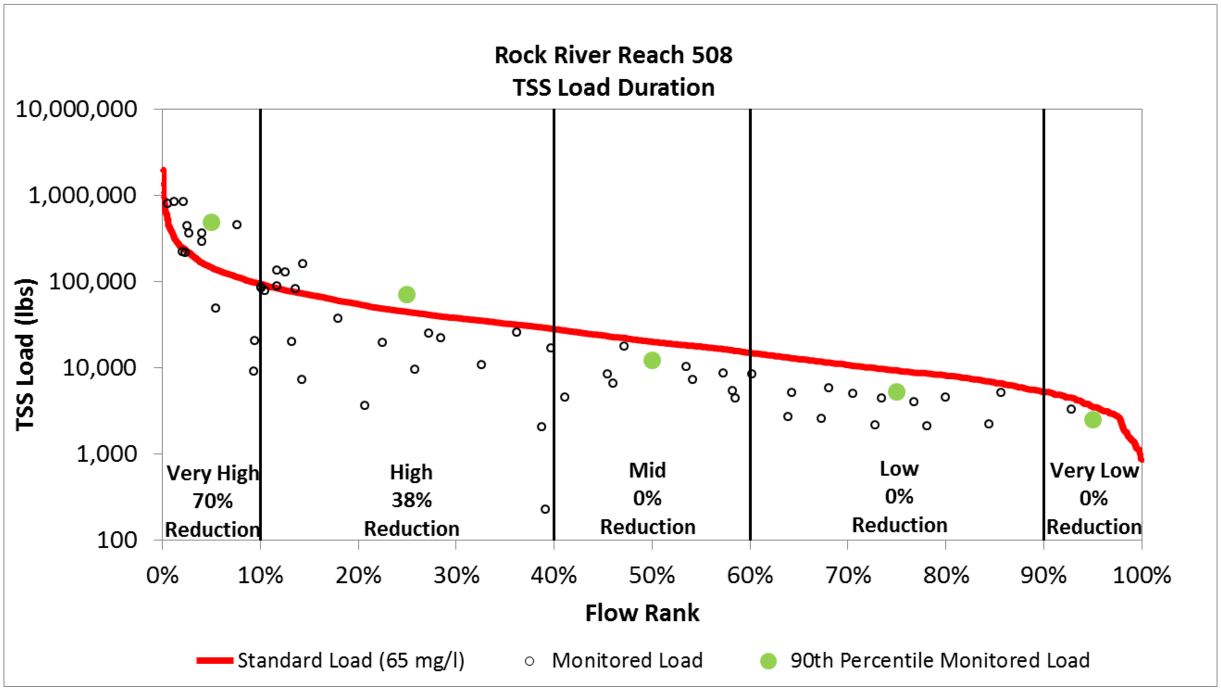

Figure 19. Rock River Reach 508 TSS load duration and TMDL reductions.

Table 29. Rock River Reach 508 TSS TMDL.

		Flow Zone*				
		Very High	High	Mid	Low	Very Low
		TSS Load (pounds/day)				
Wasteload	Total WLA	1,925	1,449	1,314	1,256	1,224
	Construction & Industrial Stormwater	720	244	109	51	19
	Edgerton WWTP	275	275	275	275	275
	Chandler WWTP	611	611	611	611	611
	Hardwick WWTP	115	115	115	115	115
	Woodstock WWTP	68	68	68	68	68
	Holland WWTP	24	24	24	24	24
	Leota Sanitary District WWTP	112	112	112	112	112
Load	Total LA	117,382.6	38,941.2	16,815.6	7,206.7	1,939.5
	MN Watershed Nonpoint Sources	117,382.6	38,941.2	16,815.6	7,206.7	1,939.5
MOS		13,256.4	4,487.8	2,014.4	940.3	351.5
TOTAL LOAD (TMDL)		132,564	44,878	20,144	9,403	3,515
Existing Load (90th percentile of observed data)		441,880	71,804	12,389	5,354	2,542
Estimated Reduction (%)		70%	38%	0%	0%	0%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

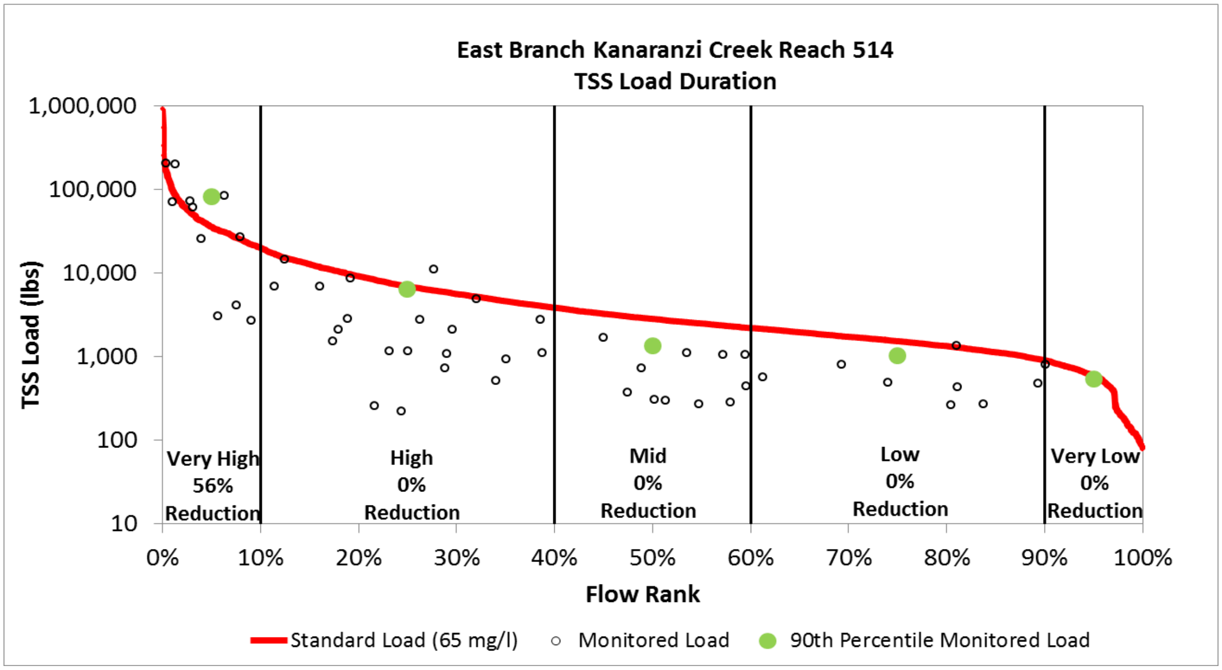

Figure 20. East Branch Kanaranzi Creek Reach 514 TSS load duration and TMDL reductions.

Table 30. East Branch Kanaranzi Creek Reach 514 TSS TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		TSS Load (pounds/day)				
Wasteload	**Total WLA**	**301**	**144**	**121**	**114**	**109**
	Construction & Industrial Stormwater	195	38	15	8	3
	Wilmont WWTP	106	106	106	106	106
Load	**Total LA**	**32,034.2**	**6,098.4**	**2,437.7**	**1,272.0**	**432.8**
	MN Watershed Nonpoint Sources	32,034.2	6,098.4	2,437.7	1,272.0	432.8
MOS		**3,592.8**	**693.6**	**284.3**	**154**	**60.2**
TOTAL LOAD (TMDL)		**35,928**	**6,936**	**2,843**	**1,540**	**602**
Existing Load (90th percentile of observed data)		82,689	6,513	1,357	1,031	537
Estimated Reduction (%)		56%	0%	0%	0%	0%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

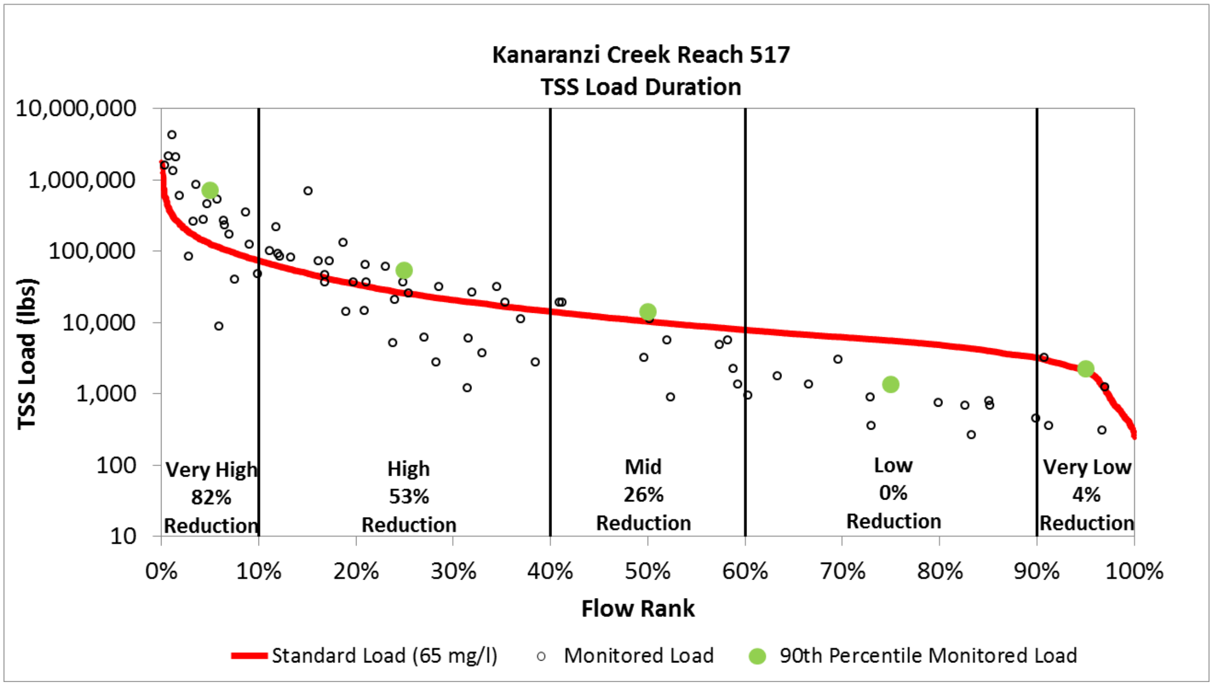

Figure 21. Kanaranzi Creek Reach 517 TSS load duration and TMDL reductions.

Table 31. Kanaranzi Creek Reach 517 TSS TMDL.

		Flow Zone*				
		Very High	High	Mid	Low	Very Low
		TSS Load (pounds/day)				
Wasteload	**Total WLA**	**1,874**	**1,330**	**1,246**	**1,220**	**1,202**
	Construction & Industrial Stormwater	684	140	56	30	12
	Ellsworth WWTP	342	342	342	342	342
	Adrian WWTP	644	644	644	644	644
	Wilmont WWTP	106	106	106	106	106
	Lismore WWTP	98	98	98	98	98
Load	**Total LA**	**111,512.5**	**21,883.7**	**8,093.3**	**3,804.7**	**719.5**
	MN Watershed Nonpoint Sources	111,512.5	21,883.7	8,093.3	3,804.7	719.5
MOS		**12,598.5**	**2,579.3**	**1,037.7**	**558.3**	**213.5**
TOTAL LOAD (TMDL)		**125,985**	**25,793**	**10,377**	**5,583**	**2,135**
Existing Load (90th percentile of observed data)		714,959	54,781	14,122	1,349	2,225
Estimated Reduction (%)		82%	53%	26%	0%	4%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

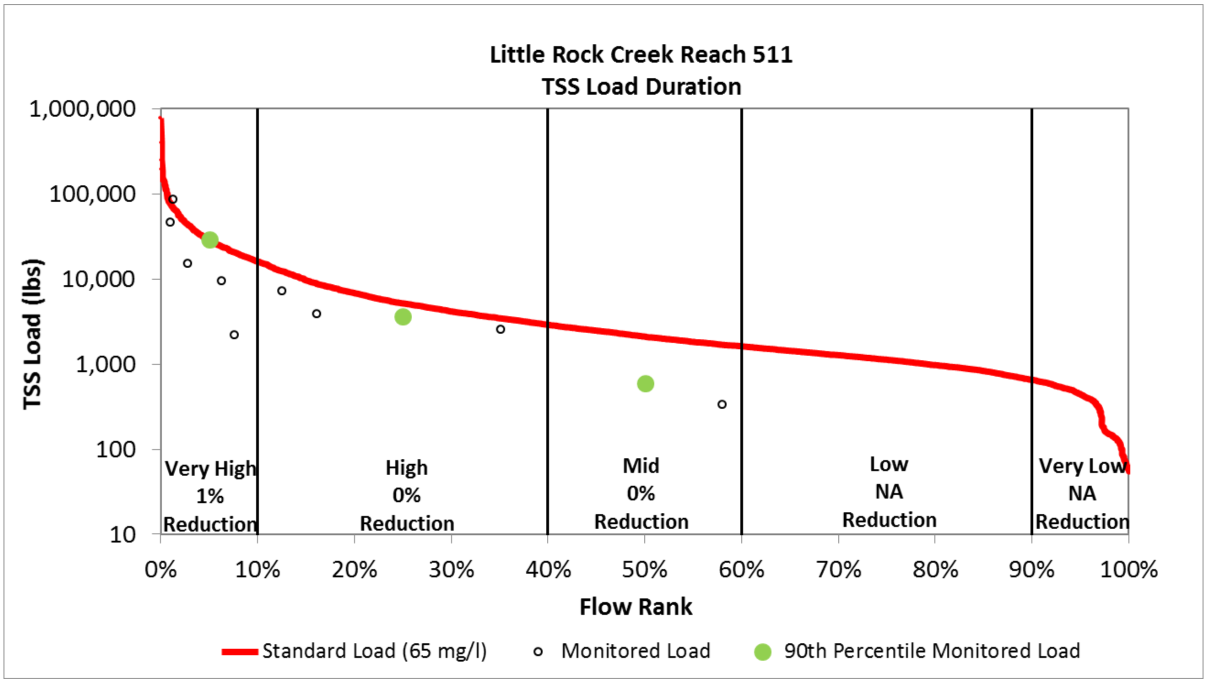

Figure 22. Little Rock Creek Reach 511 TSS load duration and TMDL reductions.

Table 32. Little Rock Creek Reach 511 TSS TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		TSS Load (pounds/day)				
Wasteload	**Total WLA**	**510**	**382**	**365**	**360**	**356**
	Construction & Industrial Stormwater	156	28	11	6	2
	Rushmore WWTP	354	354	354	354	354
Load	**Total LA**	**25,351.5**	**4,259.3**	**1,526.8**	**652.5**	**37.3**
	MN Watershed Nonpoint Sources	25,351.5	4,259.3	1,526.8	652.5	37.3
MOS		**2,873.5**	**515.7**	**210.2**	**112.5**	**43.7**
TOTAL LOAD (TMDL)		**28,735**	**5,157**	**2,102**	**1,125**	**437**
Existing Load (90th percentile of observed data)		29,049	3,660	596	NA **	NA **
Estimated Reduction (%)		1%	0%	0%	NA **	NA **

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

** Not enough data at this time to estimate a reduction.

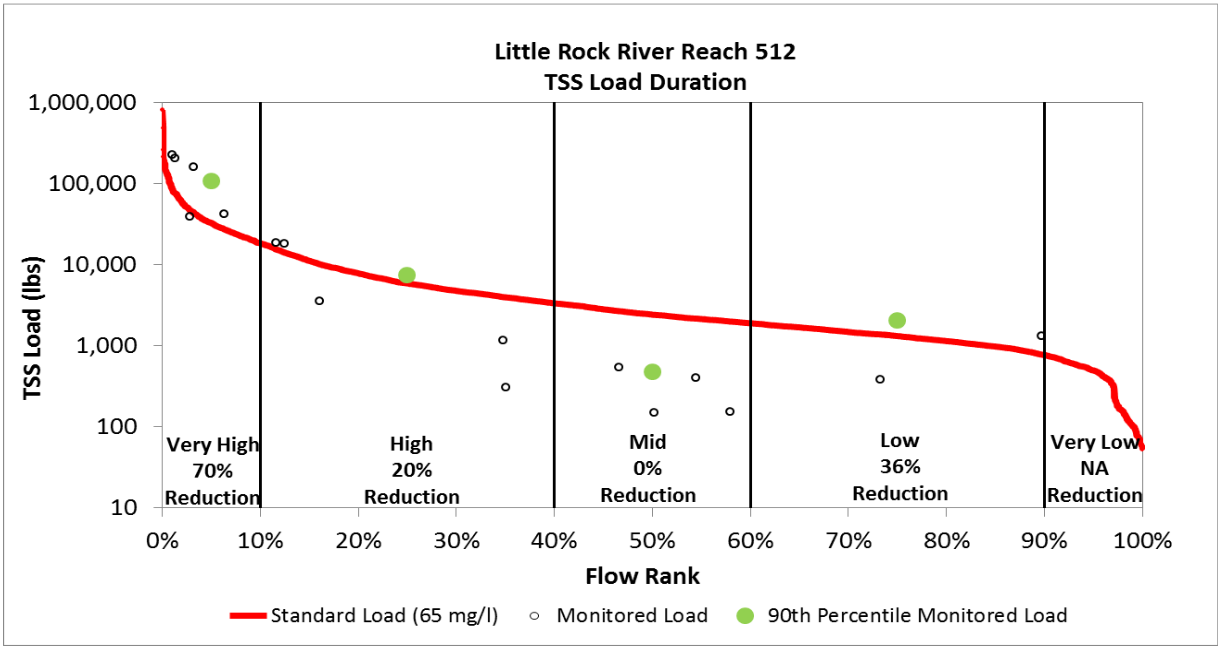

Figure 23. Little Rock River Reach 512 TSS load duration and TMDL reductions.

Table 33. Little Rock River Reach 512 TSS TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		TSS Load (pounds/day)				
Wasteload	**Total WLA**	**178**	**32**	**13**	**7**	**3**
	Construction & Industrial Stormwater	178	32	13	7	3
Load	**Total LA**	**29,409**	**5,295**	**2,174**	**1,183**	**444**
	MN Watershed Nonpoint Sources	29,409	5,295	2,174	1,183	444
MOS		**3,287.4**	**591.9**	**243**	**132.2**	**49.7**
TOTAL LOAD (TMDL)		**32,874**	**5,919**	**2,430**	**1,322**	**497**
Existing Load (90th percentile of observed data)		109,112	7,437	476	2,055	NA **
Estimated Reduction (%)		70%	20%	0%	36%	NA **

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.
** Not enough data at this time to estimate a reduction.

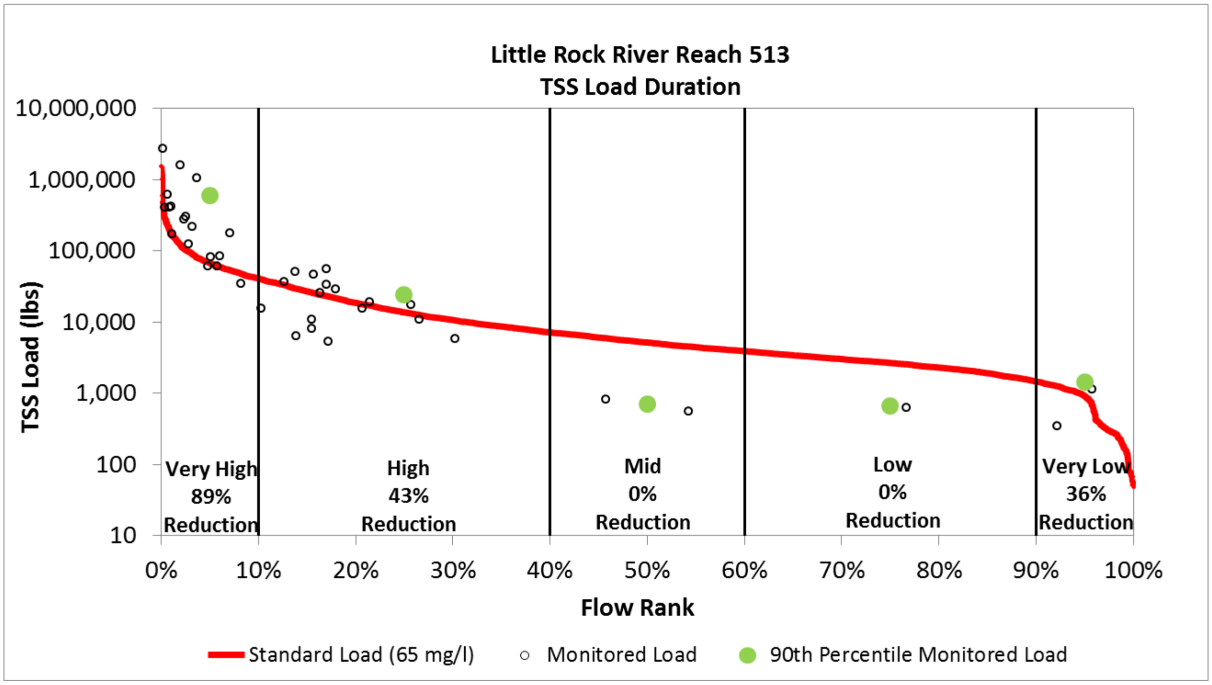

Figure 24. Little Rock River Reach 513 TSS load duration and TMDL reductions.

Table 34. Little Rock River Reach 513 TSS TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		TSS Load (pounds/day)				
Wasteload	**Total WLA**	**722**	**428**	**382**	**368**	**359**
	Construction & Industrial Stormwater	368	74	28	14	5
	Rushmore WWTP	354	354	354	354	354
Load	**Total LA**	**60,267**	**11,924**	**4,278**	**2,032**	**458**
	MN Watershed Nonpoint Sources	60,267	11,924	4,278	2,032	458
MOS		**6,776.6**	**1,372.4**	**517.8**	**266.7**	**90.8**
TOTAL LOAD (TMDL)		**67,766**	**13,724**	**5,178**	**2,667**	**908**
Existing Load (90th percentile of observed data)		593,902	24,030	710	658	1,421
Estimated Reduction (%)		89%	43%	0%	0%	36%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

4.5 E. coli

4.5.1 Loading Capacity Methodology

LDCs were used to represent the loading capacity for each *E. coli* impaired reach. The flow component of the loading capacity curve is based on the HSPF simulated daily average flows (2000 through 2009), and the concentration component is the *E. coli* concentration standard of 126 cfu/100 mL. *E. coli* LDCs for each impaired reach are shown in Section 4.5.6. On these figures the red curve represents the allowable *E. coli* loading capacity of the reach for each daily flow. The median (or midpoint) load of each flow zone were used to represent the total load capacity in the TMDL tables. Each reach's loading capacity can be compared to current conditions by plotting the measured load during each water quality sampling event (black circles in Figures 25 through 52). Each value that is above the curve represents an exceedance of the water quality standard while those below the line are below the water quality standard. Also plotted are the monitored *E. coli* geometric mean concentrations for each flow zone (solid green circles). The difference between the loading capacity line and monitored geometric means provide a general percent reduction in *E. coli* that will be needed to remove each reach from the impaired waters list.

4.5.2 Wasteload Allocation Methodology

The WLAs for *E. coli* TMDLs were divided into three categories: NPDES permitted wastewater dischargers, NPDES permitted MS4 stormwater, and NPDES permitted construction and industrial stormwater. The following sections describe how each of these WLAs was assigned. The NPDES permitted livestock CAFOs are zero discharge facilities and are given a WLA of zero and should not impact water quality in the basin as a point source. Therefore it is not necessary to put them in the *E.coli* TMDL Tables 36 through 63. Straight pipe septic systems are illegal and receive a WLA of zero. Therefore it is not necessary to put them in the *E.coli* TMDL Tables 36 through 63.

4.5.2.1 Permitted Wastewater Dischargers

In this TMDL there are 21 active NPDES permitted surface wastewater dischargers in the Lower Big Sioux River, Little Sioux River, and Rock River impaired reach watersheds (Table 35, Figures 1 through 3). WLAs for each facility were calculated by multiplying the facility's wet weather design flow by the *E. coli* standard (126 cfu/100 mL). DMRs were downloaded to assess the typical monthly discharge values and bacteria concentrations at which each facility discharges. It should be noted that NPDES Wastewater Permit limits for bacteria are currently expressed in fecal coliform concentrations, not *E. coli*. However, the fecal coliform permit limit for each wastewater treatment facility (200 organisms/100 mL) is equivalent to 126 organism/100 mL *E. coli* criterion. The fecal coliform-*E. coli* relationship is documented extensively in the SONAR for the 2007 and 2008 revisions of Minn. R. ch. 7050. Results of DMRs are presented in Appendix A.

The WLA for permitted wastewater dischargers is based on facility design flow. In some reaches, however, the WLA exceeds the very low flow zone's daily loading capacity because the facilities in these reaches typically discharge less than their design flows. To account for this, the WLA and nonpoint source LA for the very low flow zone are determined by the following formula:

Allocation = (flow contribution from a given source) X (*E. coli* concentration limit or standard)

Table 35. *E. coli* allocations for permitted point source dischargers in the Lower Big Sioux River, Little Sioux River, and Rock River Watersheds.

