Mississippi River – Winona Watershed Pollutant Reduction Project (Total Maximum Daily Load Study) for Nutrients, Sediment and Bacteria

Minnesota Pollution Control Agency

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Acronyms

ac-ft/yr	acre feet per year
AFO	Animal Feeding Operation
AUID	Assessment Unit ID
BMP	Best Management Practice
CAFO	Concentrated Animal Feeding Operation
Chl-*a*	Chlorophyll-*a*
CRP	Conservation Reserve Program
CSO	Combined Sewer Overflow
Deg C	Degrees Celsius
DNR	Minnesota Department of Natural Resources
DO	Dissolved Oxygen
E. coli	*Escherichia coli*
EPA	Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
EQuIS	Environmental Quality Information System
FLC	farmer-led council
GIS	Geographic Information Systems
GW	Groundwater
HUC	Hydrologic Unit Code
IBI	Index of Biological Integrity
in/yr	inches per year
ISTS	Individual Sewage Treatment System
ITPHS	Imminent Threat to Public Health and Safety
km^2	square kilometer
LA	Load Allocation
Lb	pound
lb/day	pounds per day
lb/yr	pounds per year
LDC	load duration curves
m	meter
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
N	Nitrogen
NA	North American
NASS	National Agricultural Statistics Service
NCHF	North Central Hardwood Forests
NLCD	National Land Cover Dataset
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resources Conservation Service
NTU	Nephelometric Turbidity Units
P	Phosphorus
SDS	State Disposal System
SID	Stressor Identification
SSTS	Subsurface Sewage Treatment Systems
SWCD	Soil and Water Conservation District
SWPPP	Stormwa EPAter Pollution Prevention Plan
T	Temperature
TMDL	Total Maximum Daily Load
TP	Total phosphorus
TPEC	total phosphorus export coefficients
TSS	total suspended solids
µg/L	microgram per liter
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WLA	Wasteload Allocation
WRAPS	Watershed Restoration and Protection Strategies
WWTF	Wastewater Treatment Facility
WWTP	Wastewater Treatment Plant

Executive Summary

The Clean Water Act (1972) requires that each State develop a plan to identify and restore any waterbody that is deemed impaired by state regulations. A Total Maximum Daily Load Study (TMDL) is required by the Environmental Protection Agency (EPA) as a result of the federal Clean Water Act. A TMDL identifies the pollutant that is causing the impairment and how much of that pollutant can enter the waterbody and still meet water quality standards.

This TMDL study includes two lake basins and seventeen stream reaches located in the Mississippi River-Winona Watershed (HUC 07040003) in southeastern Minnesota that are on the 2014 EPA's 303(d) list of impaired waters.

Information from multiple sources was used to evaluate the ecological health of each waterbody:

- All available water quality data over the past 10 years
- Fisheries surveys
- Plant surveys
- Published studies
- Stressor Identification (SID) investigations
- SWAT model
- Stakeholder input

The following pollutant sources were evaluated for each lake or stream: watershed runoff, loading from upstream waterbodies, atmospheric deposition, lake internal loading, point sources, feedlots, septic systems, and in-stream alterations. An inventory of pollutant sources was used to develop a lake response model for each impaired lake and a load duration curve model for each impaired stream. These models were then used to determine the pollutant reductions needed for the impaired waterbodies to meet water quality standards.

The findings from this TMDL study will be used to aid the selection of implementation activities as part of the Mississippi River-Winona Watershed Restoration and Protection Strategy (WRAPS) process. The purpose of the WRAPS report is to support local working groups and jointly develop scientifically-supported restoration and protection strategies to be used for subsequent implementation planning. Following completion, the WRAPS report will be publically available on the Minnesota Pollution Control Agency (MPCA) Mississippi River-Winona Watershed website:

http://www.pca.state.mn.us/index.php/water/water-types-and-programs/watersheds/mississippi-river-winona.html

1 Project Overview

1.1 Purpose

This TMDL study addresses 35 impairments on 19 waterbodies (2 lakes and 17 stream reaches/AUIDs) in the Mississippi River-Winona Watershed (HUC 07040003) in southeastern Minnesota (Figure 1):

- aquatic recreation use impairments due to eutrophication (phosphorus) in 2 lake basins,
- aquatic recreation use impairments due to *E. coli* or fecal coliform in 7 stream reaches,
- aquatic life use impairments due to turbidity/suspended sediment in 12 stream reaches,
- aquatic life use impairments due to fish or macroinvertebrate bioassessments in 12 stream reaches, and
- drinking water use impairments due to excess nitrates in 2 stream reaches.