Major Watershed	Impaired Reach(es)	Facility Name	NPDES ID#	Facility Type	Effluent Design Flow (MGD)	*E. coli* Concentration Basis for WLA (cfu/100 mL)	Permitted Load (billions of organisms/day)
Little Sioux River	508, 509	Round Lake WWTP	MNG580198	WWTP	0.93	126	4.4
Lower Big Sioux River	502	Lake Benton WWTP	MN0023884	WWTP	0.65	126	3.1
	502	Heartland Hutterian Brethren WWTP	MNG56019	WWTP	0.10	126	0.5
	505, 512	Pipestone WWTP	MN0054801	WWTP	10.16	126	48.5
	512	Jasper WWTP	MNG58002	WWTP	0.98	126	4.7
	522	Beaver Creek WWTP	MNG58005	WWTP	0.37	126	1.8
Rock River	504, 506, 508	Woodstock WWTP	MNG580192	WWTP	0.18	126	0.9
	504, 506, 508	Holland WWTP	MN0021270	WWTP	0.10	126	0.5
	506, 508, 522	Edgerton WWTP	MNG580011	WWTP	0.73	126	3.5
	506, 508, 522	Chandler WWTP	MN0039748	WWTP	1.63	126	7.8
	506, 508, 545	Leota District WWTP	MNG580219	WWTP	0.33	126	1.6
	508	Hardwick WWTP	MNG580194	WWTP	0.31	126	1.5
	519	Magnolia WWTP	MNG580190	WWTP	0.48	126	2.3
	515, 517	Lismore WWTP	MGN580076	WWTP	0.26	126	1.2
	513, 514, 517	Wilmont WWTP	MNG580200	WWTP	0.28	126	1.3
	517, 518	Ellsworth WWTP	MNG580015	WWTP	0.91	126	4.4
	517	Adrian WWTP	MNG580001	WWTP	1.72	126	8.2
	511, 513	Rushmore WWTP	MNG580201	WWTP	0.95	126	4.5

4.5.2.2 Permitted MS4 Stormwater

For this TMDL there are no MS4s located in the Lower Big Sioux River, Little Sioux River, and Rock River *E. coli* impaired reach watersheds. Although the city of Worthington is a MS4, they do not discharge to an *E. coli* impaired reach.

4.5.2.3 Permitted Construction and Industrial Stormwater

WLAs for regulated construction stormwater (permit #MNR100001) were not developed, since *E. coli* is not a typical pollutant from construction sites. 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 bacteria or *E. coli* benchmarks associated with any of the Industrial Stormwater Permits (permit #MNR050000) in these watersheds and therefore no industrial stormwater *E. coli* WLAs were assigned.

4.5.3 Load Allocation Methodology

As stated in the governing TMDL equation, the LA, also referred to as the watershed LA, is comprised of the nonpoint source load that is allocated to an impaired AUID after the MOS and WLA are subtracted from the total loading capacity for each flow regime. This residual load is meant to represent the watershed LA that includes all non-regulated sources *E. coli* upstream of the impaired reach, which are summarized in Section 3.5.2.

The relationship between bacterial sources and bacterial concentrations found in streams is complex, involving precipitation and flow, temperature, livestock management practices, wildlife activities, survival rates, land use practices, and other environmental factors. Section 3.5.2 discussed possible sources of bacteria found in streams and highlighted the observation that *E. coli* populations can be naturalized in the sediment and persist over an extended period of time. Sadowsky et. al. (2015) concluded that approximately 36.5% of *E. coli* strains were represented by multiple isolates, suggesting persistence of specific *E. coli*. The authors suggested that 36% might be used as a rough indicator of "background" levels of bacteria at this site during the study period. While these results may not be transferable to other locations, they do suggest the presence of background *E. coli* and a fraction of *E. coli* may be present regardless of the control measures taken by traditional implementation strategies. The following *E. coli* LAs include natural background.

Split Rock Creek (10170203-512), Pipestone Creek (10170203-505), and Flandreau Creek (10170203-502) in the Lower Big Sioux River Watershed have watershed areas in both states. Two reaches in the West Fork Little Sioux River (10230003-508, 10230003-509) in the Little Sioux River Watershed have watershed areas in both states. See Section 1.2 and Figures 1 and 2 for description. For these reaches, individual state watershed LAs were assigned by multiplying each state's percent watershed coverage (determined in GIS) by the total watershed LA.

For these reaches, individual state watershed LAs were assigned by multiplying each state's percent watershed coverage (determined in the GIS) by the total watershed LA.

4.5.4 Margin of Safety

The MOS is a portion of the TMDL that is set aside to account for the uncertainties associated with achieving water quality standards. The MOS can be either implicitly or explicitly defined as a set-aside amount. An explicit MOS was calculated as 10% of the loading capacity. Ten percent was considered an appropriate MOS since the LDC approach minimizes a great deal of uncertainty. The LDC calculations are based on *E. coli* target concentrations and modeled flow data that has been calibrated to long-term monitored flow data. Most of the uncertainty with this calculation is therefore associated with the HSPF modeled flow output for each reach. The Missouri River Basin HSPF model was calibrated and validated using 15 years (1995 through 2009) of flow data from gaging stations: 6482610, 6605000, 6605850, 6483290, 6483 500, H82042001, H82035001, H82015001, H83027001, H83016001. Calibration results indicate that the HSPF model is a valid representation of hydrological and chemical conditions in the watershed. See Appendix E of this TMDL report for the HSPF model calibration and validation results. The *E. coli* LDCs were developed using HSPF modeled daily flow data from April through October. The *E. coli* TMDLs applied a MOS to each flow zone along the duration curves by subtracting 10% of the flow zones loading capacity.

4.5.5 Seasonal Variation

Geometric means for *E. coli* bacteria within the impaired reaches are often above the state chronic standard from April through October. Exceedances of the acute standard are also common in these reaches during this time period. Fecal bacteria are most productive at temperatures similar to their origination environment in animal digestive tracts. Thus, these organisms are expected to be at their highest concentrations during warmer summer months when stream flow is low and water temperatures are high. High *E. coli* concentrations in many of the reaches continue into the fall, which may be attributed to constant sources of *E. coli* (such as failing SSTS and animal access to the stream) and less flow for dilution. However, some of the data may be skewed as more samples were collected in the summer months than in October. Seasonal and annual variations are accounted for by setting the TMDL across the entire flow record using the load duration method.

4.5.6 *E. coli* TMDL Summary

The TMDL summary tables (Tables 36 through 63) present the existing load, the total loading capacity (Total Load (TMDL) in tables, MOS, WLA (Wasteload in tables), and LA (Load in tables) for each *E. coli* impaired reach. Allocations for these TMDLs were established using the 126 cfu/100 mL *E. coli* standard. All LAs are reported in billions of organisms/day and were rounded to one significant figure to prevent zero load values. The bottom line of the table shows the estimated load reduction for each flow zone. This reduction was calculated based on the difference between the monitored geometric mean *E. coli* concentration of each flow zone and the 126 cfu/100 mL standard. At this time, there is not enough information or data available to estimate or calculate the existing (current conditions) load contribution from each of the WLA and LA sources presented in the TMDL tables. Thus, the estimated load reduction for each flow zone applies to all sources. See Section 8 of this report and the WRAPS report for each major watershed to further information on which sources and geographical locations within the impaired reach watersheds should be targeted for bacteria BMPs and restoration strategies.

4.5.6.1 Lower Big Sioux River Watershed *E. coli* TMDLs

This TMDL covers four *E. coli* impaired reaches in the Lower Big Sioux River Watershed: Flandreau Creek Reach 502, Pipestone Creek Reach 505, Split Rock Creek Reach 512 and Beaver Creek Reach 522. There are three other bacteria impaired reaches in the Lower Big Sioux River Watershed (Reaches 527, 514 and 501) that were covered under the Pipestone Creek Fecal Coliform Bacteria and Turbidity TMDL (MPCA 2008). TMDL allocations for the reaches covered in this TMDL include the entire watershed draining to each impaired reach. For example, allocations for Split Rock Creek Reach 512 include the watershed draining to Pipestone Creek Reach 505, as well as the watershed draining to non-impaired Reach 507 (Split Rock Creek). Tables 36 through 39 contain the TMDL allocations for each impaired reach in the Lower Big Sioux River Watershed, organized upstream to downstream and from north to south through the watershed.

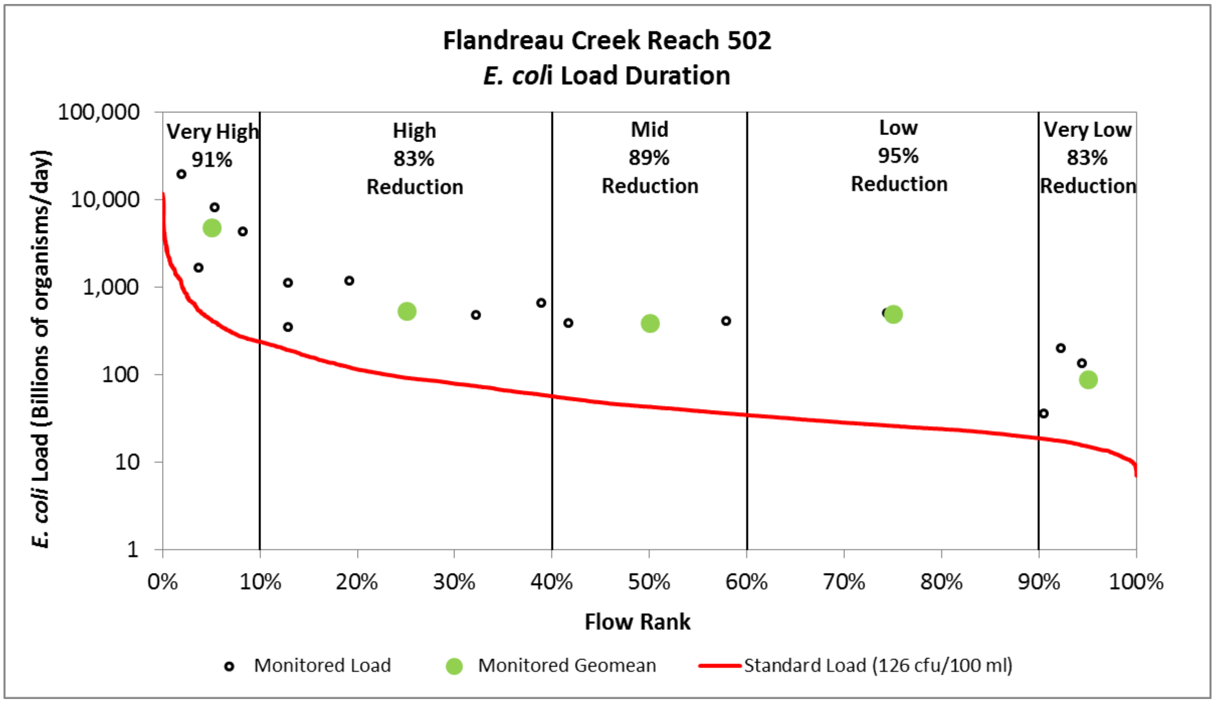

Figure 25. Flandreau Creek Reach 502 *E. coli* load duration and TMDL reductions.

Table 36. Flandreau Creek Reach 502 *E. coli* TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		***E. coli* Load (billions of organisms/day)**				
Wasteload	**Total WLA**	**3.6**	**3.6**	**3.6**	**3.6**	**3.6**
	Lake Benton WWTP	3.1	3.1	3.1	3.1	3.1
	Heartland Hutterian Brethren WWTP	0.5	0.5	0.5	0.5	0.5
Load	**Total LA**	**372.6**	**79.11**	**34.92**	**19.71**	**9.99**
	MN Watershed Nonpoint Sources	365.1	77.5	34.2	19.3	9.8
	SD Watershed Nonpoint Sources	7.5	1.61	0.72	0.41	0.19
MOS		**41.8**	**9.19**	**4.28**	**2.59**	**1.51**
TOTAL LOAD (TMDL)		**418.0**	**91.9**	**42.8**	**25.9**	**15.1**
Existing Load (geomean of observed data)		4,904	544	388	498	87
Estimated Reduction (%)		91%	83%	89%	95%	83%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

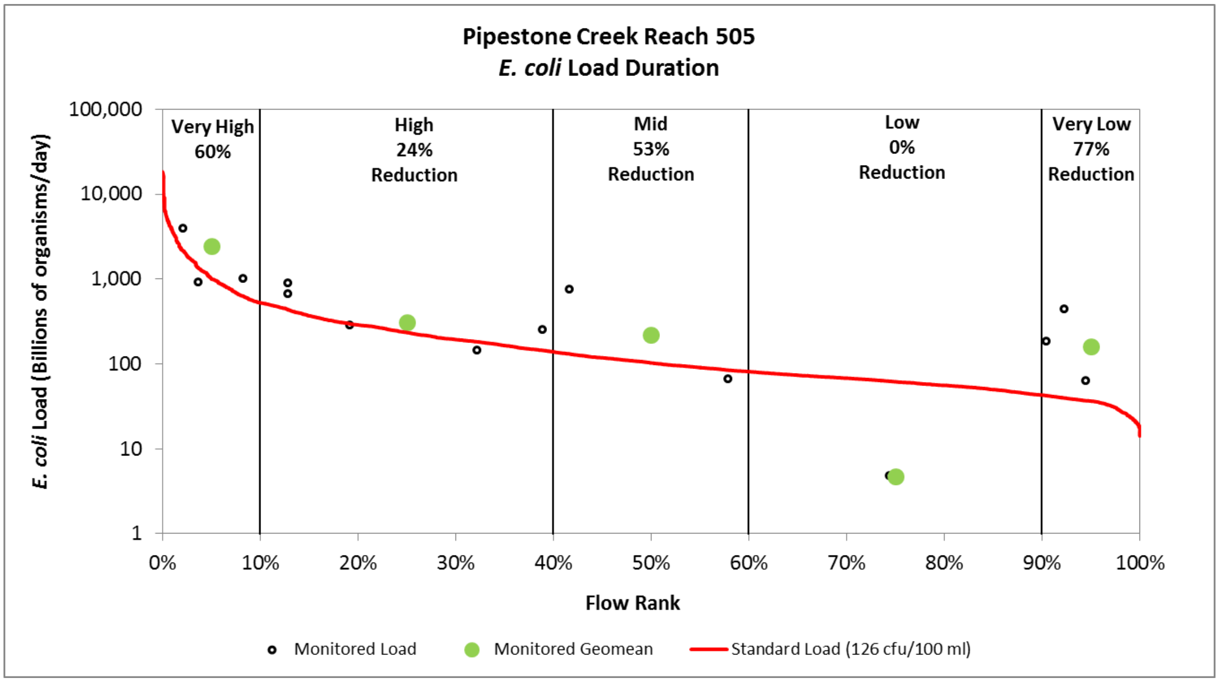

Figure 26. Pipestone Creek Reach 505 *E. coli* load duration and TMDL reductions.

Table 37. Pipestone Creek Reach 505 *E. coli* TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		***E. coli* Load (billions of organisms/day)**				
Wasteload	**Total WLA**	**48.5**	**48.5**	**48.5**	**48.5**	**
	Pipestone WWTP	48.5	48.5	48.5	48.5	**
Load	**Total LA**	**848.26**	**161.83**	**43.84**	**6.94**	**
	MN Watershed Nonpoint Sources	582.75	111.18	30.12	4.77	**
	SD Watershed Nonpoint Sources	265.51	50.65	13.72	2.17	**
MOS		**99.64**	**23.37**	**10.26**	**6.16**	**3.64**
TOTAL LOAD (TMDL)		**996.4**	**233.7**	**102.6**	**61.6**	**36.4**
Existing Load (geomean of observed data)		2,471	309	218	5	160
Estimated Reduction (%)		60%	24%	53%	0%	77%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.
** The WLA for the permitted wastewater dischargers (Table 33) are based on facility design flow. The WLA exceeded the very low flow zones total daily loading capacity and is denoted in the table by "**". For this flow zone, the WLA and LAs are determined by the following formula: Allocation = (flow contribution from a given source) X (*E. coli* concentration limit or standard).

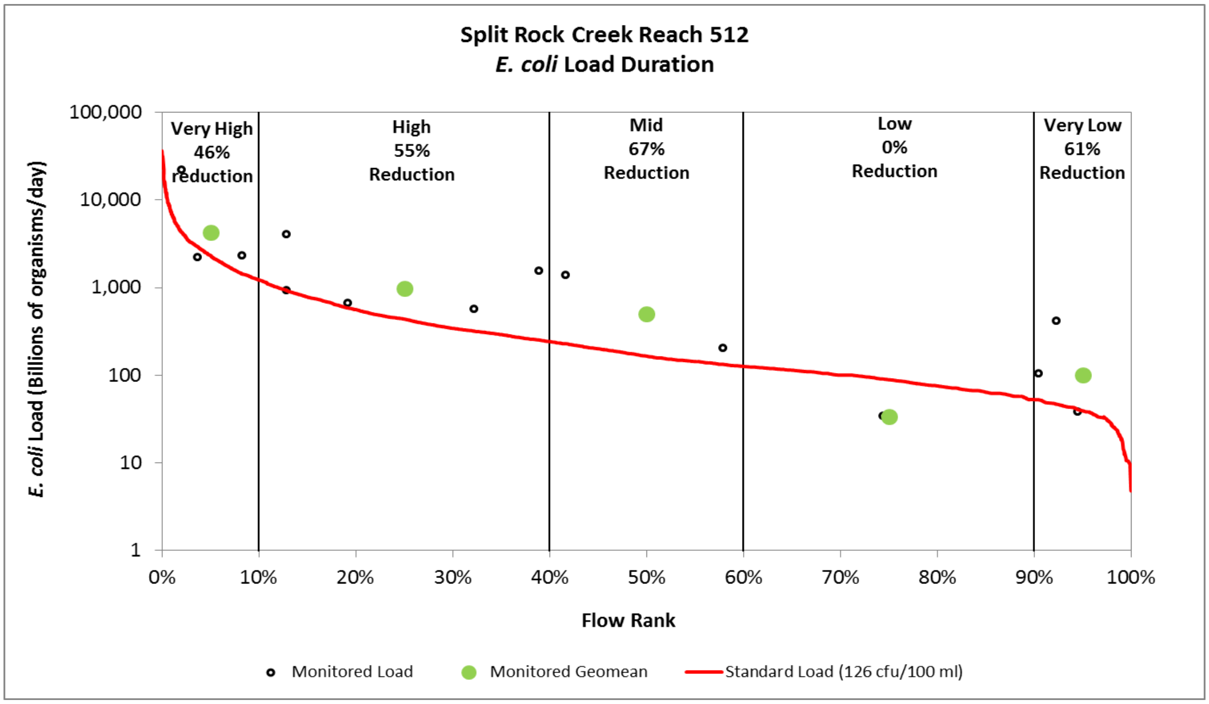

Figure 27. Split Rock Creek Reach 512 *E. coli* load duration and TMDL reductions.

Table 38. Split Rock Creek Reach 512 *E. coli* TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		***E. coli* Load (billions of organisms/day)**				
Wasteload	**Total WLA**	**53.2**	**53.2**	**53.2**	**53.2**	**
	Pipestone WWTP	48.5	48.5	48.5	48.5	**
	Jasper WWTP	4.7	4.7	4.7	4.7	**
Load	**Total LA**	**2,038.04**	**340.37**	**95.21**	**27.26**	**
	MN Watershed Nonpoint Sources	1608.01	268.55	75.12	21.51	**
	SD Watershed Nonpoint Sources	430.03	71.82	20.09	5.75	**
MOS		**232.36**	**43.73**	**16.49**	**8.94**	**4**
TOTAL LOAD (TMDL)		**2,323.6**	**437.3**	**164.9**	**89.4**	**40.0**
Existing Load (geomean of observed data)		4,268	975	503	34	102
Estimated Reduction (%)		46%	55%	67%	0%	61%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.
** The WLA for the permitted wastewater dischargers (Table 33) are based on facility design flow. The WLA exceeded the very low flow zones total daily loading capacity and is denoted in the table by "**". For this flow zone, the WLA and LAs are determined by the following formula: Allocation = (flow contribution from a given source) X (*E. coli* concentration limit or standard).

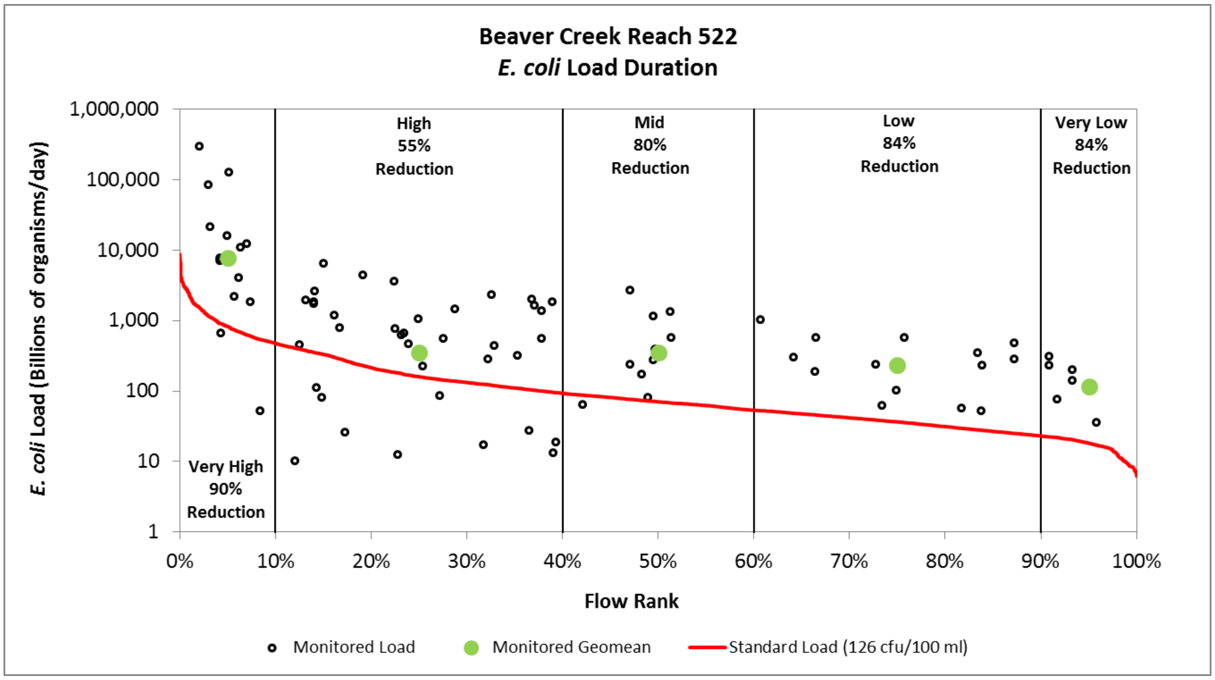

Figure 28. Beaver Creek Reach 522 *E. coli* load duration and TMDL reductions.

Table 39. Beaver Creek Reach 522 *E. coli* TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		***E. coli* Load (billions of organisms/day)**				
Wasteload	**Total WLA**	**1.8**	**1.8**	**1.8**	**1.8**	**1.8**
	Beaver Creek WWTP	1.8	1.8	1.8	1.8	1.8
Load	**Total LA**	**735.12**	**141.03**	**61.38**	**30.96**	**14.58**
	MN Watershed Nonpoint Sources	735.12	141.03	61.38	30.96	14.58
MOS		**81.88**	**15.87**	**7.02**	**3.64**	**1.82**
TOTAL LOAD (TMDL)		**818.8**	**158.7**	**70.2**	**36.4**	**18.2**
Existing Load (geomean of observed data)		7,848	352	353	234	115
Estimated Reduction (%)		90%	55%	80%	84%	84%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

4.5.6.2 Little Sioux River Watershed *E. coli* TMDLs

There are six *E. coli* impaired reaches in the Little Sioux River Watershed. Three of the impaired reaches (508, 511, and 509) are located in the West Fork Little Sioux River major subwatershed, while the other three (Reaches 514, 516, and 515) are located in the Headwaters – Little Sioux River major subwatershed. TMDL allocations for all reaches include the entire watershed draining to each impaired reach. For example, allocations for Little Sioux River Reach 515 include the watershed draining directly to the reach, as well as the watersheds draining to upstream impaired Reaches 516 and 514. Tables 40 through 45 contain the TMDL allocations for each impaired reach in the Little Sioux River Watershed, organized upstream to downstream and from east to west through the watershed.

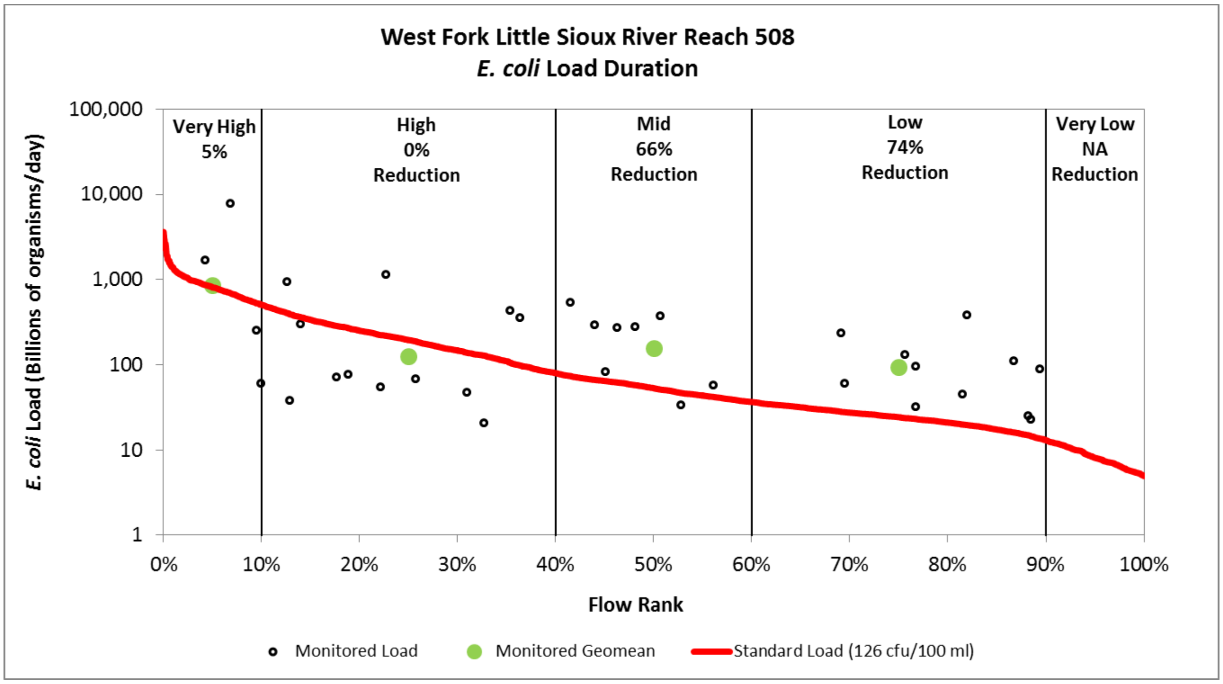

Figure 29. West Fork Little Sioux River Reach 508 *E. coli* load duration and TMDL reductions.

Table 40. West Fork Little Sioux River Reach 508 *E. coli* TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		***E. coli* Load (billions of organisms/day)**				
Wasteload	**Total WLA**	**4.4**	**4.4**	**4.4**	**4.4**	**4.4**
	Round Lake WWTP	4.4	4.4	4.4	4.4	4.4
Load	**Total LA**	**720.19**	**170.65**	**43.12**	**17.29**	**2.8**
	MN Watershed Nonpoint Sources	606.4	143.7	36.3	14.6	2.4
	IA Watershed Nonpoint Sources	113.79	26.95	6.82	2.69	0.4
MOS		**80.51**	**19.45**	**5.28**	**2.41**	**0.8**
TOTAL LOAD (TMDL)		**805.1**	**194.5**	**52.8**	**24.1**	**8.0**
Existing Load (geomean of observed data)		850	125	158	94	NA**
Estimated Reduction (%)		5%	0%	66%	74%	NA**

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

** Not enough data at this time to estimate a reduction.

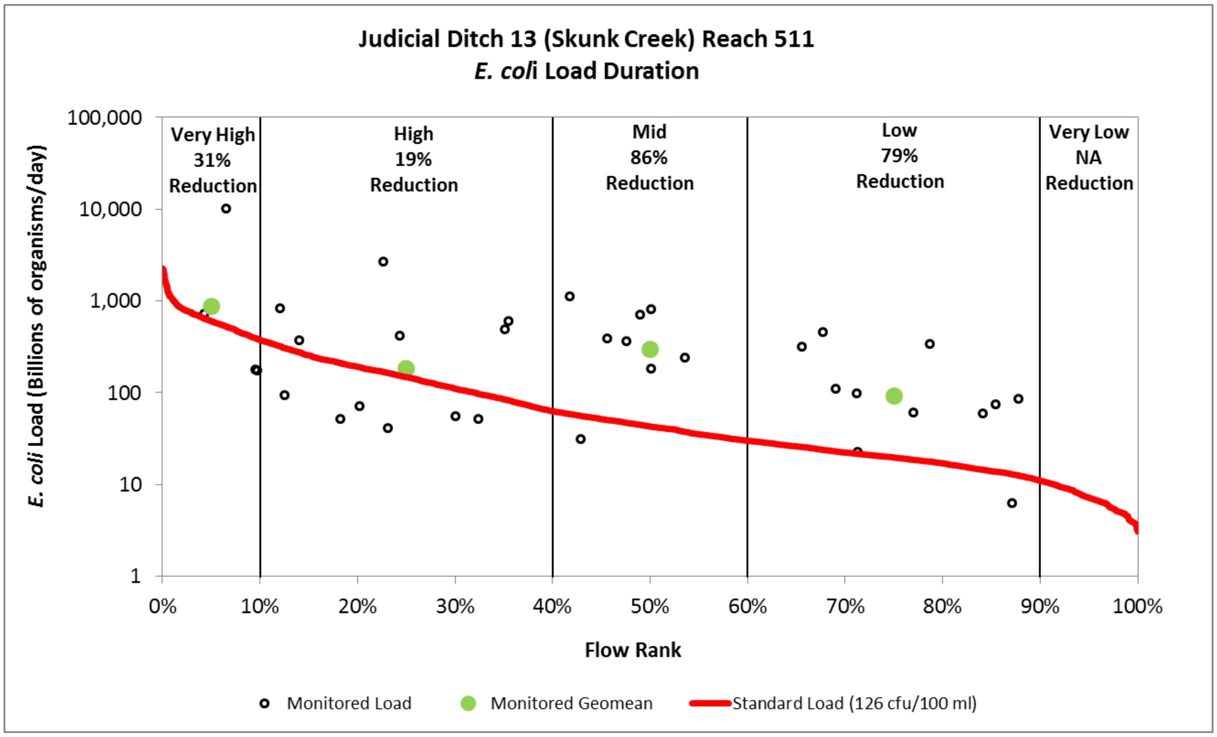

Figure 30. Judicial Ditch 13 (Skunk Creek) Reach 511 *E. coli* load duration and TMDL reductions.

Table 41. Judicial Ditch 13 (Skunk Creek) Reach 511 *E. coli* TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		***E. coli* Load (billions of organisms/day)**				
Wasteload	**Total WLA**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Load	**Total LA**	**540.27**	**132.84**	**38.52**	**17.64**	**6.39**
	MN Watershed Nonpoint Sources	540.27	132.84	38.52	17.64	6.39
MOS		**60.03**	**14.76**	**4.28**	**1.96**	**0.71**
TOTAL LOAD (TMDL)		**600.3**	**147.6**	**42.8**	**19.6**	**7.1**
Existing Load (geomean of observed data)		873	182	298	93	NA**
Estimated Reduction (%)		31%	19%	86%	79%	NA**

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

** Not enough data at this time to estimate a reduction.

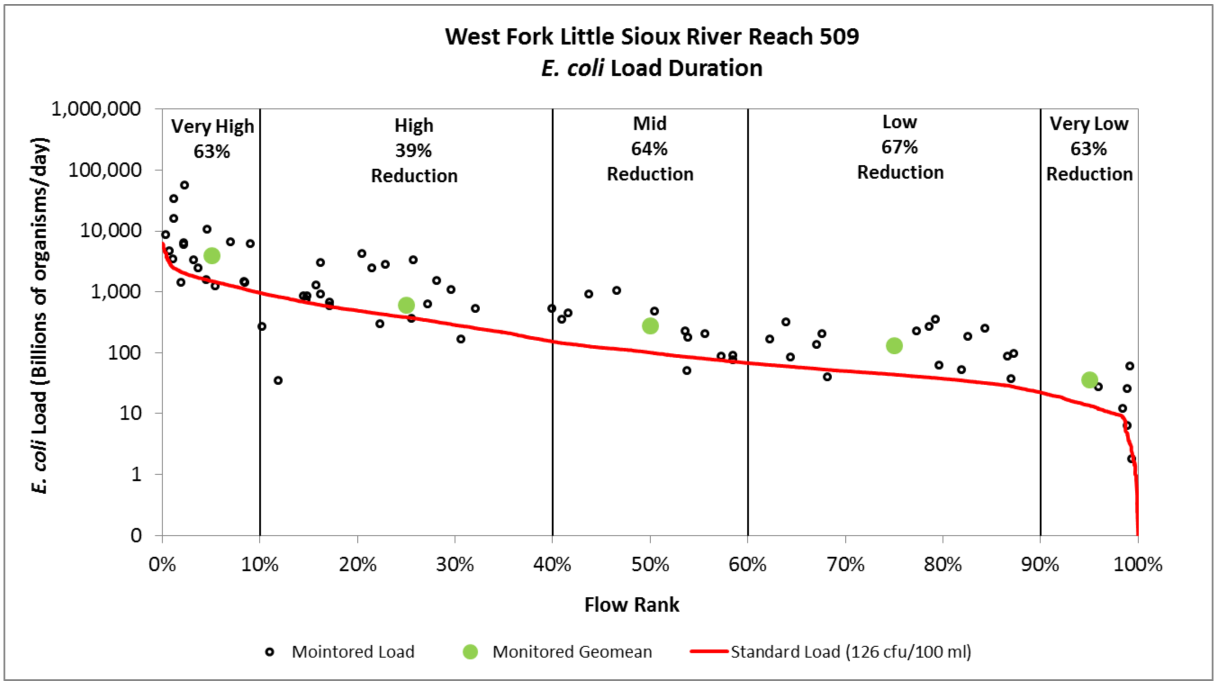

Figure 31. West Fork Little Sioux River Reach 509 *E. coli* load duration and TMDL reductions.

Table 42. West Fork Little Sioux River Reach 509 *E. coli* TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		***E. coli* Load (billions of organisms/day)**				
Wasteload	**Total WLA**	**4.4**	**4.4**	**4.4**	**4.4**	**4.4**
	Round Lake WWTP	4.4	4.4	4.4	4.4	4.4
Load	**Total LA**	**1,356.76**	**342.28**	**86.59**	**35.2**	**7.93**
	MN Watershed Nonpoint Sources	1231.67	310.72	78.61	31.95	7.20
	IA Watershed Nonpoint Sources	125.09	31.56	7.98	3.25	0.73
MOS		**151.24**	**38.52**	**10.11**	**4.4**	**1.37**
TOTAL LOAD (TMDL)		**1,512.4**	**385.2**	**101.1**	**44.0**	**13.7**
Existing Load (geomean of observed data)		4,047	621	281	135	37
Estimated Reduction (%)		63%	39%	64%	67%	63%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

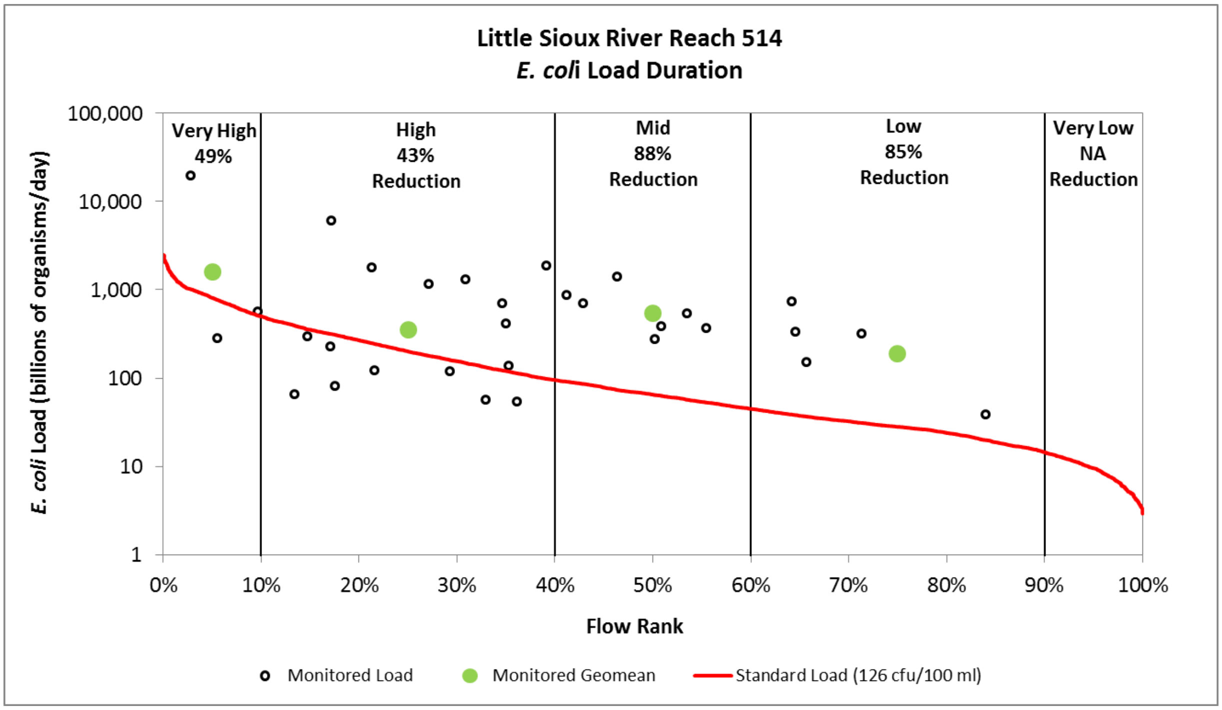

Figure 32. Little Sioux River Reach 514 *E. coli* load duration and TMDL reductions.

Table 43. Little Sioux River Reach 514 *E. coli* TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		***E. coli* Load (billions of organisms/day)**				
Wasteload	**Total WLA**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Load	**Total LA**	**729**	**180.18**	**58.32**	**25.29**	**8.55**
	MN Watershed Nonpoint Sources	729	180.18	58.32	25.29	8.55
MOS		**81**	**20.02**	**6.48**	**2.81**	**0.95**
TOTAL LOAD (TMDL)		**810.0**	**200.2**	**64.8**	**28.1**	**9.5**
Existing Load (geomean of observed data)		1,601	349	536	190	NA**
Estimated Reduction (%)		49%	43%	88%	85%	NA**

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

** Not enough data at this time to estimate a reduction.

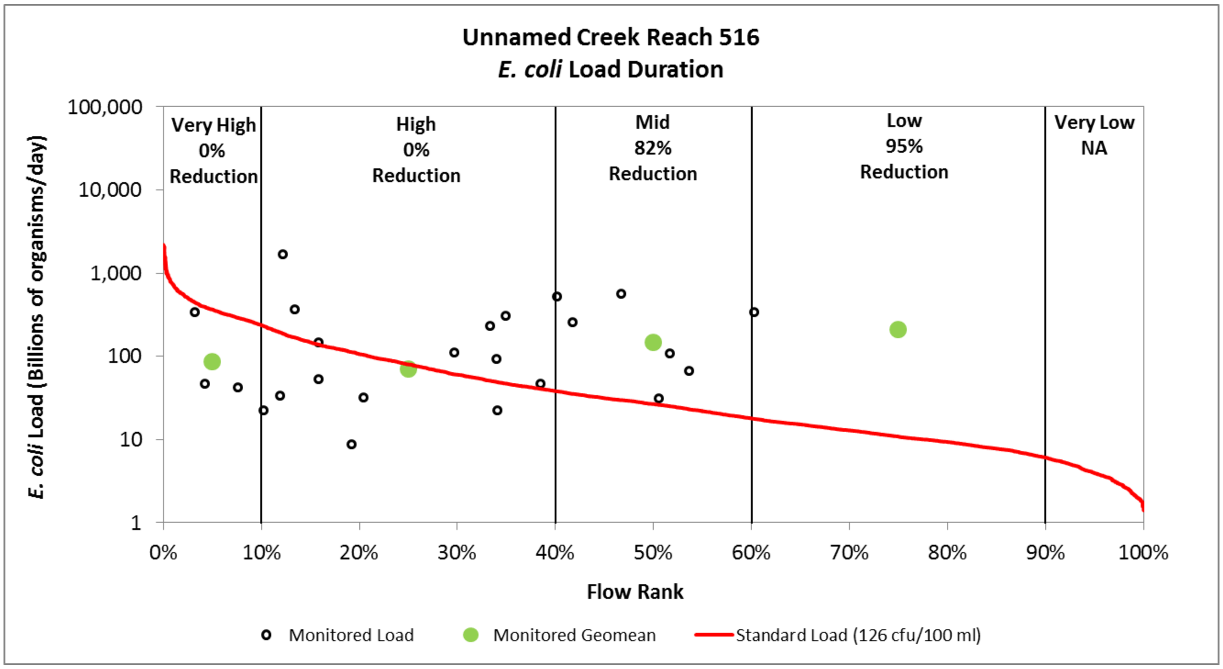

Figure 33. Unnamed Creek Reach 516 *E. coli* load duration and TMDL reductions.

Table 44. Unnamed Creek Reach 516 *E. coli* TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		***E. coli* Load (billions of organisms/day)**				
Wasteload	**Total WLA**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Load	**Total LA**	**328.68**	**72.09**	**23.94**	**9.72**	**3.51**
	MN Watershed Nonpoint Sources	328.68	72.09	23.94	9.72	3.51
MOS		**36.52**	**8.01**	**2.66**	**1.08**	**0.39**
TOTAL LOAD (TMDL)		**365.2**	**80.1**	**26.6**	**10.8**	**3.9**
Existing Load (geomean of observed data)		86	71	148	208	NA**
Estimated Reduction (%)		0%	0%	82%	95%	NA**

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

** Not enough data at this time to estimate a reduction.

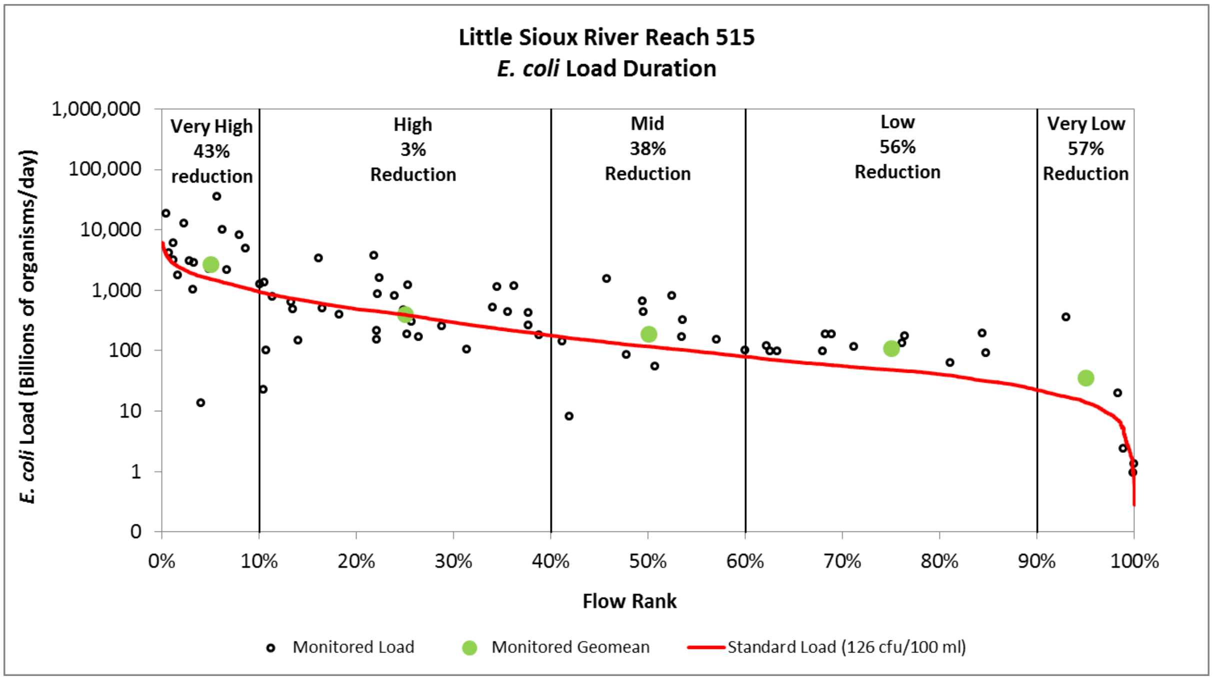

Figure 34. Little Sioux River Reach 515 *E. coli* load duration and TMDL reductions.

Table 45. Little Sioux River Reach 515 *E. coli* TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		***E. coli* Load (billions of organisms/day)**				
Wasteload	**Total WLA**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Load	**Total LA**	**1,373.85**	**354.24**	**105.93**	**43.38**	**12.51**
	MN Watershed Nonpoint Sources	1,373.85	354.24	105.93	43.38	12.51
MOS		**152.65**	**39.36**	**11.77**	**4.82**	**1.39**
TOTAL LOAD (TMDL)		**1,526.5**	**393.6**	**117.7**	**48.2**	**13.9**
Existing Load (geomean of observed data)		2,692	406	191	110	36
Estimated Reduction (%)		43%	3%	38%	56%	57%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

4.5.6.3 Rock River Watershed *E. coli* TMDLs

There are 18 *E. coli* impaired reaches in the Rock River Watershed located in the following major subwatersheds: Mud Creek (Reach 525), Headwaters – Rock River (Reach 504, 522, 523, 506, 545, 521, 508, and 551), Champepadan Creek (Reach 520 and 519), Kanaranzi Creek (Reach 515, 514, 518, and 517), and Little Rock River (Reach 511, 512, and 513). There also is one other bacteria impaired reach in the Rock River Watershed (Reach 501) that was covered under the Rock River Fecal Coliform and Turbidity TMDL (Minnesota State University 2008).

TMDL allocations for all reaches covered in this TMDL include the entire watershed draining to each impaired reach. For example, allocations for Rock River Reach 508 includes the watershed draining directly to the reach, as well as the watersheds draining to Reaches 521, 506, 522, and 504. Tables 46 through 63 contain the TMDL allocations for each impaired reach in the Rock River Watershed, organized upstream to downstream and from east to west through the watershed.

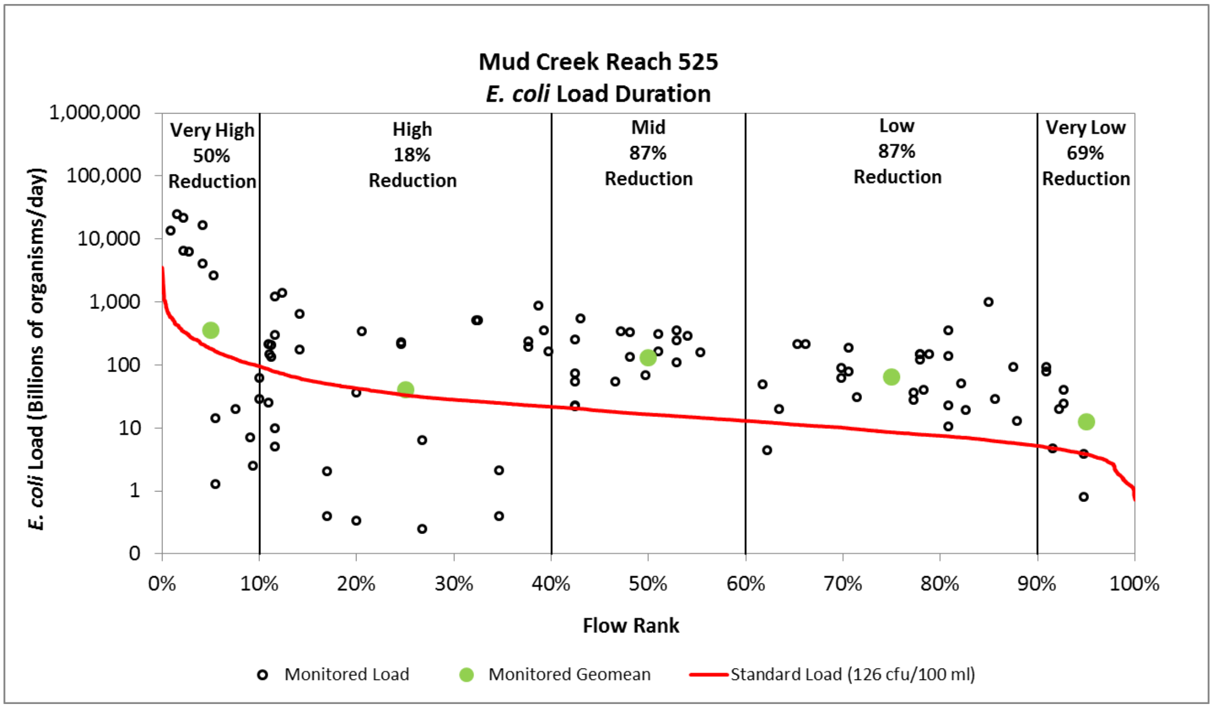

Figure 35. Mud Creek Reach 525 *E. coli* load duration and TMDL reductions.