The goal of this TMDL is to provide wasteload allocations (WLAs) and load allocations (LAs) for impaired lakes and streams and to quantify the pollutant reductions needed to meet the state water quality standards. There were seven *E. coli*, 12 TSS, four nitrate and two phosphorus TMDL calculations completed for this report. Many waterbodies had more than one impairment type with one pollutant TMDL potentially addressing more than one. For example, a TSS TMDL calculation could have addressed both a turbidity impairment and macroinvertebrate bioassessment impairment.

Other completed studies for this watershed that were referenced in the development of this TMDL include:

- Mississippi River-Winona SID Study (MPCA 2014b)
- Mississippi River-Winona Monitoring and Assessment Report (MPCA 2013)
- Mississippi River-Winona Watershed Water Quality Data Compilation and Trend Analysis Report (Whitewater Watershed Joint Powers Board 2012)
- Lower Mississippi River Basin Fecal Coliform Implementation Plan (Cannon River Watershed Partnership and MPCA 2007)
- Revised Regional Total Maximum Daily Load Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota (MPCA 2006)

The findings from this TMDL study will be used to aid the selection of implementation activities as part of the Mississippi River-Winona WRAPS process. The purpose of the WRAPS report is to support local working groups and jointly develop scientifically-supported restoration and protection strategies to be used for subsequent implementation planning. Following completion, the WRAPS report will be publically available on the MPCA Mississippi River-Winona Watershed website:

http://www.pca.state.mn.us/index.php/water/water-types-and-programs/watersheds/mississippi-river-winona.html

1.2 Identification of Waterbodies

Table 1. Mississippi River – Winona Watershed Impaired Streams and Lakes

Stream AUID/ Lake ID	Stream or Lake Name	Stream Reach/ Lake Location Description	Designated Use Class	Listing Year	Target Start/ Completion	Cause of impairment (beneficial use in parantheses)	Impairment addressed by:
85-0011-01	Lake Winona (Southeast Bay)	In Winona	2B, 3C	2014	2010/2014	Phosphorus (ARU)	Phosphorus TMDL
85-0011-02	Lake Winona (Northwest Bay)	In Winona	2B, 3C	2014	2010/2014	Phosphorus (ARU)	Phosphorus TMDL
07040003-512	Whitewater River, South Fork	T106 R10W S1, west line to N Fk Whitewater R	1B, 2A, 3B	2002	N/A	Bacteria (ARU)	Completed Fecal Coliform TMDL±
				2014	2010/2014	Degraded habitat (ALU)	Not addressed in this TMDL
				2010	2010/2014	Nitrates (ACU)	Nitrate TMDL in this report
				2002	2009/2014	Turbidity (ALU)	TSS TMDL in this report
07040003-515	Whitewater River, Middle Fork	Headwaters to T107 R11W S34, east line	2B, 3C	2014	2010/2014	Bacteria (ARU)	*E. coli* TMDL in this report
				2014	2010/2014	Degraded habitat (ALU)	Not addressed in this TMDL
				2014	2010/2014	Low dissolved oxygen (ALU)	Not addressed in this TMDL
				2014	2010/2014	Nitrates (ALU)	Future nitrate TMDL***
				2014	2010/2014	Suspended sediment (ALU)	**Not addressed in this TMDL
				2008	2009/2014	Turbidity (ALU)	**Proposed list correction
07040003-F16	Whitewater River, South Fork	Headwaters to St Charles Twp Rd 7	2B, 3C	2002	N/A	Bacteria (ARU)	Completed Fecal Coliform TMDL±
				2014	2010/2014	Degraded habitat (ALU)	Not addressed in this TMDL
				2014	2010/2014	Low dissolved oxygen (ALU)	Not addressed in this TMDL
				2014	2010/2014	Nitrates (ALU)	Future nitrate TMDL***