Table 46. Mud Creek Reach 525 *E. coli* TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		***E. coli* Load (billions of organisms/day)**				
Wasteload	**Total WLA**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Load	**Total LA**	**162**	**29.79**	**14.4**	**8.19**	**3.6**
	MN Watershed Nonpoint Sources	162	29.79	14.4	8.19	3.6
MOS		**18**	**3.31**	**1.6**	**0.91**	**0.4**
TOTAL LOAD (TMDL)		**180.0**	**33.1**	**16.0**	**9.1**	**4.0**
Existing Load (geomean of observed data)		358	40	127	68	13
Estimated Reduction (%)		50%	18%	87%	87%	69%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

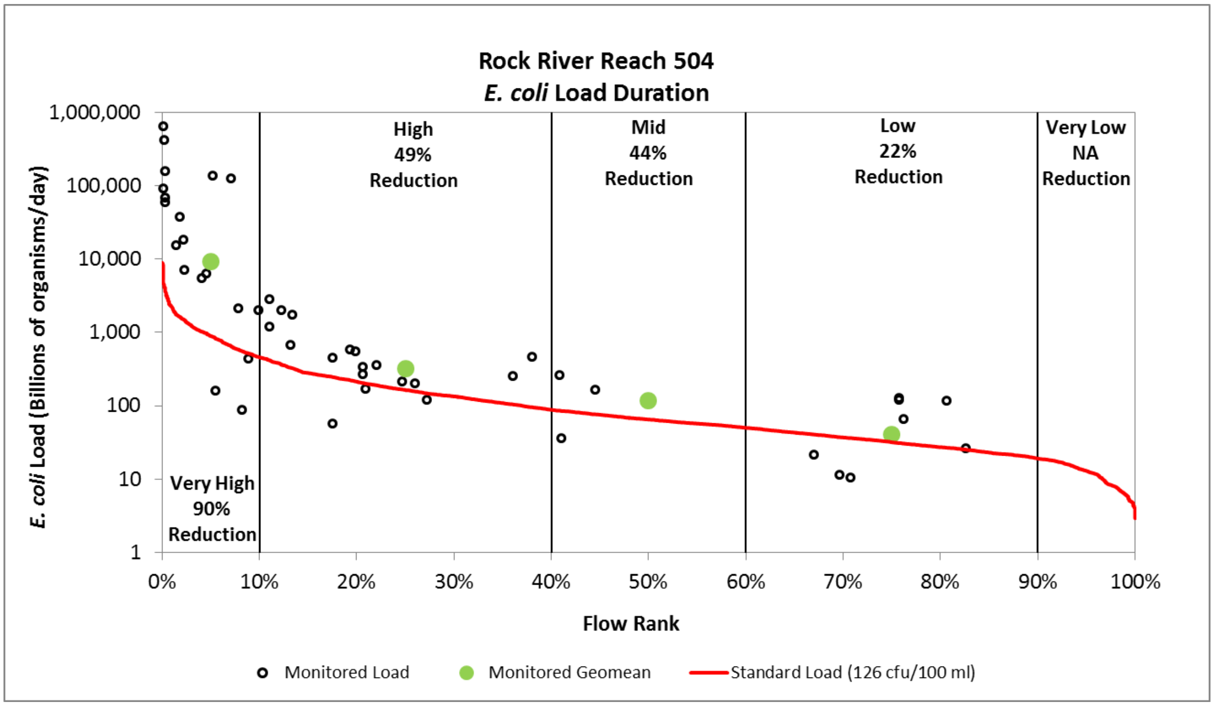

Figure 36. Rock River Reach 504 *E. coli* load duration and TMDL reductions.

Table 47. Rock River Reach 504 *E. coli* TMDL.

		Flow Zone*				
		Very High	High	Mid	Low	Very Low
		E. coli Load (billions of organisms/day)				
Wasteload	**Total WLA**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**
	Woodstock WWTP	0.9	0.9	0.9	0.9	0.9
	Holland WWTP	0.5	0.5	0.5	0.5	0.5
Load	**Total LA**	**802.57**	**145.48**	**56.92**	**27.22**	**10.21**
	MN Watershed Nonpoint Sources	802.57	145.48	56.92	27.22	10.21
MOS		**89.33**	**16.32**	**6.48**	**3.18**	**1.29**
TOTAL LOAD (TMDL)		**893.3**	**163.2**	**64.8**	**31.8**	**12.9**
Existing Load (geomean of observed data)		9,231	321	116	41	NA**
Estimated Reduction (%)		90%	49%	44%	22%	NA**

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

** Not enough data at this time to estimate a reduction.

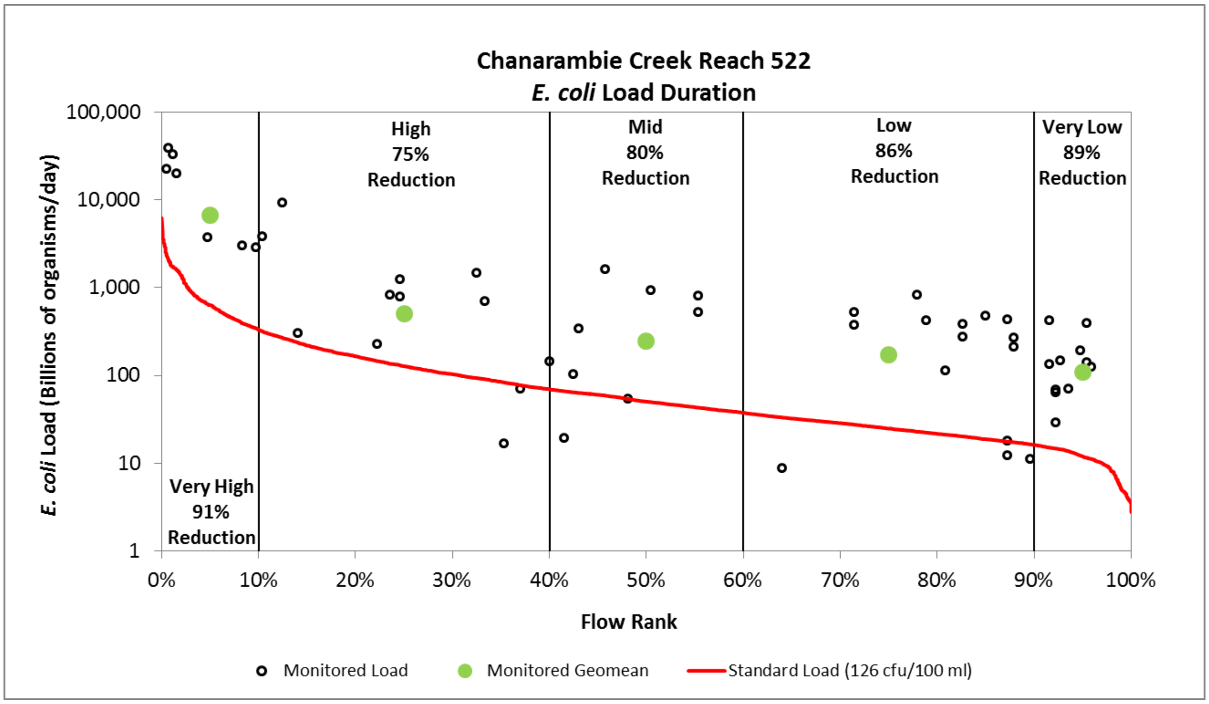

Figure 37. Chanarambie Creek Reach 522 *E. coli* load duration and TMDL reductions.

Table 48. Chanarambie Creek Reach 522 *E. coli* TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		***E. coli* Load (billions of organisms/day)**				
Wasteload	**Total WLA**	**11.3**	**11.3**	**11.3**	**11.3**	**
	Edgerton WWTP	3.5	3.5	3.5	3.5	**
	Chandler WWTP	7.8	7.8	7.8	7.8	**
Load	**Total LA**	**556.15**	**103.09**	**33.79**	**11.02**	**
	MN Watershed Nonpoint Sources	556.15	103.09	33.79	11.02	**
MOS		**63.05**	**412.71**	**5.01**	**2.48**	**1.18**
TOTAL LOAD (TMDL)		**630.5**	**127.1**	**50.1**	**24.8**	**11.8**
Existing Load (geomean of observed data)		6,761	502	245	172	109
Estimated Reduction (%)		91%	75%	80%	86%	89%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.
** The WLA for the permitted wastewater dischargers (Table 33) are based on facility design flow. The WLA exceeded the very low flow zone total daily loading capacity (minus margin of safety) and is denoted in the table by "**". For this flow zone, the WLA and LAs are determined by the following formula: Allocation = (flow contribution from a given source) X (*E. coli* concentration limit or standard).

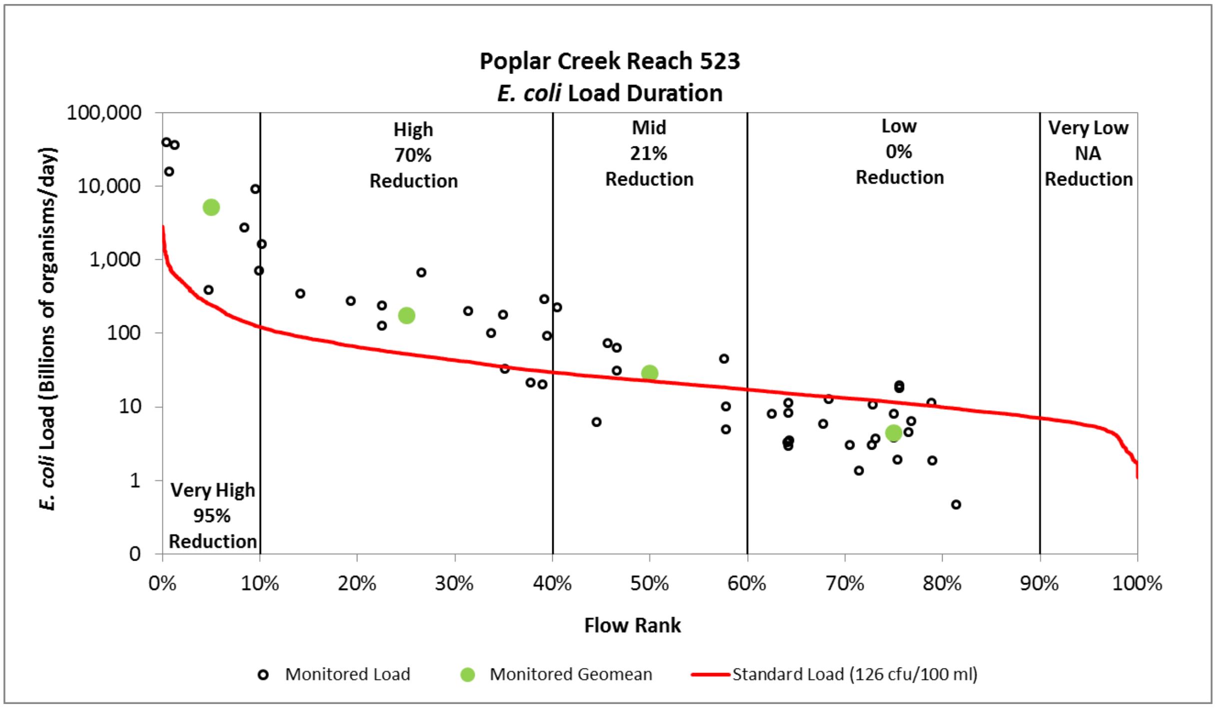

Figure 38. Poplar Creek Reach 523 *E. coli* load duration and TMDL reductions.

Table 49. Poplar Creek Reach 523 *E. coli* TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		***E. coli* Load (billions of organisms/day)**				
Wasteload	**Total WLA**	**0.0**	**0.0**	**0.0**	**0.0**	0.0
Load	**Total LA**	**217.89**	**47.25**	**20.25**	**10.44**	**5.04**
	MN Watershed Nonpoint Sources	217.89	47.25	20.25	10.44	5.04
MOS		**24.21**	**5.25**	**2.25**	**1.16**	**0.56**
TOTAL LOAD (TMDL)		**242.1**	**52.5**	**22.5**	**11.6**	**5.6**
Existing Load (geomean of observed data)		5,194	176	28	4	NA**
Estimated Reduction (%)		95%	70%	21%	0%	NA**

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

** Not enough data at this time to estimate a reduction.

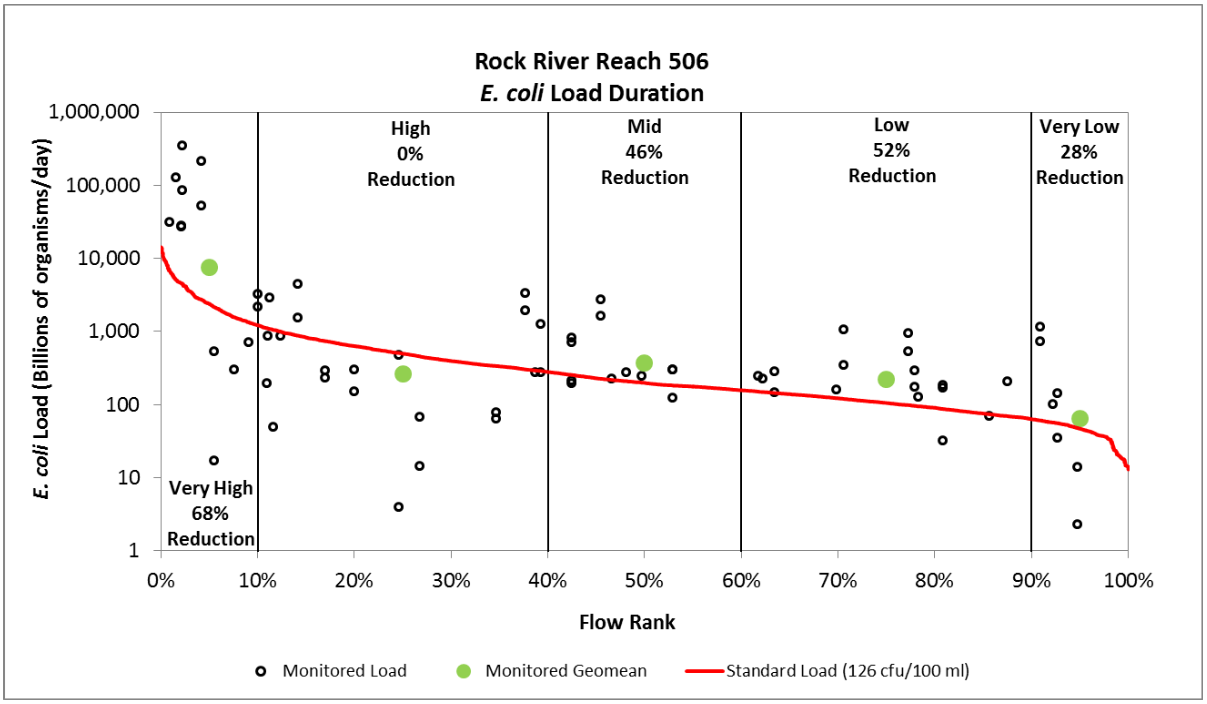

Figure 39. Rock River Reach 506 *E. coli* load duration and TMDL reductions.

Table 50. Rock River Reach 506 *E. coli* TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		***E. coli* Load (billions of organisms/day)**				
Wasteload	**Total WLA**	**14.3**	**14.3**	**14.3**	**14.3**	**14.3**
	Woodstock WWTP	0.9	0.9	0.9	0.9	0.9
	Holland WWTP	0.5	0.5	0.5	0.5	0.5
	Leota District WWTP	1.6	1.6	1.6	1.6	1.6
	Edgerton WWTP	3.5	3.5	3.5	3.5	3.5
	Chandler WWTP	7.8	7.8	7.8	7.8	7.8
Load	**Total LA**	**2,111.23**	**434.44**	**164.35**	**80.65**	**27.91**
	MN Watershed Nonpoint Sources	2,111.23	434.44	164.35	80.65	27.91
MOS		**236.17**	**49.86**	**19.85**	**10.55**	**4.69**
TOTAL LOAD (TMDL)		**2,361.7**	**498.6**	**198.5**	**105.5**	**46.9**
Existing Load (geomean of observed data)		7,461	265	370	221	65
Estimated Reduction (%)		68%	0%	46%	52%	28%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

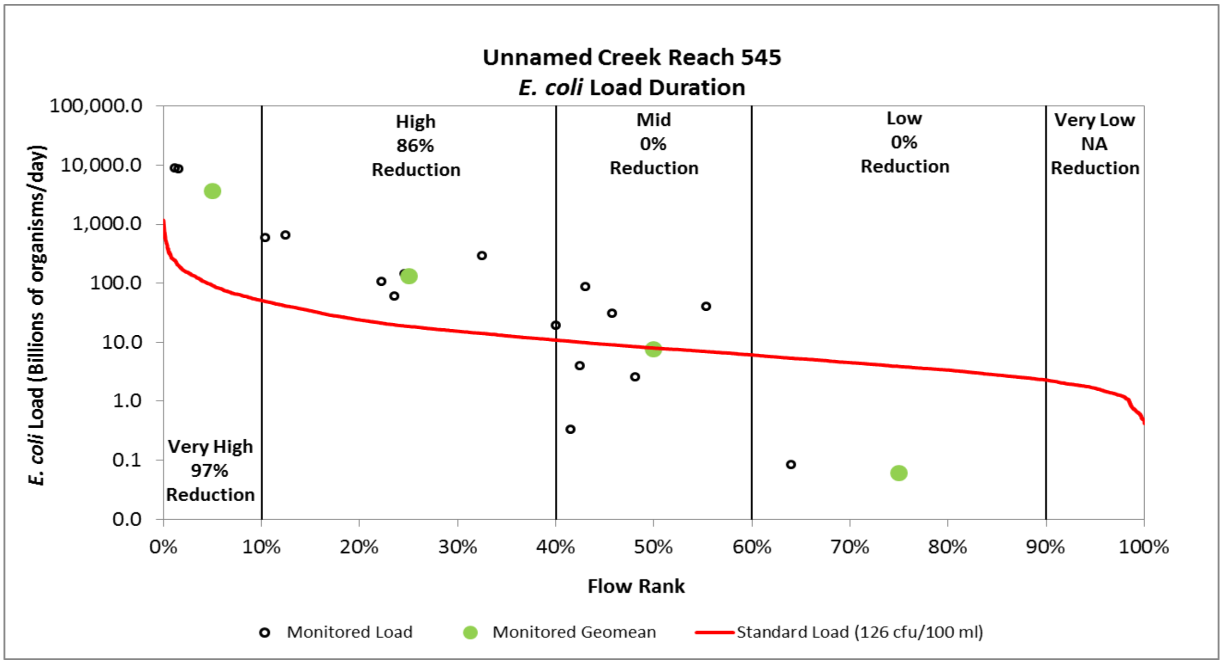

Figure 40. Unnamed Reach 545 *E. coli* load duration and TMDL reductions.

Table 51. Unnamed Creek Reach 545 *E. coli* TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		***E. coli* Load (billions of organisms/day)**				
Wasteload	**Total WLA**	**1.6**	**1.6**	**1.6**	**1.6**	**
	Leota District WWTP	1.6	1.6	1.6	1.6	**
Load	**Total LA**	**79.94**	**15.05**	**5.6**	**1.91**	**
	MN Watershed Nonpoint Sources	79.94	15.05	5.6	1.91	**
MOS		**9.06**	**1.85**	**0.8**	**0.39**	**0.17**
TOTAL LOAD (TMDL)		**90.6**	**18.5**	**8.0**	**3.9**	**1.7**
Existing Load (geomean of observed data)		3,614	131	8	0	NA***
Estimated Reduction (%)		97%	86%	0%	0%	NA***

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.
** The WLA for the permitted wastewater dischargers (Table 33) are based on facility design flow. The WLA exceeded the very low flow zone total daily loading capacity (minus margin of safety) and is denoted in the table by "**". For this flow zone, the WLA and LAs are determined by the following formula: Allocation = (flow contribution from a given source) X (*E. coli* concentration limit or standard).
*** Not enough data at this time to estimate a reduction.

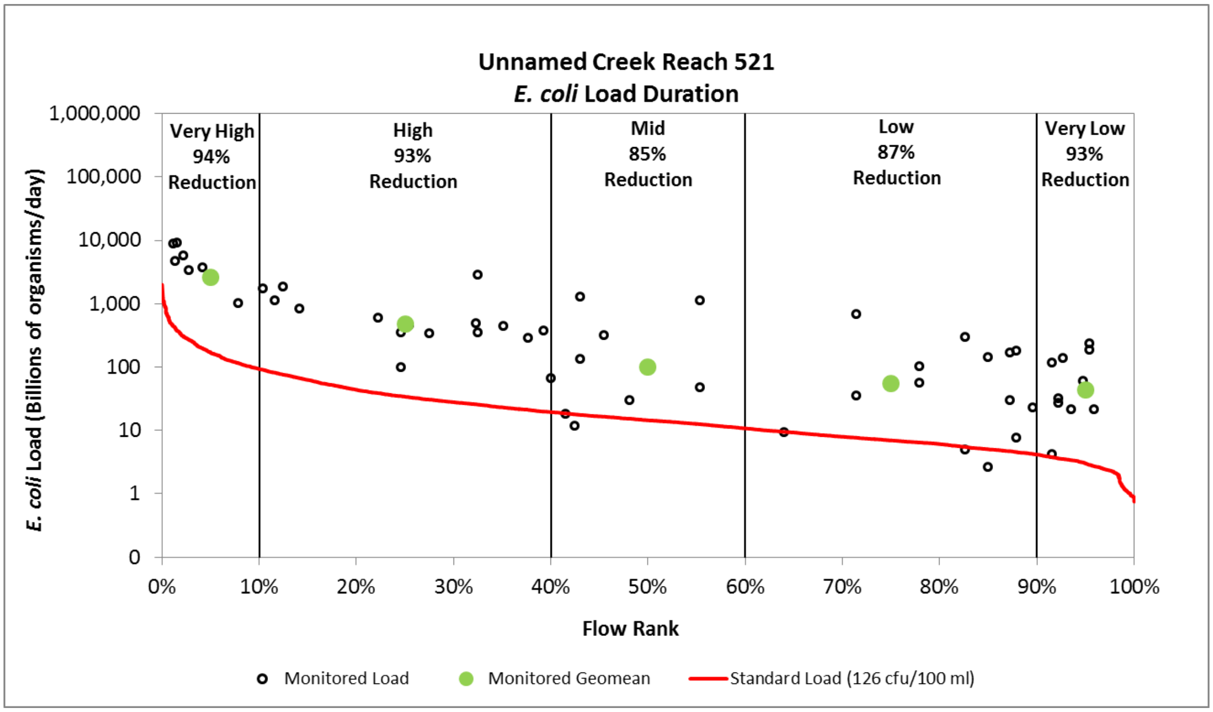

Figure 41. Unnamed Creek Reach 521 *E. coli* load duration and TMDL reductions.

Table 52. Unnamed Creek Reach 521 *E. coli* TMDL.

		Flow Zone*				
		Very High	High	Mid	Low	Very Low
		E. coli Load (billions of organisms/day)				
Wasteload	**Total WLA**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Load	**Total LA**	**150.03**	**30.6**	**12.96**	**6.21**	**2.79**
	MN Watershed Nonpoint Sources	150.03	30.6	12.96	6.21	2.79
MOS		**16.67**	**3.4**	**1.44**	**0.69**	**0.31**
TOTAL LOAD (TMDL)		**166.7**	**34.0**	**14.4**	**6.9**	**3.1**
Existing Load (geomean of observed data)		2,586	486	99	55	44
Estimated Reduction (%)		94%	93%	85%	87%	93%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

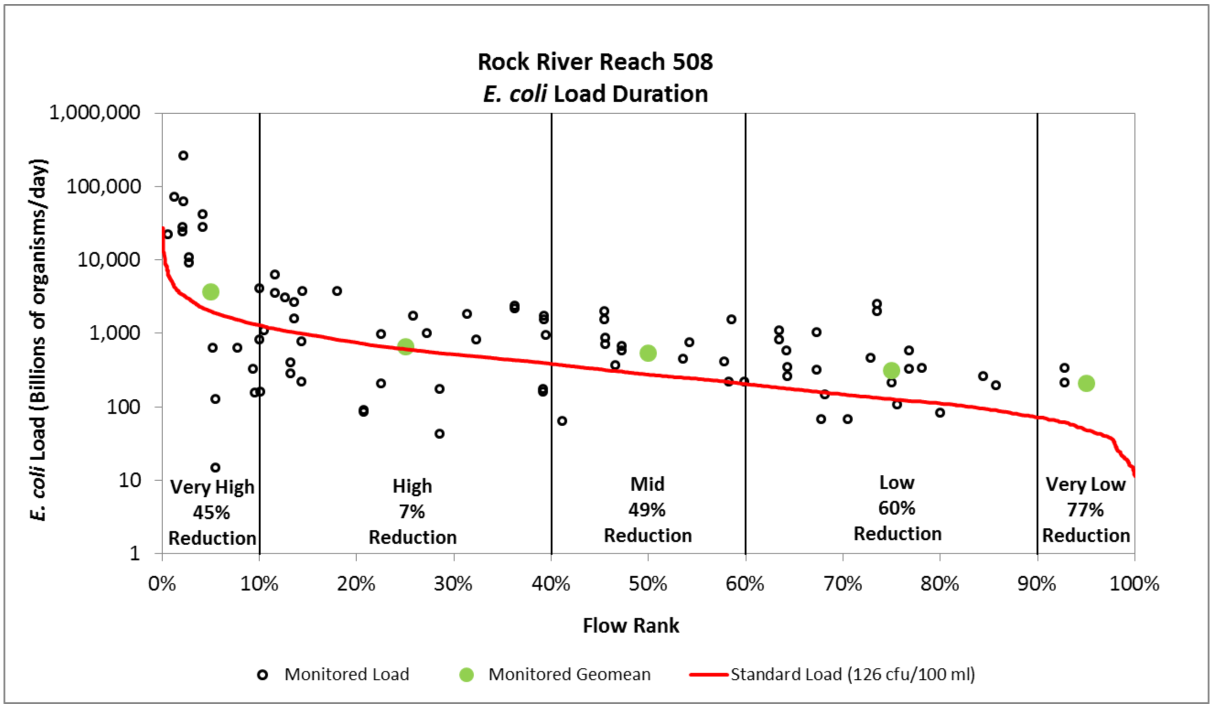

Figure 42. Rock River Reach 508 *E. coli* load duration and TMDL reductions.

Table 53. Rock River Reach 508 *E. coli* TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		***E. coli* Load (billions of organisms/day)**				
Wasteload	**Total WLA**	**15.8**	**15.8**	**15.8**	**15.8**	**15.8**
	Woodstock WWTP	0.9	0.9	0.9	0.9	0.9
	Holland WWTP	0.5	0.5	0.5	0.5	0.5
	Hardwick WWTP	1.5	1.5	1.5	1.5	1.5
	Leota District WWTP	1.6	1.6	1.6	1.6	1.6
	Edgerton WWTP	3.5	3.5	3.5	3.5	3.5
	Chandler WWTP	7.8	7.8	7.8	7.8	7.8
Load	**Total LA**	**1,783.48**	**534.28**	**230.98**	**99.58**	**27.58**
	MN Watershed Nonpoint Sources	1,783.48	534.28	230.98	99.58	27.58
MOS		**199.92**	**61.12**	**27.42**	**12.82**	**4.82**
TOTAL LOAD (TMDL)		**1,999.2**	**611.2**	**274.2**	**128.2**	**48.2**
Existing Load (geomean of observed data)		3,656	657	539	316	209
Estimated Reduction (%)		45%	7%	49%	60%	77%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

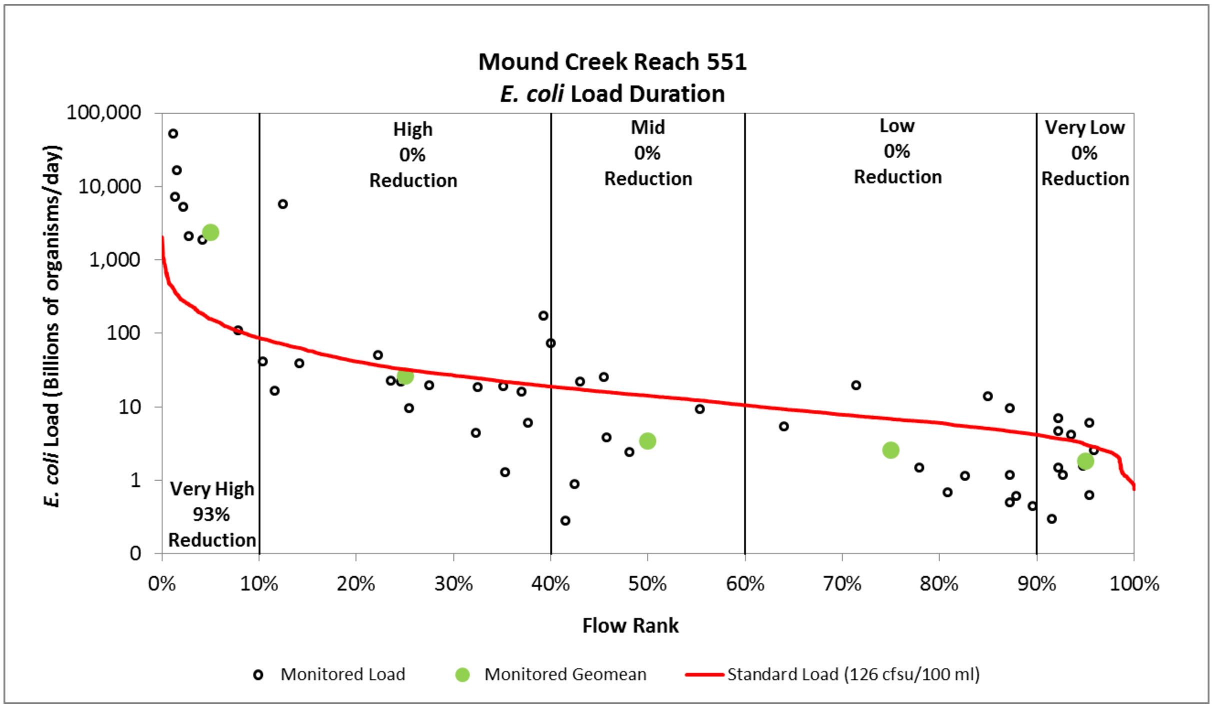

Figure 43. Mound Creek Reach 551 *E. coli* load duration and TMDL reductions.

Table 54. Mound Creek Reach 551 *E. coli* TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		***E. coli* Load (billions of organisms/day)**				
Wasteload	**Total WLA**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Load	**Total LA**	**141.39**	**28.8**	**12.6**	**6.39**	**2.79**
	MN Watershed Nonpoint Sources	141.39	28.8	12.6	6.39	2.79
MOS		**15.71**	**3.2**	**1.4**	**0.71**	**0.31**
TOTAL LOAD (TMDL)		**157.1**	**32.0**	**14.0**	**7.1**	**3.1**
Existing Load (geomean of observed data)		2,394	27	3	3	2
Estimated Reduction (%)		93%	0%	0%	0%	0%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

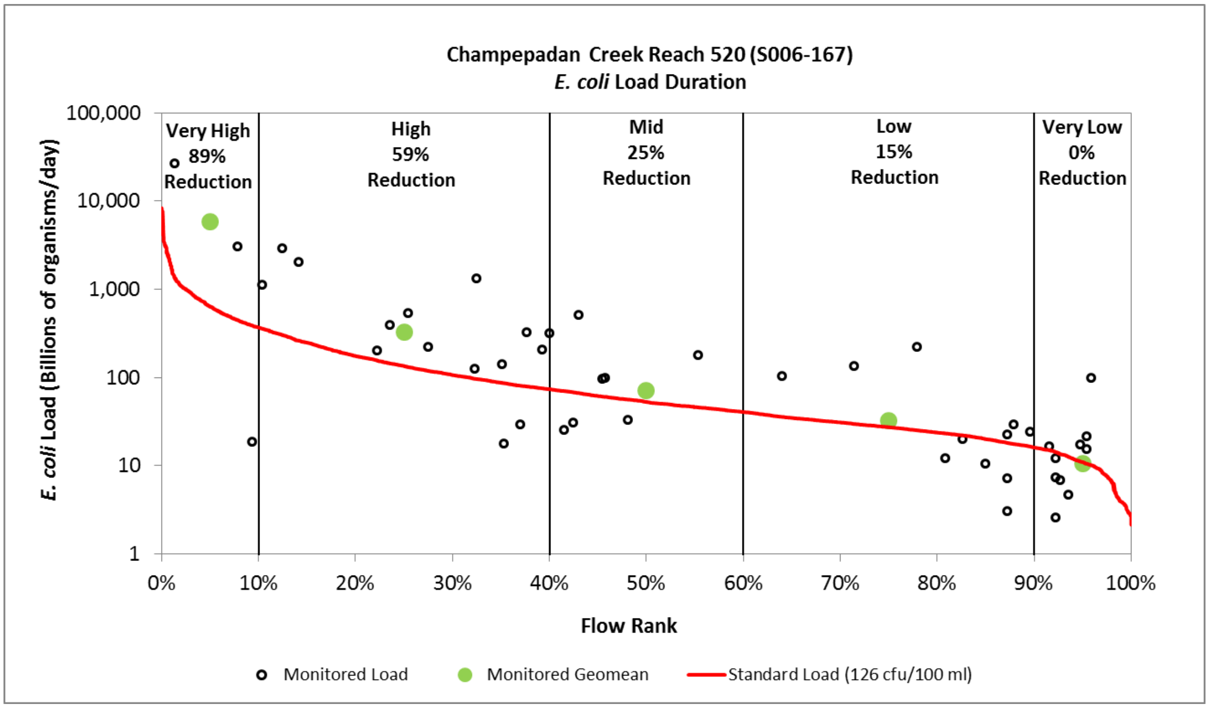

Figure 44. Champepadan Creek Reach 520 *E. coli* load duration and TMDL reductions.

Table 55. Champepadan Creek Reach 520 *E. coli* TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		***E. coli* Load (billions of organisms/day)**				
Wasteload	**Total WLA**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Load	**Total LA**	**571.59**	**120.6**	**47.79**	**24.39**	**9.99**
	MN Watershed Nonpoint Sources	571.59	120.6	47.79	24.39	9.99
MOS		**63.51**	**13.40**	**5.31**	**2.71**	**1.11**
TOTAL LOAD (TMDL)		**635.1**	**134.0**	**53.1**	**27.1**	**11.1**
Existing Load (geomean of observed data)		5,883	328	71	32	11
Estimated Reduction (%)		89%	59%	25%	15%	0%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

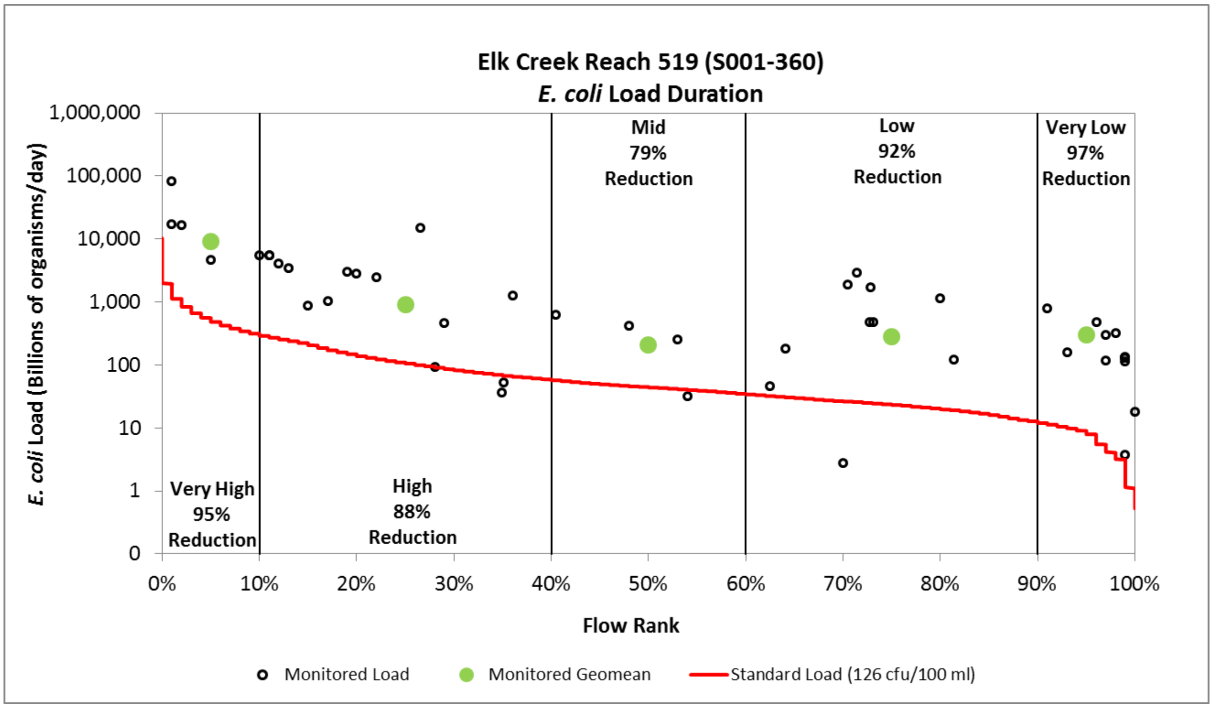

Figure 45. Elk Creek Reach 519 *E. coli* load duration and TMDL reductions.

Table 56. Elk Creek Reach 519 *E. coli* TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		***E. coli* Load (billions of organisms/day)**				
Wasteload	**Total WLA**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**
	Magnolia WWTP	2.3	2.3	2.3	2.3	2.3
Load	**Total LA**	**444.1**	**92.29**	**37.3**	**18.49**	**4.9**
	MN Watershed Nonpoint Sources	444.1	92.29	37.3	18.49	4.9
MOS		**49.6**	**10.51**	**4.4**	**2.31**	**0.8**
TOTAL LOAD (TMDL)		**496.0**	**105.1**	**44.0**	**23.1**	**8.0**
Existing Load (geomean of observed data)		9,196	898	205	280	298
Estimated Reduction (%)		95%	88%	79%	92%	97%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

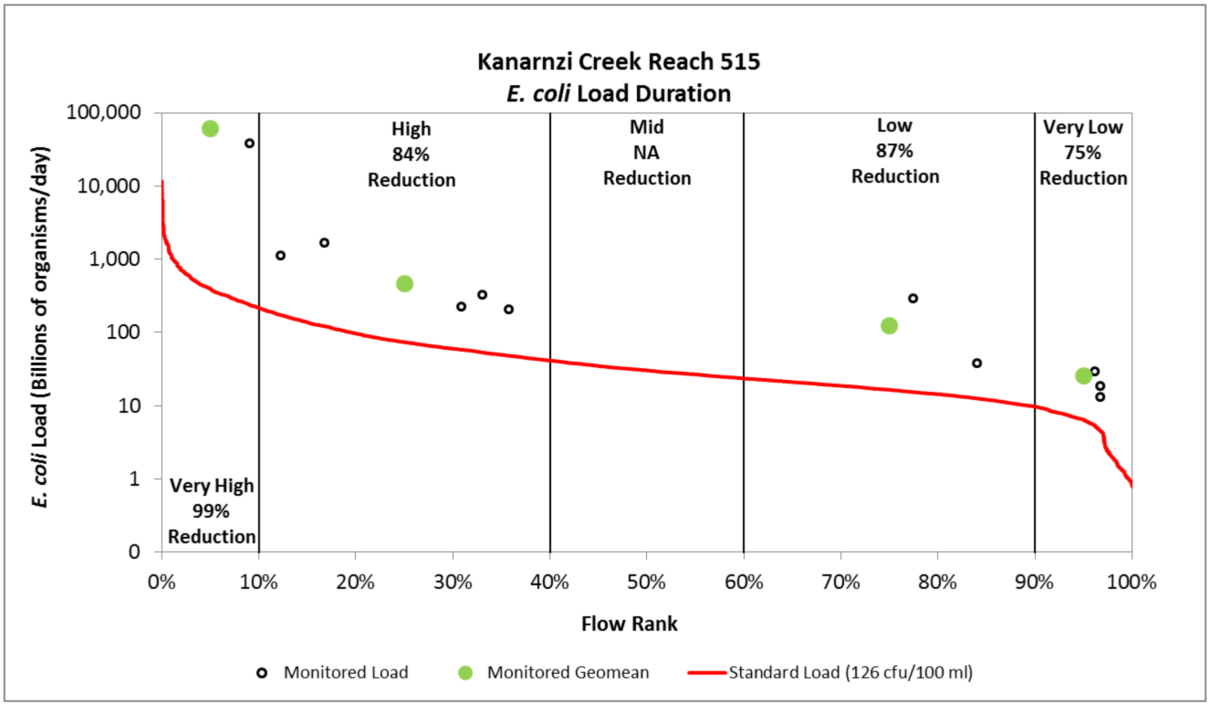

Figure 46. Kanaranzi Creek Reach 515 *E. coli* load duration and TMDL reductions.

Table 57. Kanaranzi Creek Reach 515 *E. coli* TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		***E. coli* Load (billions of organisms/day)**				
Wasteload	**Total WLA**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**
	Lismore WWTP	1.2	1.2	1.2	1.2	1.2
Load	**Total LA**	**349.8**	**65.4**	**25.8**	**14.1**	**4.2**
	MN Watershed Nonpoint Sources	349.8	65.4	25.8	14.1	4.2
MOS		**39**	**7.4**	**3.0**	**1.7**	**0.6**
TOTAL LOAD (TMDL)		**390.0**	**74.0**	**30.0**	**17.0**	**6.0**
Existing Load (geomean of observed data)		61,493	457	NA**	126	24
Estimated Reduction (%)		99%	84%	NA**	87%	75%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

** Not enough data at this time to estimate a reduction.

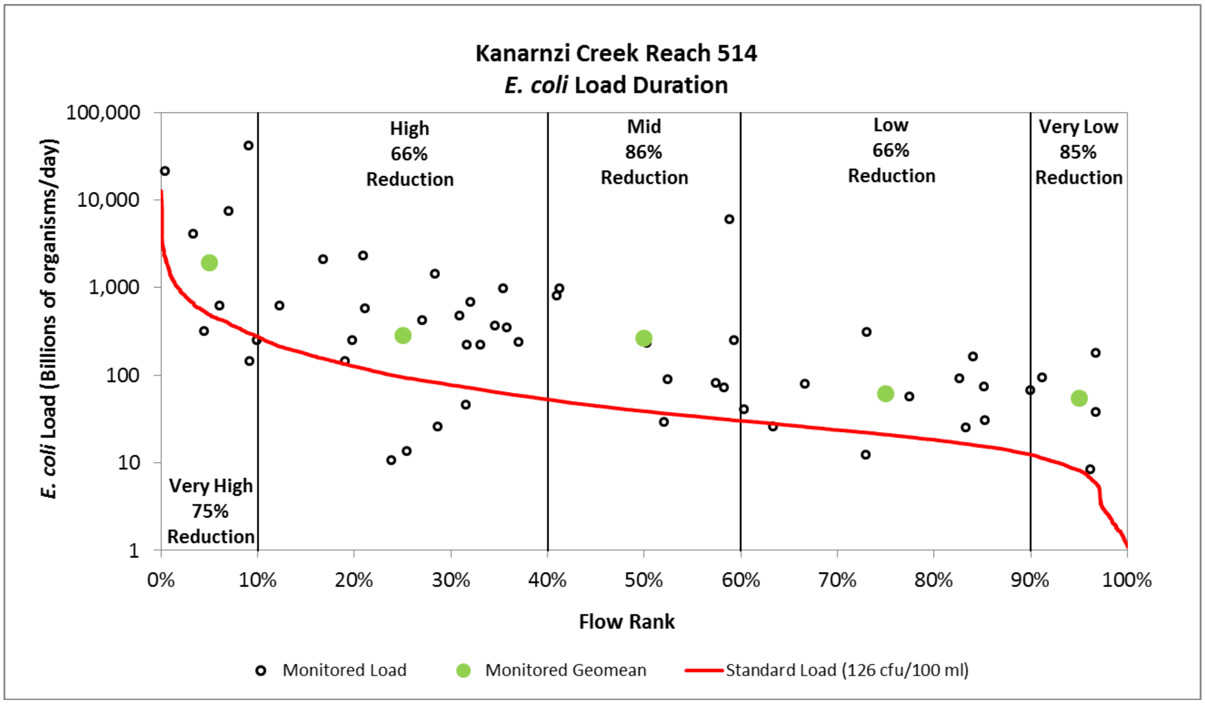

Figure 47. Kanaranzi Creek Reach 514 *E. coli* load duration and TMDL reductions.

Table 58. Kanaranzi Creek Reach 514 *E. coli* TMDL.

		Flow Zone*				
		Very High	High	Mid	Low	Very Low
		E. coli Load (billions of organisms/day)				
Wasteload	**Total WLA**	**1.3**	**1.3**	**1.3**	**1.3**	**1.3**
	Wilmont WWTP	1.3	1.3	1.3	1.3	1.3
Load	**Total LA**	**438.8**	**83.3**	**33.8**	**17.6**	**5.9**
	MN Watershed Nonpoint Sources	438.8	83.3	33.8	17.6	5.9
MOS		**48.9**	**9.4**	**3.9**	**2.1**	**0.8**
TOTAL LOAD (TMDL)		**489.0**	**94.0**	**39.0**	**21.0**	**8.0**
Existing Load (geomean of observed data)		1,924	280	266	61	55
Estimated Reduction (%)		75%	66%	86%	66%	85%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

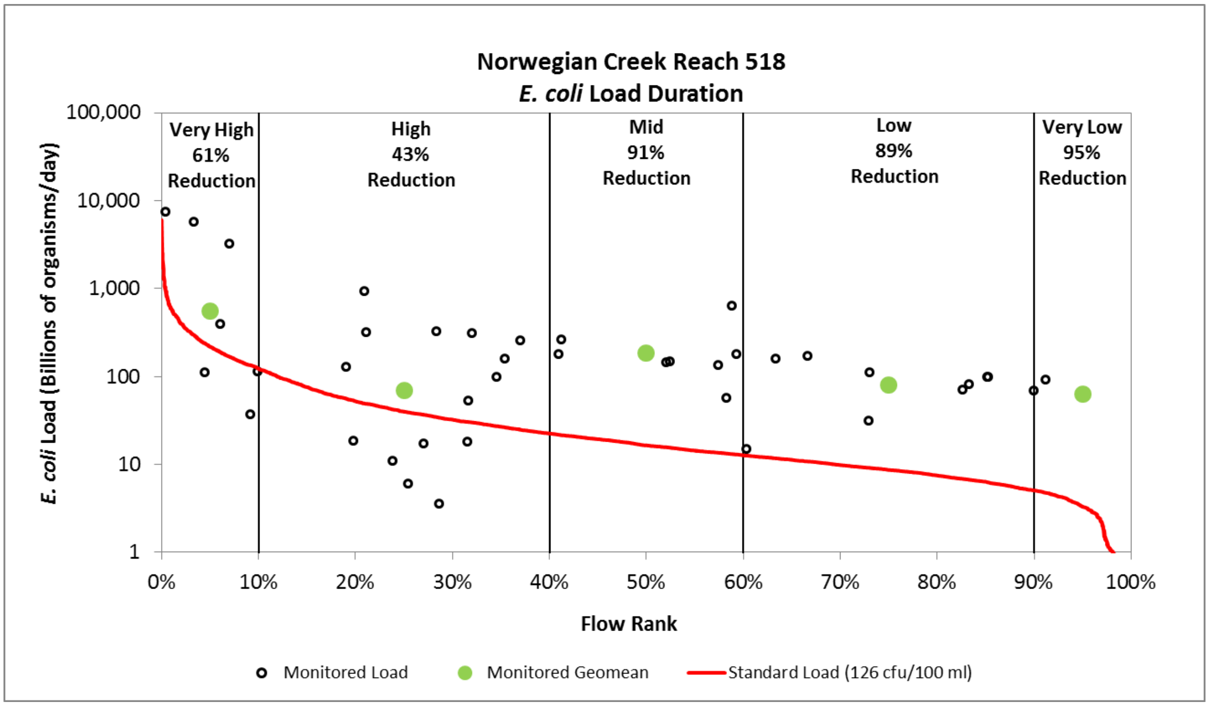

Figure 48. Norwegian Creek Reach 518 *E. coli* load duration and TMDL reductions.

Table 59. Norwegian Creek Reach 518 *E. coli* TMDL.

		Very High	High	Mid	Low	Very Low
		Flow Zone*				
		E. coli Load (billions of organisms/day)				
Wasteload	**Total WLA**	**4.4**	**4.4**	**4.4**	**4.4**	**
	Ellsworth WWTP	4.4	4.4	4.4	4.4	**
Load	**Total LA**	**190.99**	**31.6**	**10**	**3.79**	**
	MN Watershed Nonpoint Sources	190.99	31.6	10	3.79	**
MOS		**21.71**	**4.0**	**1.6**	**0.91**	**0.3**
TOTAL LOAD (TMDL)		**217.1**	**40.0**	**16.0**	**9.1**	**3.0**
Existing Load (geomean of observed data)		554	70	185	80	63
Estimated Reduction (%)		61%	43%	91%	89%	95%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.
** The WLA for the permitted wastewater dischargers (Table 33) are based on facility design flow. The WLA exceeded the very low flow zones total daily loading capacity (minus margin of safety) and is denoted in the table by "**". For this flow zone, the WLA and LAs are determined by the following formula: Allocation = (flow contribution from a given source) X (*E. coli* concentration limit or standard).

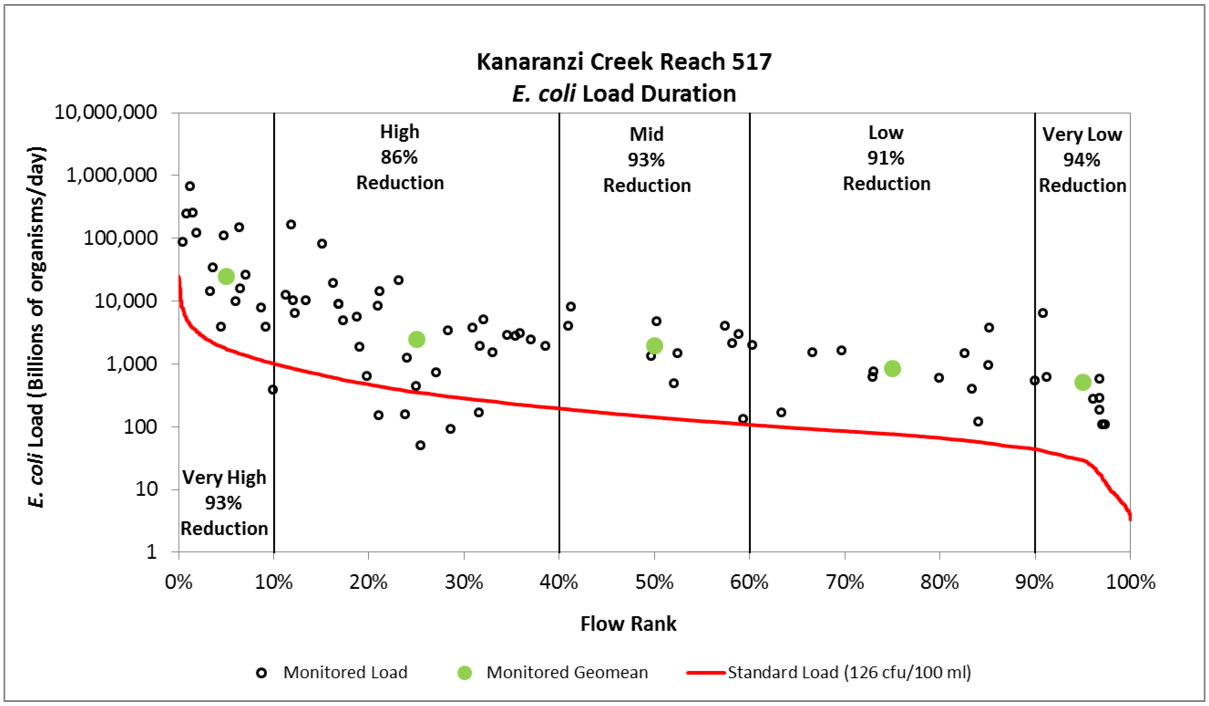

Figure 49. Kanaranzi Creek Reach 517 *E. coli* load duration and TMDL reductions.