Stream AUID/ Lake ID	Stream or Lake Name	Stream Reach/ Lake Location Description	Designated Use Class	Listing Year	Target Start/ Completion	Cause of impairment (beneficial use in parantheses)	Impairment addressed by:
				2014	2010/2014	Suspended sediment (ALU)	**Not addressed in this TMDL
				2002	2010/2014	Turbidity (ALU)	**Proposed list correction
07040003-F17	Whitewater River, South Fork	St Charles Twp Rd 7 to T106 R10W S2, east line	1B, 2A, 3B	2002	N/A	Bacteria (ARU)	Completed Fecal Coliform TMDL±
07040003-F17	Whitewater River, South Fork	St Charles Twp Rd 7 to T106 R10W S2, east line	1B, 2A, 3B	*pending	N/A	Nitrates (ALU)	Nitrate TMDL in this report
				*pending	N/A	Stressful temperatures (ALU)	Not addressed in this TMDL
				*pending	N/A	Suspended sediment (ALU)	TSS TMDL in this report
				2002	2010/2014	Turbidity (ALU)	TSS TMDL in this report
07040003-F19	Whitewater River, Middle Fork	Crow Spring to N Fk Whitewater R	1B, 2A, 3B	2002	N/A	Bacteria (ARU)	Completed Fecal Coliform TMDL±
				2010	2010/2014	Nitrates (ACU)	Nitrate TMDL in this report
				2014	2010/2014	Nitrates (ALU)	Nitrate TMDL in this report
				2014	2010/2014	Suspended sediment (ALU)	TSS TMDL in this report
				2002	2010/2014	Turbidity (ALU)	TSS TMDL in this report
07040003-523	Whitewater River, North Fork	M Fk Whitewater R to S Fk Whitewater R	1B, 2A, 3B	2006	2009/2014	Turbidity (ALU)	TSS TMDL in this report
07040003-529	Peterson Creek	T106 R8W S7, west line to Garvin Bk	1B, 2A, 3B	2008	2010/2014	Bacteria (ARU)	*E. coli* TMDL in this report
07040003-533	Rollingstone Creek	Unnamed cr to Garvin Bk	1B, 2A, 3B	2008	2010/2014	Bacteria (ARU)	*E. coli* TMDL in this report
				2008	2009/2014	Turbidity (ALU)	TSS TMDL in this report
07040003-536	Logan Branch	Headwaters to T107 R11W S4, east line	2B, 3C	1994	N/A	Bacteria (ARU)	Completed Fecal Coliform TMDL±
				2002	2010/2014	Turbidity (ALU)	TSS TMDL in this report