Table 60. Kanaranzi Creek Reach 517 *E. coli* TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		***E. coli* Load (billions of organisms/day)**				
Wasteload	**Total WLA**	**15.1**	**15.1**	**15.1**	**15.1**	**15.1**
	Ellsworth WWTP	4.4	4.4	4.4	4.4	4.4
	Adrian WWTP	8.2	8.2	8.2	8.2	8.2
	Wilmont WWTP	1.3	1.3	1.3	1.3	1.3
	Lismore WWTP	1.2	1.2	1.2	1.2	1.2
Load	**Total LA**	**1,527.50**	**300.8**	**111.8**	**53.3**	**11**
	MN Watershed Nonpoint Sources	1,527.50	300.8	111.8	53.3	11
MOS		**171.4**	**35.1**	**14.1**	**7.6**	**2.9**
TOTAL LOAD (TMDL)		**1,714.0**	**351.0**	**141.0**	**76.0**	**29.0**
Existing Load (geomean of observed data)		24,708	2,485	1,975	840	503
Estimated Reduction (%)		93%	86%	93%	91%	94%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

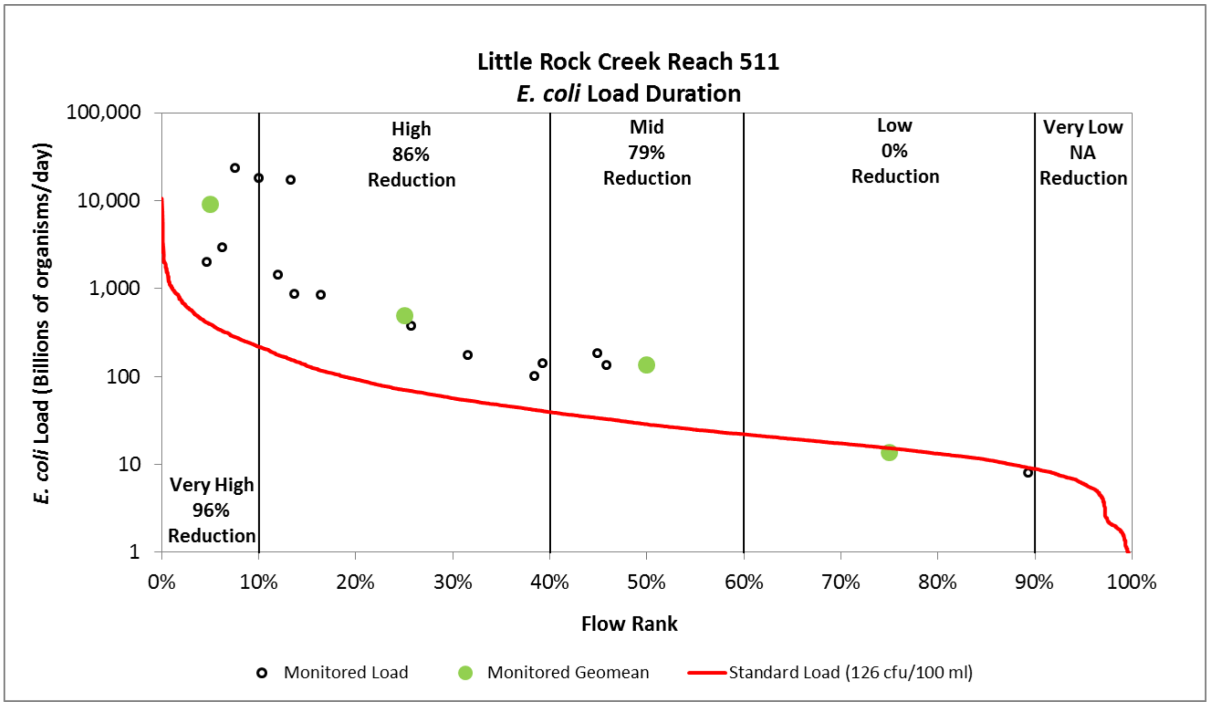

Figure 50. Little Rock Creek Reach 511 *E. coli* load duration and TMDL reductions.

Table 61. Little Rock Creek Reach 511 *E. coli* TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		***E. coli* Load (billions of organisms/day)**				
Wasteload	**Total WLA**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**
	Rushmore WWTP	4.5	4.5	4.5	4.5	4.5
Load	**Total LA**	**347.4**	**58.5**	**21.6**	**9**	**0.9**
	MN Watershed Nonpoint Sources	347.4	58.5	21.6	9	0.9
MOS		**39.1**	**7**	**2.9**	**1.5**	**0.6**
TOTAL LOAD (TMDL)		**391.0**	**70.0**	**29.0**	**15.0**	**6.0**
Existing Load (geomean of observed data)		9,136	492	135	14	NA**
Estimated Reduction (%)		96%	86%	79%	0%	NA**

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

** Not enough data at this time to estimate a reduction.

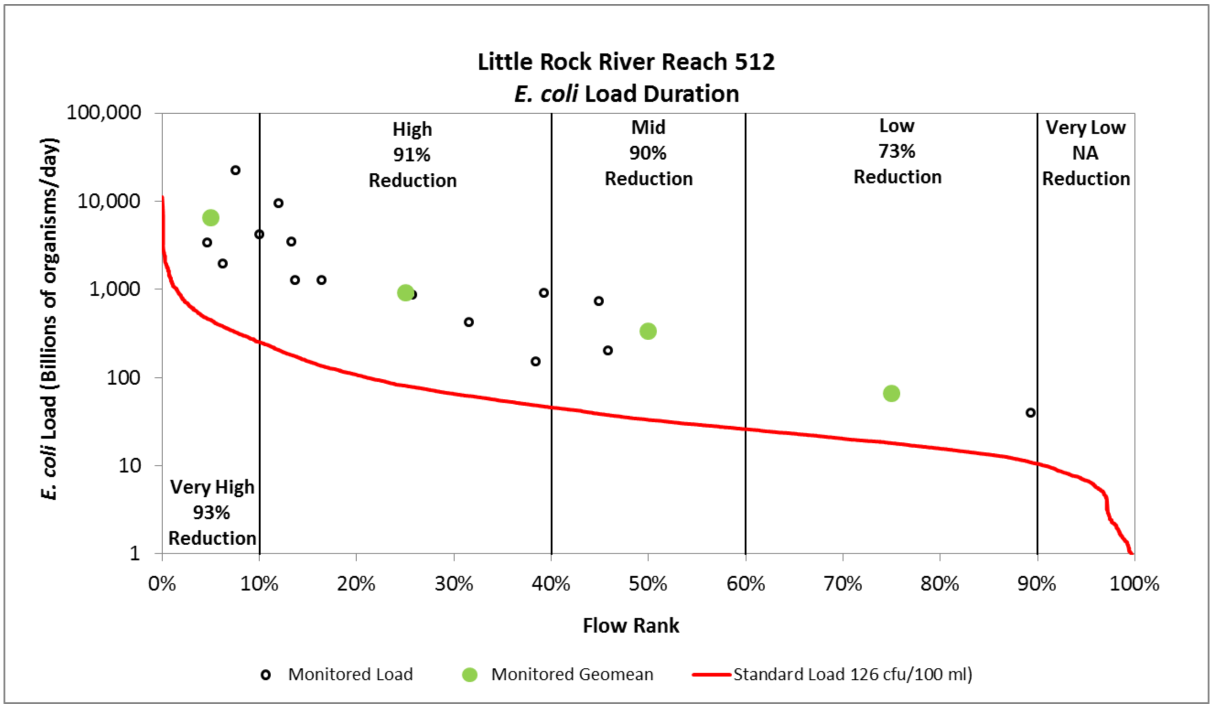

Figure 51. Little Rock River Reach 512 *E. coli* load duration and TMDL reductions.

Table 62. Little Rock River Reach 512 *E. coli* TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		***E. coli* Load (billions of organisms/day)**				
Wasteload	**Total WLA**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Load	**Total LA**	**402.39**	**72.99**	**29.79**	**16.2**	**6.39**
	MN Watershed Nonpoint Sources	402.39	72.99	29.79	16.2	6.39
MOS		**44.71**	**8.11**	**3.31**	**1.8**	**0.71**
TOTAL LOAD (TMDL)		**447.1**	**81.1**	**33.1**	**18.0**	**7.1**
Existing Load (geomean of observed data)		6,444	919	338	66	NA**
Estimated Reduction (%)		93%	91%	90%	73%	NA**

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

** Not enough data at this time to estimate a reduction.

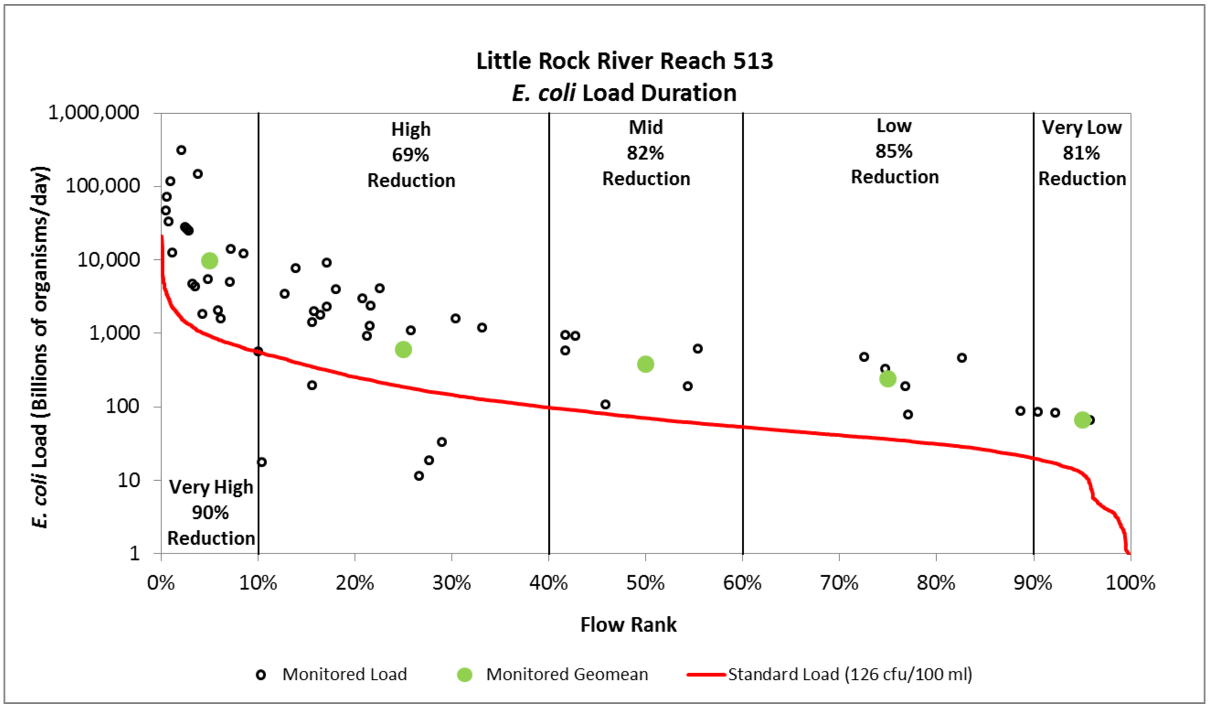

Figure 52. Little Rock River Reach 513 *E. coli* load duration and TMDL reductions.

Table 63. Little Rock River Reach 513 *E. coli* TMDL.

		Flow Zone*				
		Very High	**High**	**Mid**	**Low**	**Very Low**
		***E. coli* Load (billions of organisms/day)**				
Wasteload	**Total WLA**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**
	Rushmore WWTP	4.5	4.5	4.5	4.5	4.5
Load	**Total LA**	**825.3**	**163.8**	**58.5**	**27.9**	**6.3**
	MN Watershed Nonpoint Sources	825.3	163.8	58.5	27.9	6.3
MOS		**92.2**	**18.7**	**7**	**3.6**	**1.2**
TOTAL LOAD (TMDL)		**922.0**	**187.0**	**70.0**	**36.0**	**12.0**
Existing Load (geomean of observed data)		9,678	608	387	243	64
Estimated Reduction (%)		90%	69%	82%	85%	81%

* HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.

4.6 Nutrients

4.6.1 Loading Capacity Methodology

The first step in developing excess nutrient TMDLs for lakes is to determine the total nutrient loading capacity for the lake. A key component for this determination is to estimate each source's current phosphorus loading to the lake. Next, lake response to phosphorus loading is modeled using the Canfield-Bachmann lake equation for each impaired lake and the final loading capacity is determined. The components of this process are described in the following sub-sections below.

4.6.1.1 Watershed Loading

For Okabena Lake, watershed flow and phosphorus loads were estimated using monitored data and P8 model results from the Okabena Lake Diagnostic Study (Wenck Associates 2015; Appendix F). For all other lakes, watershed flow and phosphorus loads were estimated using the Little Sioux River HSPF model. Annual flow and phosphorus loads for each lake were incorporated into a spreadsheet version of the Canfield-Bachmann lake equation (Appendix G).

4.6.1.2 SSTS Loading

Failing SSTS can be an important source of phosphorus to surface waters. Currently, the exact number and status of SSTS in the Little Sioux River Watershed is unclear. The MPCA's 10 Year Plan to Upgrade and Maintain Minnesota's On-Site Treatment Systems (MPCA 2013) includes some information regarding the performance of SSTS in the Little Sioux River Watershed. To address noncompliant or failing SSTS and phosphorus loading to impaired lakes, HSPF modeled phosphorus loading from SSTS (RESPEC 2014a) was used in the Canfield-Bachmann lake equation.

4.6.1.3 Upstream Lakes

Some of the lakes have upstream impaired lakes which are also addressed in this TMDL. Meeting water quality standards in the downstream lakes is contingent on water quality improvements in the impaired upstream lakes. For these situations, lake outflow loads from the upstream lakes were routed directly into the downstream lake, and were estimated using flow results from the HSPF model and monitored lake water quality data. The allowable loads in the tables for Ocheda Lake (West Basin), Bella Lake and Loon Lake are based on the assumption that the upstream lakes are meeting their WQ standard. The estimated loads coming out of these lakes are based on the WQ standard of 90 ppb. As such, significant reductions in phosphorus load from upstream lakes would be expected for the downstream lakes to achieve standards. The spreadsheet output in Appendix G (Tables G3 – G6; G15 – G16) allows for comparison of the current estimate for P load outflow from upstream lakes and the expected P load outflow if the lakes were meeting standards.

4.6.1.4 Atmospheric Deposition

The atmospheric load refers to the load applied directly to the surface of the lake through atmospheric deposition. Atmospheric inputs of phosphorus from wet and dry deposition were estimated using results of the Okabena Lake Diagnostic Study (Wenck Associates 2015; Appendix F).

4.6.1.5 Internal Loading

Internal phosphorus loading from lake sediments can be a major component of a lake's phosphorus budget. Internal loading is typically the result of organic sediment releasing phosphorus to the water column. This often occurs when anoxic conditions are present, meaning that the water in and above the sediment is devoid of oxygen. Studies have shown that internal loading occurs even when the overlying water column is well oxygenated, however, release rates are typically an order of magnitude lower. To estimate internal load in lakes, an anoxic factor (AF)(Nürnberg 2004) is often used which estimates the period of anoxia over the lake sediments. The AF is typically calculated using temperature-DO profiles. However, AFs are often difficult to measure in shallow lakes since they can have intermittent anoxic periods that aren't measured with routine monitoring. For this reason, AFs for shallow lakes are regularly underestimated, which subsequently will result in inaccurate internal release rate calculations. Due to the difficulty of measuring shallow lake anoxia, a shallow lake AF equation was used to calculate AFs for all of the impaired lakes in this TMDL (Nurnberg 2005).

To calculate total internal load for each lake, the AF (days) was multiplied by an estimated phosphorus release rate (mg/m^2/day). Release rates can be obtained by collecting sediment cores in the field and incubating them in the lab under oxic and/or anoxic conditions to measure phosphorus release over time. For Okabena Lake, sediment cores were collected and release rates were measured in the lab as part of the Okabena Lake Diagnostic Study (Wenck Associates 2015; Appendix F). Sediment release rates were not measured for any of the other lakes in this TMDL. For these lakes, model residuals were used to determine an appropriate sediment release rate value. Selected release rates and calculated AFs are provided in Appendix G.

For some of the lakes in the Missouri River Basin, internal load is a significant source of phosphorus and in-lake efforts will be important to achieve water quality standards. Any improvements to water quality derived from in-lake efforts will be temporary if external sources are not better controlled so as to reduce the build-up of internal phosphorus. First, implementation activities will need to focus on upland BMPs to prevent phosphorus sources from getting in to the lake. Once upland sources have been addressed, in-land management activities such as rough fish management, alum treatment, aquatic plant management, and various others are options to decrease phosphorus loading from the lake sediments.

4.6.1.6 Canfield-Bachmann Lake Response Model

Once the nutrient budget for a lake has been developed, the response of the lake to those nutrient loads must be established. Lake response was modeled using the Canfield-Bachmann lake equation (Canfield and Bachmann 1981). This equation estimates the lake phosphorus sedimentation rate, which is needed to predict the relationship between in-lake phosphorus concentrations and phosphorus load inputs. The phosphorus sedimentation rate is an estimate of net phosphorus loss from the water column through sedimentation to the lake bottom, and is used in concert with lake-specific characteristics such as annual phosphorus loading, mean depth, and hydraulic flushing rate to predict in-lake phosphorus concentrations. These model predictions are compared to measured data to evaluate how well the model describes the lake system. If necessary, the model parameters are adjusted appropriately to achieve an approximate match to monitored data. Once a model is calibrated, the resulting relationship between phosphorus load and in-lake water quality is used to determine the assimilative capacity.

To set the TMDL for each impaired lake, the nutrient inputs partitioned between sources in the lake response models were systematically reduced until the model predicted that each lake met their current ecoregion TP standard. Construction, calibration, and results of the Canfield-Bachmann lake response models for each lake are presented in Appendix G.

4.6.2 Wasteload Allocation Methodology

The WLA were divided into three primary categories: NPDES permitted wastewater dischargers, NPDES permitted MS4s stormwater, and NPDES-permitted construction and industrial stormwater. The following sections describe how each permitted source was calculated for the impaired lakes covered in this TMDL.

4.6.2.1 Permitted Wastewater Dischargers

There are currently no permitted wastewater dischargers located in the impaired lake watersheds.

4.6.2.2 Permitted MS4 Stormwater

The city of Worthington in the Okabena Lake Watershed is the only MS4 in the Little Sioux River Watershed. Figure 2 of this TMDL shows the city of Worthington’s municipal boundary and its location in the Little Sioux River Watershed. The city accounts for approximately 15% of the Okabena Lake Watershed. Allocations for the city of Worthington were calculated using the watershed P8 model developed for the Okabena Lake Diagnostic Study (Wenck Associates 2015; Appendix F). The watershed model was set up so that contributions from the city of Worthington and the non-city (rural) portions of the watershed could be evaluated independently (see Appendix B of the Diagnostic Study).

4.6.2.3 Permitted Construction and Industrial Stormwater

Construction and industrial stormwater WLAs were established based on estimated percentage of land in the Little Sioux River Watershed currently under construction or permitted for industrial use. A recent permit review across the Little Sioux River Watershed (see section 4.3.3.3) showed minimal construction and industrial activities (0.3% of the watershed).

4.6.3 Load Allocation Methodology

The LA, also referred to as the watershed LA, includes all non-permitted and nonpoint sources, including: natural background, atmospheric deposition, SSTS, discharge from upstream lakes, watershed loading from non-regulated areas, and internal loading.

The LA is the portion of the total loading capacity assigned to nonpoint and natural background sources of nutrient loading. These sources include the atmospheric loading and nearly all of the loading from watershed runoff. The only portion of the watershed runoff not included in the LA is the small loading set aside for regulated stormwater runoff from construction and industrial sites. The LA includes nonpoint sources that are not subject to NPDES Permit requirements, as well as natural background sources. These include sources of phosphorus such as soil erosion or nutrient leaching from cropland, phosphorus-laden runoff from communities not covered by NPDES Permits, and streambed and streambank erosion resulting from human-induced hydrologic changes and disturbance of stream channels and riparian areas. In addition, some phosphorus may leach into the reservoir/lake or its upstream tributaries from failing SSTS.

Natural background sources of phosphorus include atmospheric deposition, as well as the relatively low levels of soil erosion from both stream channels and upland areas that would occur under natural conditions. The TMDL does not attempt to quantify the natural background load as a separate component of the LA for the impaired lakes. Natural background load is likely a very small part of the LA for lakes in the Missouri River Basin. Studies indicate runoff load of nutrients and other pollutants from urban, agricultural and other developed or disturbed lands is generally at least an order of magnitude greater than runoff loads from natural landscapes (Barr Engineering 2004). Any estimate of natural background as a separate component of the LA would be very difficult to derive and would have a large potential for error without expensive, special studies such as paleolimnological analysis of sediment cores. Given the highly altered landscape in which the Missouri River Basin lakes are located, it is unlikely natural background is a major component of phosphorus loading.

There are three impaired lakes (Bella, Indian and Iowa) in the Little Sioux River Watershed that cross the Minnesota – Iowa state boundary and/or have watershed areas in both states. See Section 1.2 and Figure 2 for description. For these lakes, individual state watershed LAs were assigned by multiplying each state’s percent watershed coverage (determined in the GIS) by the total watershed LA.

4.6.4 Margin of Safety

An explicit MOS was used for each of the impaired lake TMDLs in this TMDL. Five percercnt of the load was set aside in the Okabena Lake TMDL to account for uncertainty in the lake response model while 10% of the load was set aside for the other lakes. The Missouri River Basin HSPF model was calibrated and validated using 15 years (1995 through 2009) of flow data from gaging stations: 6605000 and 6605850. Calibration results indicate that the HSPF model is a valid representation of hydrological and chemical conditions in the watershed. See Appendix E of this TMDL report for the HSPF model calibration and validation results. The 5% MOS was considered reasonable for Okabena Lake since this lake has a longer period of in-lake monitoring compared to the other lakes and has a more thorough understanding of external and internal loads (see Appendix F). A slightly higher MOS of 10% was used for the other lakes due to less watershed and in-lake monitoring data.

4.6.5 Seasonal Variation

Seasonal variation is accounted for through the use of annual loads and developing targets for the summer period, where the frequency and severity of nuisance algal growth will be the greatest. Although the critical period is the summer, lakes are not sensitive to short term changes in water quality, rather lakes respond to long-term changes such as changes in the annual load. Therefore, seasonal variation is accounted for in the annual loads. By setting the TMDL to meet targets established for the most critical period (summer), the TMDL will inherently be protective of water quality during the other seasons.

4.6.6 Lake Nutrient Reduction Methodology

This is an explanation of the steps used in the lake model to calculate lake nutrient reductions to meet the TMDLs. The following items were taken into account: atmospheric sources, upstream lakes, SSTS loading, watershed conditions, and internal load. A uniform methodology was established to assign load reductions to the various sources to meet TMDL goals. The steps for nutrient reductions are discussed below:

- No reductions to atmospheric load were assigned since these loads were generally a small portion of the total load to the lake and the sources are extremely difficult to define and control
- All upstream lakes are expected to meet water quality standards, and the resultant reductions are applied to the lake being evaluated. If these reductions result in the lake meeting water quality standards, then the TMDL allocations are done. If more reductions are required, then the internal and external loads are evaluated simultaneously.
- Loading from failing SSTS is reduced to zero since properly functioning SSTS should have zero phosphorus export. See Reasonable Assurance SSTS Section 6.1.5.
- Watershed loading will ideally be reduced until the lake response model indicates the lake is meeting lake water quality standards. Watershed loading will be incrementally reduced until watershed TP concentrations meet river/stream eutrophication standards. If the lake is still not meeting water quality standards and watershed phosphorus concentrations have been reduced to meet the river/stream eutrophication standards, the remaining phosphorus reduction will be taken from internal loading.

- For some of the lakes in the Missouri River Basin, internal load is a significant source of phosphorus and in-lake efforts will be important to achieve water quality standards. Any improvements to water quality derived from in-lake efforts will be temporary if external sources are not better controlled so as to reduce the build-up of internal phosphorus. First, implementation activities will need to focus on upland BMPs to prevent phosphorus sources from getting in to the lake. Once upland sources have been addressed, in-lake management activities such as rough fish management, alum treatment, aquatic plant management, and various others are options to decrease phosphorus loading from the lake sediments. It is believed that if external sources can be controlled, the internal load will reduce itself over time.
- The general approach to internal load reductions is based on review of the existing sediment release rates and lake morphometry. This is accomplished by reviewing the release rates versus literature values of healthy lakes. If the estimated release rate is high, then the rate is reduced systematically until either a minimum of 1 $mg/m^2/day$ is reached or the lake meets TMDL requirements. In a few cases, internal release rates less than 1 $mg/m^2/day$ were required in order for the lake to meet State water quality standards.

4.6.7 Little Sioux River Watershed Lake Nutrient TMDLs

The allowable TP load (TMDL) for each lake was divided among the WLA, LA , and the MOS as described in the preceding sections. The following tables summarize the existing and allowable TP loads (Total Load in tables), the TMDL allocations (Wasteload and Load in tables), and required reductions for each lake. In these tables the total load reduction is the sum of the required WLA reductions plus the required LA reductions; this is not the same as the net difference between the existing and allowable total loads, however, because the WLA and LA reductions must accommodate the MOS.

The following rounding conventions were used in the TMDL tables:

- Values ≥1.0 reported in lbs/yr have been rounded to the nearest pound.
- Values <1.0 reported in lbs/yr have been rounded to enough significant digits so that the value is greater than zero and a number is displayed in the table.
- Values ≥0.01 reported in lbs/day have been rounded to the nearest hundredth of a pound
- Values <0.01 reported in lbs/day have been rounded to enough significant digits so that the value is greater than zero and a number is displayed in the table.
- While some of the numbers in the tables show multiple digits, they are not intended to imply great precision; this is done primarily to make the arithmetic accurate.

Tables 64 through 71 present the allocations for the impaired lakes in the Little Sioux River Watershed.

Table 64. Okabena Lake TP TMDL.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr[1]	%
Wasteload	**Total WLA**	**512**	**1.40**	**439**	**1.21**	**73**	**14%**
	Construction and Industrial Stormwater	6	0.02	6	0.02	0	0%
	Worthington City MS4	506	1.38	433	1.19	73	14%
Load	**Total LA**	**6,298**	**17.25**	**2,486**	**6.80**	**3,812**	**61%**
	MN Watershed Nonpoint Sources	4,495	12.31	1,485	4.06	3,010	67%
	Atmosphere	379	1.04	379	1.04	0	0%
	Internal Load	1,413	3.87	622	1.70	791	56%
	SSTS	11	0.03	0	0.00	11	100%
MOS				**154**	**0.42**		
Total Load		**6,810**	**18.65**	**3,079**	**8.43**	**3,885**	**57%**

[1] Net reduction from current load to TMDL is 3,731 lbs/yr; but the gross load reduction from all sources must accommodate the MOS as well, and hence is 3,731 + 154 = 3,885 lbs/yr.
Model Calibration Year(s): 2010 through 2015

Table 65. Ocheda Lake (West Basin) TP TMDL.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr[1]	%
Wasteload	**Total WLA**	**25**	**0.07**	**25**	**0.07**	**0**	**0%**
	Construction and Industrial Stormwater	25	0.07	25	0.07	0	0%
Load	**Total LA**	**22,131**	**60.60**	**6,646**	**18.20**	**15,485**	**70%**
	MN Watershed Nonpoint Sources	7,973	21.83	3,497	9.57	4,476	56%
	Upstream Lake (Ocheda – Middle Basin)	9,338	25.57	2,785	7.63	6,553	70%
	Atmosphere	229	0.63	229	0.63	0	0%
	Internal Load	4,581	12.54	135	0.37	4,446	97%
	SSTS	10	0.03	0	0.00	10	100%
MOS				**741**	**2.03**		
Total Load		**22,156**	**60.67**	**7,412**	**20.30**	**15,485**	**70%**

[1] Net reduction from current load to TMDL is 14,744 lbs/yr; but the gross load reduction from all sources must accommodate the MOS as well, and hence is 14,744 + 741 = 15,485 lbs/yr.
Model Calibration Year(s): 2007 & 2008
(Please note that there is a portion of Worthington MS4 that drains to Ocheda Lake – Middle Basin, however for the purposes of the TMDL for the West Basin, the Middle Basin was modeled as an upstream boundary condition and included in the LA. Therefore, Worthington would be included in the Ocheda – Middle Basin LA and not receive a WLA for the West Basin TMDL.)

Table 66. Bella Lake TP TMDL.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr[1]	%
Wasteload	**Total WLA**	**11**	**0.03**	**11**	**0.03**	**0**	**0%**
	Construction and Industrial Stormwater	11	0.03	11	0.03	0	**0%**
Load	**Total LA**	**13,386**	**36.65**	**5,591**	**15.31**	**7,795**	**58%**
	MN Watershed Nonpoint Sources	3,243	8.88	1,871	5.12	1,372	42%
	IA Watershed Nonpoint Sources	220	0.60	127	0.35	93	42%
	Upstream Lake (Ocheda – West Basin)	9,825	26.90	3,502	9.59	6,323	64%
	Atmosphere	81	0.22	81	0.22	0	0%
	Internal Load	10	0.03	10	0.03	0	0%
	SSTS	8	0.02	0	0.00	8	100%
MOS				**622**	**1.70**		
Total Load		**13,397**	**36.68**	**6,224**	**17.04**	**7,795**	**58%**

[1] Net reduction from current load to TMDL is 7,173 lbs/yr; but the gross load reduction from all sources must accommodate the MOS as well, and hence is 7,173 + 622 = 7,795 lbs/yr.
Model Calibration Year(s): 2008 & 2009

Table 67. Indian Lake TP TMDL.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr[1]	%
Wasteload	**Total WLA**	**17**	**0.05**	**17**	**0.05**	**0**	**0%**
	Construction and Industrial Stormwater	17	0.05	17	0.05	0	**0%**
Load	**Total LA**	**5,420**	**14.84**	**2,280**	**6.25**	**3,140**	**58%**
	MN Watershed Nonpoint Sources	4,865	13.32	2,001	5.48	2,864	59%
	IA Watershed Nonpoint Sources	457	1.25	189	0.52	268	59%
	Atmosphere	80	0.22	80	0.22	0	0%
	Internal Load	10	0.03	10	0.03	0	0%
	SSTS	8	0.02	0	0.00	8	100%
MOS				**255**	**0.70**		
Total Load		**5,437**	**14.89**	**2,552**	**7.00**	**3,140**	**58%**

[1] Net reduction from current load to TMDL is 2,885 lbs/yr; but the gross load reduction from all sources must accommodate the MOS as well, and hence is 2,885 + 255 = 3,140 lbs/yr.
Model Calibration Year(s): 2009 - 2011

Table 68. Iowa Lake TP TMDL.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr[1]	%
Wasteload	**Total WLA**	**12**	**0.03**	**12**	**0.03**	**0**	**0%**
	Construction and Industrial Stormwater	12	0.03	12	0.03	0	**0%**
Load	**Total LA**	**4,288**	**11.74**	**1,224**	**3.35**	**3,064**	**71%**
	MN Watershed Nonpoint Sources	690	1.89	163	0.45	527	76%
	IA Watershed Nonpoint Sources	3,254	8.91	812	2.22	2,442	75%
	Atmosphere	120	0.33	120	0.33	0	0%
	Internal Load	219	0.60	129	0.35	90	41%
	SSTS	5	0.01	0	0.00	5	100%
MOS				**137**	**0.38**		
Total Load		**4,300**	**11.77**	**1,373**	**3.76**	**3,064**	**71%**

[1] Net reduction from current load to TMDL is 2,927 lbs/yr; but the gross load reduction from all sources must accommodate the MOS as well, and hence is 2,927 + 137 = 3,064 lbs/yr.
Model Calibration Year(s): 2010 & 2011

Table 69. Round Lake TP TMDL.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr[1]	%
Wasteload	**Total WLA**	**11**	**0.03**	**11**	**0.03**	**0**	**0%**
	Construction and Industrial Stormwater	11	0.03	11	0.03	0	**0%**
Load	**Total LA**	**4,255**	**11.65**	**2,260**	**6.19**	**1,995**	**47%**
	MN Watershed Nonpoint Sources	3,561	9.75	1,573	4.31	1,988	56%
	Atmosphere	411	1.12	411	1.12	0	0%
	Internal Load	276	0.76	276	0.76	0	0%
	SSTS	7	0.02	0	0.00	7	100%
MOS				**252**	**0.69**		
Total Load		**4,266**	**11.68**	**2,523**	**6.91**	**1,995**	**47%**

[1] Net reduction from current load to TMDL is 1,743 lbs/yr; but the gross load reduction from all sources must accommodate the MOS as well, and hence is 1,743 + 252 = 1,995 lbs/yr.
Model Calibration Year(s): 2008 & 2009

Table 70. Clear Lake TP TMDL.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr[1]	%
Wasteload	**Total WLA**	**3**	**0.01**	**3**	**0.01**	**0**	**0%**
	Construction and Industrial Stormwater	3	0.01	3	0.01	0	0%
Load	**Total LA**	**2,121**	**5.81**	**1,370**	**3.75**	**751**	**35%**
	MN Watershed Nonpoint Sources	1,003	2.75	577	1.58	426	43%
	Atmosphere	206	0.56	206	0.56	0	0%
	Internal Load	910	2.49	587	1.61	323	35%
	SSTS	2	0.01	0	0.00	2	100%
MOS				**153**	**0.42**		
Total Load		**2,124**	**5.82**	**1,526**	**4.18**	**751**	**35%**

[1] Net reduction from current load to TMDL is 598 lbs/yr; but the gross load reduction from all sources must accommodate the MOS as well, and hence is 598 + 153 = 751 lbs/yr.
Model Calibration Year(s): 2005 through 2009

Table 71. Loon Lake TP TMDL.

		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr[1]	%
Wasteload	**Total WLA**	**57**	**0.15**	**57**	**0.15**	**0**	**0%**
	Construction and Industrial Stormwater	57	0.15	57	0.15	0	**0%**
Load	**Total LA**	**28,085**	**76.84**	**5,478**	**15.00**	**22,607**	**80%**
	MN Watershed Nonpoint Sources	17,985	49.20	4,747	13.00	13,238	74%
	Upstream Lake (Clear Lake)	151	0.40	126	0.35	25	16%
	Atmosphere	337	0.90	337	0.92	0	0%
	Internal Load	9,597	26.30	268	0.73	9,329	97%
	SSTS	15	0.04	0	0.00	15	100%
MOS				**615**	**1.68**		
Total Load		**28,142**	**76.99**	**6,150**	**16.83**	**22,607**	**80%**

[1] Net reduction from current load to TMDL is 21,992 lbs/yr; but the gross load reduction from all sources must accommodate the MOS as well, and hence is 21,992 + 615 = 22,607 lbs/yr.
Model Calibration Year(s): 2005 through 2009

5 Future Growth Considerations

According to the Minnesota State Demographic Center (Minnesota Department of Administration 2015) from 2015 to 2035, the populations of Nobles and Jackson counties are both projected to increase by 1% and 4%, respectively. This population growth will likely occur in the few urban areas in these two counties and will result in a negligible amount of change from agricultural to urban land use. Lincoln, Pipestone, Rock, and Murray counties all have negative population projections. The overall projection for all six counties is negative 5%. The MPCA does not anticipate significant population growth within the Missouri River Basin in Minnesota.

5.1 New or Expanding Permitted MS4 Allocation 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 regulated 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 regulated MS4 acquires land from another regulated MS4. Examples include annexation or highway expansions. In these cases, the transfer is WLA to WLA.
3. One or more non-regulated MS4s become regulated. 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 Urban 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 point source is identified and is covered under a NPDES 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 regulated MS4, the permittees will be notified of the transfer and have an opportunity to comment.

5.2 New or Expanding Wastewater (TSS and *E. coli* TMDLs only)

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 waterbodies with an EPA approved TMDL (MPCA 2012). 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 handled 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.

For more information on the overall process visit the MPCA's *TMDL Policy and Guidance* webpage.

6 Reasonable Assurance

A TMDL needs to provide reasonable assurance that water quality targets will be achieved through the specified combination of point and nonpoint source reductions reflected in the LAs and WLAs. According to EPA guidance (EPA 2002), "When a TMDL is developed for waters impaired by both point and nonpoint sources, and the WLA is based on an assumption that nonpoint-source load reductions will occur... the TMDL should provide reasonable assurances that nonpoint-source control measures will achieve expected load reductions in order for the TMDL to be approvable. This information is necessary for the EPA to determine that the TMDL, including the LA and WLAs, has been established at a level necessary to achieve water quality standards". In the Missouri River Basin considerable reductions in nonpoint sources are required.

The MPCA will:

- Evaluate existing programmatic, funding, and technical capacity to implement basin and watershed strategies.
- Identify gaps in current programs, funding, and local capacity to achieve the needed controls.
- Build program capacity for short-term and long-term goals. Demonstrate increased implementation and/or pollutant reductions.
- Commit to track/monitor/assess and report progress at set regular times.

6.1 Regulatory

6.1.1 Construction Stormwater

State implementation of the TMDL will be through action on NPDES Permits for regulated construction stormwater. To meet the WLA for construction stormwater, construction stormwater activities are required to meet the conditions of the Construction General Permit under the NPDES program and properly select, install, and maintain all BMPs required under the permit, including any applicable additional BMPs required in Appendix A of the Construction General Permit for discharges to impaired waters, or meet local construction stormwater requirements if they are more restrictive than requirements of the State General Permit.

6.1.2 Industrial Stormwater

To meet the WLA for industrial stormwater, industrial stormwater activities are required to meet the conditions of the industrial stormwater general permit or Nonmetallic Mining & Associated Activities general permit (MNG49) under the NPDES program and properly select, install and maintain all BMPs required under the permit.

6.1.3 Municipal Separate Storm Sewer System (MS4) Permits

Stormwater discharges associated with MS4s are regulated through NPDES/SDS Permits. The Stormwater Program for MS4s is designed to reduce the amount of sediment and pollution that enters surface and ground water from storm sewer systems to the maximum extent practicable. The MS4

Permits require the implementation of BMPs to address WLAs. The permit holder must identify BMPs and measurable goals associated with each minimum control measure. NPDES Phase II MS4 Stormwater Permits are in place for approximately 1,438 acres of the city of Worthington that flows to Okabena Lake in the Little Sioux River Watershed. Under the stormwater program, permit holders are required to develop and implement a Stormwater Pollution Prevention Plan (SWPPP; MPCA 2004). The SWPPP must cover six minimum control measures:

- Public education and outreach;
- Public participation/involvement;
- Illicit discharge, detection and elimination;
- Construction site runoff control;
- Post-construction site runoff controls;
- Pollution prevention/good housekeeping

The MPCA's MS4 general permit requires MS4 permittees to provide reasonable assurances that progress is being made toward achieving all WLAs in TMDLs approved by the EPA prior to the effective date of the permit. The current permit was made effective August 1, 2013, meaning regulatory requirements resulting from the TMDLs presented in this TMDL will not be enforced until the subsequent permit term. In doing so, they must determine if they are currently meeting their WLA(s). If the WLA is not being achieved at the time of application, a compliance schedule is required that includes interim milestones, expressed as BMPs, that will be implemented over the current five-year permit term to reduce loading of the pollutant of concern in the TMDL. Additionally, a long-term implementation strategy and target date for fully meeting the WLA must be included.

6.1.4 Wastewater NPDES & SDS Permits

The MPCA issues permits for WWTPs or industrial facilities that discharge into waters of the state. The permits have site specific limits on bacteria or TSS that are based on water quality standards. WWTPs discharging into impaired reaches did not require any changes to their discharge permit limits due to the WLAs calculated in this TMDL report. Permits regulate discharges with the goals of 1) protecting public health and aquatic life, and 2) assuring that every facility treats wastewater. In addition, NPDES and SDS Permits set limits and establish controls for land application of waste and byproducts.

Southwest Minnesota is a leader in addressing unsewered communities, which can be a source of nutrients and pathogens to surface waters. Since 1996, the MPCA southwest wastewater staff have helped 33 small communities upgrade their sewer systems throughout the region. The unsewered communites of Trosky and Reading are currently working with the state and local governments to construct wastewater treatment pond systems.

6.1.5 Subsurface Sewage Treatment Systems (SSTS) Program

SSTS, commonly known as septic systems, are regulated by Minn. Stat. §§ 115.55 and 115.56. Counties and other local units of government (LUGs) that regulate SSTS must meet the requirements for local SSTS programs in Minn. R. ch. 7082. Counties and other LUGs must adopt and implement SSTS ordinances in compliance with Minn. R. chs. 7080 - 7083.

These regulations detail:

- Miniumum technical standards for individual and mid-size SSTS;
- A framework for LUG to administer SSTS programs and;
- Statewide licensing and certification of SSTS professionals, SSTS product review and registration, and establishment of the SSTS Advisory Committee.

Counties and other LUGs enforce Minn. R. chs. 7080 through 7083 through their local SSTS ordinance and issue permits for systems designed with flows up to 10,000 gallons per day. There are approximately 200 LUGs across Minnesota, and depending on the location an LUG may be a county, city, township, or sewer district. LUG SSTS ordinances vary across the state. Some require SSTS compliance inspections prior to property transfer, require permits for SSTS repair and septic tank maintenance, and may have other requirements which are stricter than the state regulations.

Compliance inspections by Counties and other LUGs are required byMinnesota Rule for all new construction and for existing systems if the LUG issues a permit for the addition of a bedroom. In order to increase the number of compliance inspections, the MPCA has developed and administers several grants to LUGs for various ordinances, specific actions. Additional grant dollars are awarded to counties that have additional provisions in their ordinance above the minimum program requirements. The MPCA has worked with counties through the SSTS Implementation and Enforcement Task Force (SIETF) to identify the most beneficial way to use these funds to accelerate SSTS compliance statewide. Current information from the grants to date:

- Compliance inspection for property transfer – ($123,000 awarded)
- Compliance inspection for any (all) permit-countywide – ($27,000 awarded)
- Plan to improve compliance, like records catalog or inventory (past, ongoing or future) – ($32,500 awarded)
- Plan to address Unsewered Areas – $12,500 awarded

The MPCA staff keep a statewide database of known ITPHS systems that include “straight pipe systems”. These straight pipe systems are reported to the counties or the MPCA by the public. Upon confirmation of a straight pipe system, the county sends out a notification of non-compliance, which starts a 10-month deadline to fix the system and bring it into compliance. From 2006 through 2017, 742 straight pipes have been tracked by the MPCA. Seven hundred-one of those were abandoned, fixed, or were found not to be a straight pipe system as defined in Minn. Stat. 115.55, subd. 1. There have been 17 Administrative Penalty Orders issued and docketed in court. The remaining straight pipe systems received a notification of non-compliance and are currently within the 10 month deadline.

Since 1996, the MPCA southwest wastewater staff have helped 18 small communities build wastewater soil treatment systems throughout the region. The unsewered communities of Kanaranzi, Loon Lake, Pipestone North and South Subdivisions, Round Lake Campground, St. Killian, and Verdi are all addressing their wastewater treatment through SSTS upgrades regulated by county ordinances and funded by various sources, such as the Clean Water Fund and Clean Water Partnership (CWP) State Revolving Fund (SRF) Loan Program. Through local implementation of $376,424 CWP-SRF loan program funds, Murray, Nobles, Pipestone, and Rock counties upgraded 30 SSTS’s from 2010 through2013.

Nobles, Pipestone, and Rock counties are in the prcess of utilizing an additional $450,000 CWP-SRF loan program funds for upgrades of 35 more SSTS's by 2017.

6.1.6 Feedlot Program

All feedlots in Minnesota are regulated by Minn. R. ch. 7020. The MPCA has regulatory authority of feedlots but counties may choose to participate in a delegation of the feedlot regulatory authority to the local unit of government. Delegated counties are then able to enforce Minn. R. ch. 7020 (along with any other local rules and regulations) within their respective counties for facilities that are under the CAFO threshold. In the Missouri River Basin, the counties of Lincoln, Pipestone, Rock, Murray, Nobles, and Jackson are delegated the feedlot regulatory authority. The Counties will continue to implement the feedlot program and work with produces on manure management plans.

The MPCA regulates the collection, transportation, storage, processing and disposal of animal manure and other livestock operation waste. The MPCA Feedlot Program implements rules governing these activities, and provides assistance to counties and the livestock industry. The feedlot rules apply to most aspects of livestock waste management including the location, design, construction, operation and management of feedlots and manure handling facilities.

There are two primary concerns about feedlots in protecting water:

- Ensuring that manure on a feedlot or manure storage area does not run into water.
- Ensuring that manure is applied to cropland at a rate, time and method that prevents bacteria and other possible contaminants from entering streams, lakes and ground water.

6.1.7 Nonpoint Source

Existing nonpoint source statutes/rules:

- 50-foot buffer required for the shore impact zone of streams classified as protected waters (Minn. Stat. § 103F.201) for agricultural land uses. November 1, 2017 is the deadline for compliance. Currently, 64 of Minnesota's 87 counties are 60% to 100% in compliance with the buffer law.
- 16.5-foot minimum width buffer required on public drainage ditches (Minn. Stat. § 103E.021). November 1, 2018 is the deadline for compliance.
- Protecting highly erodible land within the 300-foot shoreland district (Minn. Stat. § 103F.201).
- Excessive soil loss statute (Minn. Stat. § 103F.415)
- Nuisance nonpoint source pollution (Minn. R. 7050.0210, subp. 2)

6.2 Non-regulatory

6.2.1 Pollutant Load Reduction

Reliable means of reducing nonpoint source pollutant loads are fully addressed in the WRAPS report (MPCA 2017), a document that is written to be a companion to this TMDL report. In order for the impaired waters to meet water quality standards the majority of pollutant reductions in the Missouri River Basin will need to come from nonpoint sources. Agricultural drainage and surface runoff are major contributors of nutrients, bacteria, sediment, and increased flows throughout the watershed. As described in the WRAPS report, the BMPs included there have all been demonstrated to be effective in reducing transport of pollutants to surface water. The combinations of BMPs discussed throughout the WRAPS process were derived from Minnesota's Nutrient Reduction Strategy (NRS) (MPCA 2015) and related tools. As such, they were vetted by a statewide engagement process prior to being applied in the Missouri River Basin.

Selection of sites for BMPs will be led by LUGs, county SWCDs, watershed districts, county planning and zoning, with support from state and federal agencies. These BMPs are supported by programs administered by the SWCDs and the Natural Resource Conservation Service (NRCS). Local resource managers are well-trained in promoting, placing, and installing these BMPs. Some counties within the basin have shown significant levels of adoption of these practices. State and local agencies will need to work with landowners to identify priority areas for BMPs and practices that will help reduce nutrient runoff, as well as streambank and overland erosion. Agencies, organizations, LUGs, and citizens alike need to recognize that resigning waters to an impaired condition is not acceptable. Throughout the course of the WRAPS and TMDL meetings, local stakeholders endorsed the BMPs selected in the WRAPS report. These BMPs reduce pollutant loads from runoff (i.e. phosphorus, sediment and pathogens) and loads delivered through drainage tiles or groundwater flow (e.g. nitrates).

To help achieve nonpoint source reductions, a large emphasis has been placed on public participation, where the citizens and communities that hold the power to improve water quality conditions are involved in discussions and decision-making. The watershed's citizens and communities will need to voluntarily adopt the practices at the necessary scale and rates to achieve the 10-year targets presented in Tables 15-20 of the WRAPS report. These tables also present the allocations of the pollutant/stressor goals and targets to the primary sources and the estimated years to meet the goals developed by the WRAPS Local Work Group. The strategies identified and relative adoption rates developed by the WRAPS Local Work Group were used to calculate the adoption rates needed to meet the pollutant/stressor 10-year targets. In addition to public participation, several government programs are in place to support a political and social infrastructure that aims to increase the adoption of strategies that will improve watershed conditions and reduce loading from nonpoint sources.

One example of a government program available is *The Minnesota Agricultural Water Quality Certification Program* (MAWQCP). The 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.

Water Quality Trends for Minnesota Rivers and Streams at Milestone Sites notes that sites across Minnesota, including the Missouri River Basin, show reductions over the period of record for TSS, phosphorus, ammonia, and biochemical oxygen demand (MPCA 2014b). *The Minnesota NRS* documented a 33% reduction of the phosphorus load leaving the state via the Mississippi River from the pre-2000 baseline to current (MPCA 2015). These reports generally agree that while further reductions are needed, municipal and industrial phosphorus loads as well as loads of runoff-driven pollutants (i.e. TSS and TP) are decreasing; a conclusion that lends assurance that the Missouri River Basin WRAPS and TMDL phosphorus goals and strategies are reasonable and that long-term, enduring efforts to decrease erosion and nutrient loading to surface waters have the potential to reduce pollutant loads.

6.2.2 Prioritization

The WRAPS details a number of tools that provide means for identifying priority pollutant sources and implementation work in the watershed. Further, LGUs in the Missouri River Basin often employ their own local analysis for determining priorities for work.

The state of Minnesota has provided tools to further the buffer initiative; they are being used in the implementation planning process to examine riparian land use in the Missouri River Basin, and prioritize potential buffer installation. The Buffer Initiative was signed into law by Governor Dayton in June 2015 (amended by the Legislature and signed into law by Governor Dayton on April 25, 2016). It provides clarification regarding which waters need buffers, a timeline for implementing them, and tools for local government units to use in tracking and reporting compliance. http://www.bwsr.state.mn.us/buffers/ Light Detection and Ranging (LIDAR) data is available for all of the Missouri River Basin within Minnesota. It is being increasingly used by LGUs to examine landscapes, understand watershed hydrology, and prioritize BMP targeting.

6.2.3 Funding

On November 4, 2008, Minnesota voters approved the Clean Water, Land and Legacy Amendment to the constitution to:

- protect drinking water sources;
- protect, enhance, and restore wetlands, prairies, forests, and fish, game, and wildlife habitat;
- preserve arts and cultural heritage;
- support parks and trails; and
- protect, enhance, and restore lakes, rivers, streams, and groundwater

This is a secure funding mechanism with the explicit purpose of supporting water quality improvement projects.

Additionally, there are many other funding sources for nonpoint pollutant reduction work; they include but are not limited to Clean Water Act Section 319 grant programs, Board of Water and Soil Resources (BWSR) state Clean Water Fund implementation funding, and NRCS incentive programs. Programs and activities are also occurring at the local government level, where county staff, commissioners, and residents work together to address water quality issues. There have been approximately $243,000 of BWSR Clean Water Funds utilized for livestock waste abatement through local implementation by Pipestone, Nobles, and Rock County SWCDs since 2010. In 2013, Rock County SWCD completed a manure management education project using Section 319 grant funds to address bacteria impaiments within the Rock River Watershed.

Minnesota was awarded a $500 million Conservation Reserve Enhancement Program (CREP) funding that when implemented will convert approximately 60,000 acres of land to perennial cover (perpetual easements). The proposal indicates that "riparian areas and marginal agricultural land" will be targeted. This aligns precisely with statewide and Missouri River Basin strategies focused on converting marginal lands to perennials to reduce pollutant loading to surface and groundwater.

6.2.4 Planning and Implementation

The WRAPS, TMDLs, and all the supporting documents provide a foundation for planning and implementation. Subsequent planning, including imminent development of a "One Watershed-One Plan" for the Missouri River Basin, will draw on the goals, technical information, and tools to describe in detail strategies for implementation. For the purposes of reasonable assurance, the WRAPS document is sufficient in that it provides strategies for achieving pollutant reduction goals. However, many of the goals outlined in this TMDL report are very similar to objectives outlined in the Murray, Nobles, Pipestone and Rock County Water Plans. These county plans have the same goal of removing streams from the 303(d) Impaired Waters List. These plans provide watershed specific strategies for addressing water quality issues. In addition, the commitment and support from the local governmental units will ensure that this TMDL project is carried successfully through implementation.

Bacteria and TSS TMDLs have been completed In South Dakota for many of the tributaries in the Big Sioux River Watershed and are in the process of implementation. The Central Big Sioux River Watershed Project (SDDENR 2012) is a 10-year, multi-segment, multi-part TMDL implementation strategy designed to restore and/or maintain water quality in the Big Sioux River Basin in eastern South Dakota. Through the application of BMPs targeting sediment erosion and animal waste management, this project will restore water quality of the Big Sioux River and its tributaries to support the designated beneficial uses, and reach the TMDLs established for each waterbody.

The Iowa Nutrient Reduction Strategy (Iowa 2013) is a science and technology based approach to assess and reduce nutrients delivered to Iowa waterways and the Gulf of Mexico. The strategy outlines voluntary efforts to reduce nutrients in surface water from both point sources, such as WWTPs and industrial facilities, and nonpoint sources, including farm fields and urban areas, in a scientific, reasonable and cost effective manner.

6.2.5 Tracking Progress

Water monitoring efforts within the Missouri River Basin are diverse and constitute a sufficient means for tracking progress and supporting adaptive management. See Chapter 7 and Section 8.4.

6.2.6 Reasonable Assurance Summary

In summary, significant time and resources have been devoted to identifying the best BMPs and supporting their implementation via state initiatives and dedicated funding in southwest Minnesota and in the Missouri River Basin.

The WRAPS and TMDL process engaged partners to arrive at reasonable examples of BMP combinations that achieve pollutant reduction goals. Minnesota is a leader in watershed planning, monitoring, and tracking progress toward water quality goals. Finally, examples cited herein confirm that BMPs and restoration projects have proven to be effective over time and as stated in A15-1622 MCEA vs MPCA & MCES (Minnesota Court of Appeals 2016):

> *"We conclude that substantial evidence exists to conclude that voluntary reductions from nonpoint sources have occurred in the past and can be reasonably expected to occur in the future. The Nutrient Reduction Strategy (NRS) […] provides substantial evidence of existing state programs designed to achieve reductions in nonpoint source pollution as evidence that reductions in nonpoint pollution have been achieved and can reasonably be expected to continue to occur."*

7 Monitoring Plan

Several types of monitoring are necessary to track progress toward achieving the load reductions required for the TMDLs and the achievement of water quality standards. Water monitoring combined with tracking implementation of BMPs on the ground is critical in the adaptive management approach to implementing TMDLs. The LUGs will track the implementation of BMPs annually through BWSRs e-LINK system. Monitoring results will identify progress toward obtainable benchmark goals as well as shape the next course of action for implementation through adaptive management. Data from water quality monitoring programs enables water quality condition assessment and creates a long-term data set to track progress towards water quality goals. These programs will continue to collect and analyze data in the Missouri River Basin as part of *Minnesota's Water Quality Monitoring Strategy* (MPCA 2011a). Data needs are considered by each program and additional monitoring is implemented when deemed necessary and feasible. These monitoring programs are summarized as follows:

Intensive Watershed Monitoring (MPCA 2012a) collects water quality and biological data for two years at established stream and lake monitoring stations across the Missouri River Basin every 10 years. The MPCA, with assistance from LUGs, will re-visit and re-assess these monitoring stations, as well as have capacity to visit new sites in areas with BMP implementation activity, scheduled to begin in 2021. It is expected that funding for monitoring and analysis will be available through the MPCA.

Watershed Pollutant Load Monitoring Network (MPCA 2013a) data provides a continuous and long-term record of water quality conditions at the major watershed and subwatershed scale. This program collects pollutant samples and flow data to calculate continuous daily flow, sediment, and nutrient loads. There are six sites in the Missouri River Basin with data that vary by site.

Citizen Stream and Lake Monitoring Program (MPCA 2013b) data provide a continuous record of waterbody transparency throughout much of the basin. This program relies on a network of private citizen volunteers who make monthly stream and lake measurements annually. There is currently a limited number of citizens doing monitoring within the Missouri River Basin. The MPCA will seek more citizen monitors to track trends of water quality transparency for impaired waters within the basin.

8 Implementation Strategy Summary

8.1 Implementation Framework

The strategies described in this section are potential actions to reduce TSS, bacteria, and nutrient loads (TP) in the three major watersheds. These actions will be further developed in a separate, more detailed WRAPS report.

8.2 Permitted Sources

8.2.1 MS4

The General NPDES/SDS Permit requirements must be consistent with the assumptions and requirements of an approved TMDL and associated WLAs. The BMP stormwater control measure requirements are defined in the State's General Stormwater NPDES/SDS Permit (MNR040000). For the purposes of this TMDL, the baseline year for implementation will be the mid-range year of the data years used for the lake response modeling (Table 72) and development of the TSS and bacteria LDCs. Since the TSS and bacteria LDCs were developed using the watershed HSPF models, the baseline year will coincide with the mid-range year of the HSPF model simulations. The rationale for developing a baseline year is that projects undertaken recently may take a few years to influence water quality. Any wasteload-reducing BMP implemented since the baseline year will be eligible to “count” toward an MS4’s load reductions. If a BMP was implemented during or just prior to the baseline year, the MPCA is open to presentation of evidence by the MS4 Permit holder to demonstrate that it should be considered as a credit. The WRAPS report for these watersheds was developed with input from the stakeholders to determine the appropriate BMPs and implementation strategies to meet the MS4 goals for all the TMDLs presented in this TMDL report.

Table 72. Implementation baseline years.

Impairment	Data Years Used for TMDL Development	Baseline Year
TSS Impairments (HSPF)	2000 – 2009	2005
E. coli Impairments (HSPF)	2000 – 2009	2005
Okabena	2010 – 2015	2013
Ocheda	2007 – 2008	2008
Bella	2008 – 2009	2009
Indian	2009 – 2011	2010
Iowa	2010 – 2011	2011
Round	2008 – 2009	2009
Clear	2005 – 2009	2007
Loon	2005 – 2009	2007

8.2.2 Construction Stormwater

The WLAs 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 the State'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 Appendix A of the Construction General Permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. All local construction stormwater requirements must also be met.

8.2.3 Industrial Stormwater

The WLAs for stormwater discharges from sites where there is industrial activity reflects the number of sites in the watershed for which NPDES 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. The BMPs and other stormwater control measures that should be implemented at the industrial sites are defined in the State's NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000), or NPDES/SDS General Permit for Construction Sand & Gravel, Rock Quarrying and Hot Mix Asphalt Production facilities (MNG490000). If a facility owner/operator obtains stormwater coverage under the appropriate NPDES/SDS Permit and properly selects, installs and maintains all BMPs required under the permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. All local stormwater management requirements must also be met.

8.2.4 Wastewater

The MPCA issues permits for WWTF that discharge into waters of the state. The permits have site specific limits that are based on water quality standards. WWTPs discharging into impaired reaches did not require any changes to their discharge permit limits due to the WLAs calculated in this TMDL report. Permits regulate discharges with the goals of protecting public health and aquatic life and assuring that every facility treats wastewater. In addition, SDS Permits set limits and establish controls for land application of sewage.

8.3 Non-permitted Sources

8.3.1 TSS

Potential BMPs to reduce TSS loads in the three major watersheds are presented in Table 73. Please note that loading reduced from some of the implementation actions listed in Table 73 is creditable to the LA and some to the WLA. The strategy table does not specify the applicable allocation categories. Potential BMPs and cost estimates are explored more thoroughly in the WRAPS report.

Table 73. Potential TSS reduction implementation strategies.

Potential BMP/Reduction Strategy
Streambank Stabilization/Buffer Enhancement – *Repair and stabilize degraded banks throughout and upstream of the impaired reach. Establish vegetation (preferably native) to filter runoff from urban areas, cropland and pastures adjacent to the stream. All reaches should have a buffer on both sides of the stream.*
Vegetative Practices – *Reduce sediment generation and transport through vegetative practices focusing on the establishment and protection of crop and non-crop vegetation to minimize sediment mobilization and transport. Recommended vegetative practices include grassed waterways and grass filter strips, alternative crop rotations, forest management, field windbreaks, rotational grazing, contour farming, strip cropping, cover crops, and others.*
Primary Tillage Practices – *Promote conservation tillage practices to reduce the generation and transport of soil from fields. Conservation tillage techniques emphasize the practice of leaving at least some vegetation cover or crop residue on fields as a means of reducing the exposure of the underlying soil to wind and water which leads to erosion. If managed properly, conservation tillage can reduce soil erosion on active fields by up to two-thirds (Randall et. al. 2008).*
Urban BMPs – *Promote urban BMPs such as infiltration, bioretention, increased street sweeping and others to reduce sediment runoff and transport.*
Education – *Provide educational and outreach opportunities about responsible tillage practice, vegetative management practices, and other BMPs to encourage good individual property management practices to reduce soil loss and upland erosion.*
Control Animal Access to the Stream – *Control and/or limit animal access to streambanks and areas near streams and rivers by installing fencing in pastures where access is unimpeded and installing buffer vegetation where existing fencing is directly adjacent to the stream bank.*

8.3.2 Bacteria (*E .coli*)

Table 74 lists BMPs that may be successful in reducing bacteria loads in the three major watersheds. Please note that loading reduced from some implementation actions listed in Table 74 is creditable to LA and some to the WLA. The strategy table does not specify the applicable allocation categories. These potential BMPs are explored more thoroughly, including estimating costs and targeting the most appropriate BMPs by location, in the accompanying WRAPS report.

Table 74. Potential *E. coli* reduction implementation strategies.

Potential BMP/Reduction Strategy
Streambank Stabilization/Buffer Enhancement – *Stabilize vegetation to filter runoff from pastures adjacent to the stream. Enhancements should include at least 50 feet of buffer on both sides of the stream.*
Education – *Provide educational and outreach opportunities about proper fertilizer use, manure management, grazing management, proper pet waste disposal, and other topics to encourage good individual property management practices.*
Pasture Management –*Create alternate livestock watering systems, rotational grazing, and vegetated buffer strips between grazing land and surface* water bodies.
Manure Management – *Reduce winter spreading, eliminate spreading near open inlets, apply at agronomic rates, erosion control practices, and manure stockpile runoff controls.*
SSTS Inspection Program Review - *Although not a significant source of bacteria, Counties should continue to inspect and order upgrades of existing SSTS to prioritize properties near the impaired reaches and its tributaries.*

Potential BMP/Reduction Strategy
Control Animal Access to the Stream – *Control and/or limit animal access to streambanks and areas near streams and rivers by installing fencing in pastures where access is unimpeded and installing buffer vegetation where existing fencing is directly adjacent to the stream bank.*
Pet Waste Management – *Review member cities local ordinances and associated enforcement and fines for residents who do not clean up pet waste. Increase enforcement and education about compliance with such an ordinance.*

8.3.3 Nutrients (Phosphorus)

Table 75 lists BMPs that may be successful in reducing nutrient loads and managing lake water quality. Not all BMPs are necessarily appropriate or feasible for each lake covered in this TMDL. Please note that loading reduced from some implementation actions listed in Table 75 is creditable to the LA and some to the WLA. The strategy table does not specify the applicable allocation categories. These potential BMPs are explored more thoroughly, including estimating costs and targeting the most appropriate BMPs for each water body, in the accompanying WRAPS report.

Table 75. Potential nutrient reduction strategies.

Reduction Target	Potential BMP/Reduction Strategy
Watershed Load	**Education Programs –** *Provide education and outreach on low-impact lawn care practices, proper yard waste removal, and other topics to increase awareness of sources of pollutants.*
	Shoreline Restoration – *Encourage property owners to restore their shoreline with native plants and install/enhance shoreline buffers.*
	Raingarden/Bio-filtration Basins – *Encourage the use of rain gardens and similar features as a means of increasing infiltration and evapotranspiration. Opportunities may range from a single property owner to parks and open spaces.*
	Stormwater Pond Retrofits/Installation - *As opportunities arise, retrofit stormwater treatment through a variety of BMPs. Pond expansion and pre-treatment of water before it reaches the ponds may be beneficial dependent on drainage area. Also, identify target areas for new stormwater pond installation.*
	Street Sweeping *Identify target areas for increased frequency of street sweeping and consider upgrades to traditional street sweeping equipment.*
	Agricultural BMP Implementation – *Encourage property owners to implement agricultural BMPs for nutrient load reduction. The Agricultural BMP Handbook for Minnesota (MDA 2012) provides an inventory of agricultural BMPs that address water quality in Minnesota. Several examples include conservation cover, buffer strips, grade stabilization, controlled drainage, rotational grazing, and irrigation management, among many other practices.*
Internal Load	**Technical Review –** *Prior to internal load reduction strategy implementation, a technical review is recommended to evaluate the cost and feasibility of lake management techniques such as hypolimnetic withdrawal, alum treatment, and hypolimnetic aeration to manage internal nutrient sources.*
	Alum Dosing – *If determined feasible based on technical review, chemically treat with alum to remove phosphorus from the water column as well as bind it in sediments.*

Reduction Target	Potential BMP/Reduction Strategy
	Hypolimnetic Withdrawal or Aeration – *If determined feasible based on technical review, pump nutrient-rich water from the hypolimnion to an external location for phosphorus treatment and discharge treated water back into the lake. Or as an alternate option, aerate the hypolimnetic waters to maintain oxic condition (the anoxic condition of the hypolimnetic sediments is the contributor to the internal phosphorus load).*
	Aquatic Plant Surveys/Vegetation Management – *Conduct periodic aquatic plant surveys and prepare and implement vegetation management plans.*
	Rough Fish Surveys/Management – *Consider partnership with the DNR to monitor and manage the fish population. Evaluate options to reduce rough fish populations such as installation of fish barriers to reduce rough fish access and migration.*

8.4 Adaptive Management

Adaptive management is an iterative implementation process that makes progress toward achieving water quality goals while using new data and information to reduce uncertainty and adjust implementation activities. The state of Minnesota has a unique opportunity to adaptively manage water resource plans and implementation activities every 10 years. This opportunity resulted from a voter-approved tax increase to improve state waters. The resulting interagency coordination effort is referred to as the Minnesota Water Quality Framework, which works to monitor and assess Minnesota's major watersheds every 10 years. This Framework supports ongoing implementation and adaptive management of conservation activities and watershed-based local planning efforts utilizing regulatory and non-regulatory means to achieve water quality standards.

Implementation of TMDL related activities can take many years, and water quality benefits associated with these activities can also take many years. As the pollutant source dynamics within the watershed are better understood, implementation strategies and activities will be adjusted and refined to efficiently meet the TMDL and lay the groundwork for de-listing the impaired reaches and lakes. The follow up water monitoring program outlined in Section 7 will be integral to the adaptive management approach, providing assurance that implementation measures are succeeding in achieving water quality standards. Adaptive management does not include changes to water quality standards or loading capacity. Any changes to water quality standards or loading capacity must be preceded by appropriate administrative processes, including public notice and an opportunity for public review and comment.

A list of implementation strategies in the WRAPS report prepared in conjunction with this TMDL will focus on adaptive management (Figure 53). Continued monitoring and "course corrections" responding to monitoring results are the most appropriate strategy for achieving the water quality goals established in this TMDL. Management activities will be changed or refined to efficiently meet the TMDLs and lay the groundwork for de-listing the impaired water bodies.

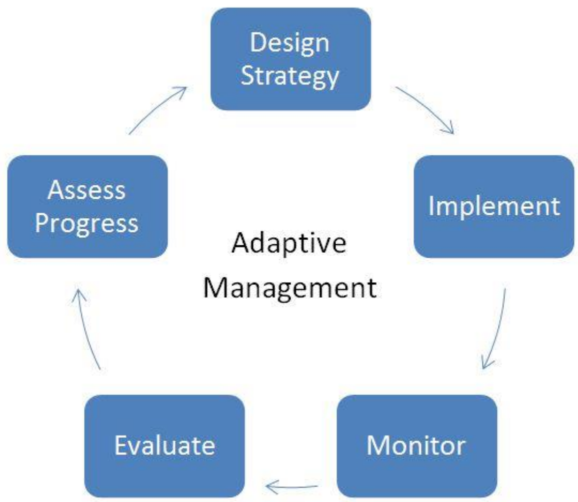

Figure 53. Adaptive management.

8.5 Cost

The CWLA requires that a TMDL include an overall approximation of the cost to implement a TMDL [Minn. Stat. 2007 § 114D.25].

8.5.1 Nutrients (Phosphorus)

A detailed analysis of the cost to implement the nutrient TMDLs was not conducted. However, as a rough approximation one can use some general results from BMP cost studies across the U.S. For example, an EPA summary of several studies of predominantly developed urban landscapes showed a median cost of approximately $2,200 per pound TP removed per year (Foraste et al. 2012). Multiplying that by the needed 58,876 pounds per year reduction for the eight lake basins in this TMDL provides a total cost of approximately $129.5 million.

8.5.2 Bacteria

The cost estimate for bacteria load reduction is based on unit costs for the two major sources of bacteria: livestock and imminent threat to public health SSTS. The unit cost for bringing AUs under manure management plans and feedlot lot runoff controls is $350/AU. This value is based on USDA EQIP payment history and includes buffers, livestock access control, manure management plans, waste storage structures, and clean water diversions. Repair or replacement of ITPHS systems was estimated at $7,500/system (EPA 2011). Multiplying those unit costs by an estimated 9,601 ITPHS systems and 649,480 AU in the three major watersheds provides a total cost of approximately $299.3 million.

8.5.3 TSS

Utilizing estimates developed by an interagency work group (BWSR, USDA, MPCA, Minnesota Association of SWCDs, Minnesota Association of Watershed Districts, NRCS) who assessed restoration costs for several TMDLs, it was determined that implementing the Missouri River Basin TSS TMDLs will cost approximately $264.2 million over 10 years. This was based on total area of the watershed (2,258 square miles) multiplied by the cost estimate of $117,000/square mile for a watershed based treatment approach.

9 Public Participation

The informational activities, meetings, education, and outreach efforts that were done during the development of this TMDL, associated WRAPS, and previous TMDLs in the Missouri River Basin include (but are not limited to) the following:

- A Kick-off meeting with local partners and stakeholders was held to provide information on the watershed approach process and Missouri River Basin project in the fall of 2010.
- A local Project Coordinator was hired to provide project oversight, administration, coordination, facilitation, data collection, information, education, and engagement of stakeholders on Missouri River Basin project.
- The Project Coordinator met with the local project partner SWCDs, county environmental offices, watershed districts, and Iowa counties to meet area staff, provide information, and answer questions on the Missouri River Basin project.
- The Project Coordinator sent letters to township boards, landowners, and interested parties on planned watershed project monitoring activities. The Project Coordinator made follow up personal calls to landowners to obtain permission for monitoring access and answer questions. Data and project information was sent to landowners upon landowner request.
- The Project Coordinator assisted local SWCDs and NRCS staff with providing Missouri River Basin project information at Cover Crop Expo, Environmental Fairs and Environmental Learning Tours for schools, teachers, and students.
- The Project Coordinator attended and presented project information at the Rock River TMDL Advisory and Technical Committee meeting on several occasions. The Project Coordinator provided Missouri River Basin project information in the Rock River TMDL newsletter. The Project Coordinator developed a press release on the Rock River TMDL Field Day for local newspapers. The Project Coordinator, in conjunction with the Rock County Land Management Office, sent a letter to landowners with information about the Rock River Terrain Analysis and the TMDL/WRAPS process.
- Several local project partners developed a project *website* and a brochure that provided the general public stakeholders information and data on the Missouri River Basin Project.
- The Project Coordinator sent letters to civic organizations and groups as an outreach effort to offer and give presentations on the Missouri River Basin Project. Presentations were given to the Pipestone Golden Club, American Legion, VFW Auxiliary, Lions Club, Kiwanis, Worthington High School, Beaver Creek Sportsman Club, and the Kanaranzi Little Rock Watershed District.
- Missouri River Basin project information was provided periodically by local project partners through newsletters and discussions with landowners during office and site visits.
- The Project Coordinator gave annual Missouri River Basin project presentations and updates to local partner Counties, SWCDs, watershed districts, Area 5, and township boards.
- The Project Coordinator provided Missouri River Basin project information through a booth at county fairs, area agricultural tours, field days, and periodically to local media. The Project

Coordinator developed a poster on the Missouri River Basin project presented at the state Water Resources Conference, and used for other events.

- A Local Work Group (LWG) was develop and facilitated by the Project Coordinator. The LWG members consisted of: six County Environmental/SWCD offices, two watershed districts, two rural water systems, East Dakota Water Development District (South Dakota), state agencies (MDA, MDH, BWSR, and DNR), and the federal NRCS. LWG meetings were held throughout the Missouri River Basin project. At various phases of the Missouri River Basin project, the LWG provided assistance, input, and feedback on the collection of watershed data, water quality monitoring, monitoring and assessment data results, stressor identification data results, geomorphology process and study results, water quality impairment data results, and the completion of the draft TMDL and WRAPS report. The LWG provided recommendations and opportunities to share information about the Missouri River Basin project process and its findings with stakeholders. The LWG worked on strategies to gather public opinion, input, and participation that would achieve watershed restoration and protection goals.
- A public meeting was held to present and discuss results of the Okabena Lake Diagnostic Study by Wenck Associates, with the city of Worthington and the Okabena Ocheda Watershed District.
- A Spatial Analysis and Targeting Workshop was conducted by the MPCA modeling and GIS staff for the LWG and other local interested partners.
- A survey was developed by the Project Coordinator with input from the LWG to gather information from the general public to use in the development of watershed wide planning efforts for local water planning, project implementation, and program development. The survey was available online through local partner SWCD's websites and the Project Coordinator attended local board meetings and made personal contacts to distribute and collect the surveys. The survey information was used by the LWG, state, county, and local agencies for the development of this TMDL, the Missouri River Basin WRAPS, for the future Missouri River Basin One Watershed One Plan.
- After the survey was completed, a follow-up questionnaire was also developed by the LWG for the survey respondents that provided their personal information and willingness to be more involved in future discussions on watershed issues, and give more specific detailed information on the results of the survey.
- A workshop was held with the LWG to develop restoration and protection strategies for the WRAPS report and implementation of this TMDL. The LWG was given the opportunity to provide input, review, and comment on the development of the WRAPS report and this TMDL.
- This TMDL is essentially a continuation and expansion of previous completed and approved TMDLs within the Missouri River Basin. In the Little Sioux River major watershed, the "Little Spirit Lake TMDL for Turbidity and Algae" was completed by the IDNR and approved by the EPA Region 7 in 2004, but not applicable to Minnesota. The majority of the lake and watershed is located in Minnesota. In the Rock River major watershed, the "Fecal Coliform and Turbidity TMDL Assessment for the Rock River Watershed" was completed by Minnesota State University at Mankato and approved by EPA in 2008. In the Lower Big Sioux major watershed, the "Pipestone Creek Fecal Coliform Bacteria and Turbidity TMDL" was completed by the MPCA and

Pipestone County and approved by EPA also in 2008. Information on the public participation process for the development of these TMDL studies can be found through the provided links in Section 10, Literature Cited.

Public Notice

An opportunity for public comment on the draft TMDL report was provided via a public notice in the State Register from September 25, 2017 to October 25, 2017.

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Appendices

Appendix A: NPDES Wastewater Discharger DMR Summaries

Appendix B: TSS Source Assessment

Appendix C: Bacteria Source Assessment

Appendix D: DNR Lake Fish Surveys

Appendix E: HSPF Model Documentation

Appendix F: Okabena Lake Diagnostic Study

Appendix G: Lake Response Models

Appendix H: Livestock NPDES/SDS Facilities