Stream AUID/ Lake ID	Stream or Lake Name	Stream Reach/ Lake Location Description	Designated Use Class	Listing Year	Target Start/ Completion	Cause of impairment (beneficial use in parantheses)	Impairment addressed by:
07040003-537	Whitewater River	S Fk Whitewater R to Beaver Cr	1B, 2A, 3B	2006	2009/2014	Turbidity (ALU)	TSS TMDL in this report
07040003-539	Whitewater River	T109 R10W S36, south line to Mississippi R	2B, 3C	2014	2010/2014	Bacteria (ARU)	*E. coli* TMDL in this report
				1998	2009/2014	Turbidity (ALU)	TSS TMDL in this report
07040003-542	Garvin Brook	T106 R8W S17, west line to Rollingstone Cr	1B, 2A, 3B	1994	N/A	Bacteria (ARU)	Completed Fecal Coliform TMDL±
07040003-552	Logan Branch	Unnamed cr to N Fk Whitewater R	1B, 2A, 3B	2008	2010/2014	Bacteria (ARU)	*E. coli* TMDL in this report
07040003-553	Whitewater River, North Fork	T108 R11W S30, west line to unnamed cr	1B, 2A, 3B	2002	N/A	Bacteria (ARU)	Completed Fecal Coliform TMDL±
				2014	2010/2014	Degraded habitat (ALU)	Not addressed in this TMDL
				2014	2010/2014	Nitrates (ALU)	Future nitrate TMDL***
				2002	2009/2014	Turbidity (ALU)	TSS TMDL in this report
				2014	2010/2014	Turbidity (ALU)	TSS TMDL in this report
07040003-554	Whitewater River, North Fork	Unnamed cr to M Fk Whitewater R	1B, 2A, 3B	1996	N/A	Bacteria (ARU)	Completed Fecal Coliform TMDL±
				1996	2009/2014	Turbidity (ALU)	TSS TMDL in this report
07040003-559	Stockton Valley Creek	T106 R8W S23 south line to Garvin Bk	1B, 2A, 3B	2002	N/A	Bacteria (ARU)	Completed Fecal Coliform TMDL±
				2008	2009/2014	Turbidity (ALU)	TSS TMDL in this report
07040003-566	Beaver Creek	T108 R11W S24, west line to Unnamed cr	1B, 2A, 3B	2014	2010/2014	Degraded habitat (ALU)	Not addressed in this TMDL
07040003-569	Gorman Creek	T110 R10W S27, west line to Unnamed cr	2B, 3C	*pending	N/A	Degraded habitat (ALU)	Not addressed in this TMDL
				*pending	N/A	Physical connectivity (ALU)	Not addressed in this TMDL

Stream AUID/ Lake ID	Stream or Lake Name	Stream Reach/ Lake Location Description	Designated Use Class	Listing Year	Target Start/ Completion	Cause of impairment (beneficial use in parantheses)	Impairment addressed by:
07040003-581	Bear Creek	Unnamed cr to Rollingstone Cr	1B, 2A, 3B	2014	2010/2014	Degraded habitat (ALU)	Not addressed in this TMDL
				2014	2010/2014	Low dissolved oxygen (ALU)	Not addressed in this TMDL
				2014	2010/2014	Nitrates (ALU)	Future nitrate TMDL***
				2014	2010/2014	Stressful temperatures (ALU)	Not addressed in this TMDL
07040003-592	Big Trout Creek	Unnamed cr to Mississippi R	1B, 2A, 3B	2014	2010/2014	Degraded habitat (ALU)	Not addressed in this TMDL
07040003-595	Garvin Brook	T107 R8W S2, south line to Mississippi R (Burleigh Slough)	2B, 3C	2008	2010/2014	Bacteria (ARU)	*E. coli* TMDL in this report
				2008	2009/2014	Turbidity (ALU)	TSS TMDL in this report
07040003-609	Unnamed Creek	Unnamed Creek to Whitewater R	1B, 2A, 3B	*pending	N/A	Degraded habitat (ALU)	Not addressed in this TMDL
07040003-611	Crow Spring (Middle Fork Whitewater River Tributary)	Unnamed cr to M Fk Whitewater R	1B, 2A, 3B	*pending	N/A	Bacteria (ARU)	*E. coli* TMDL in this report
				2014	2010/2014	Degraded habitat (ALU)	Not addressed in this TMDL
				2014	2010/2014	Nitrates (ALU)	Nitrate TMDL in this report

± Available online at http://www.pca.state.mn.us/index.php/view-document.html?gid=8006
* Monitoring data indicates that these AUIDs will be on the 2016 303(d) List of Impaired Waters for the designated use and pollutant/stressor
** Due to a shift in the TSS standard boundary between the Central and South River Nutrient Regions, TSS concentrations in these reaches do not exceed the South River Nutrient Region TSS standard of 65 mg/L and will be considered for an aquatic life use impairment list correction.
*** Nitrate TMDLs for these reaches are being deferred while a nitrate water quality standard for the protection of aquatic life is under development by MPCA
ALU = aquatic life use
ARU = aquatic recreation use
ACU = aquatic consumption use
N/A = listing start/completion not applicable because a) a TMDL has already been completed, or b) the impairment is expected to be on the 2016 303(d) List of Impaired Waters

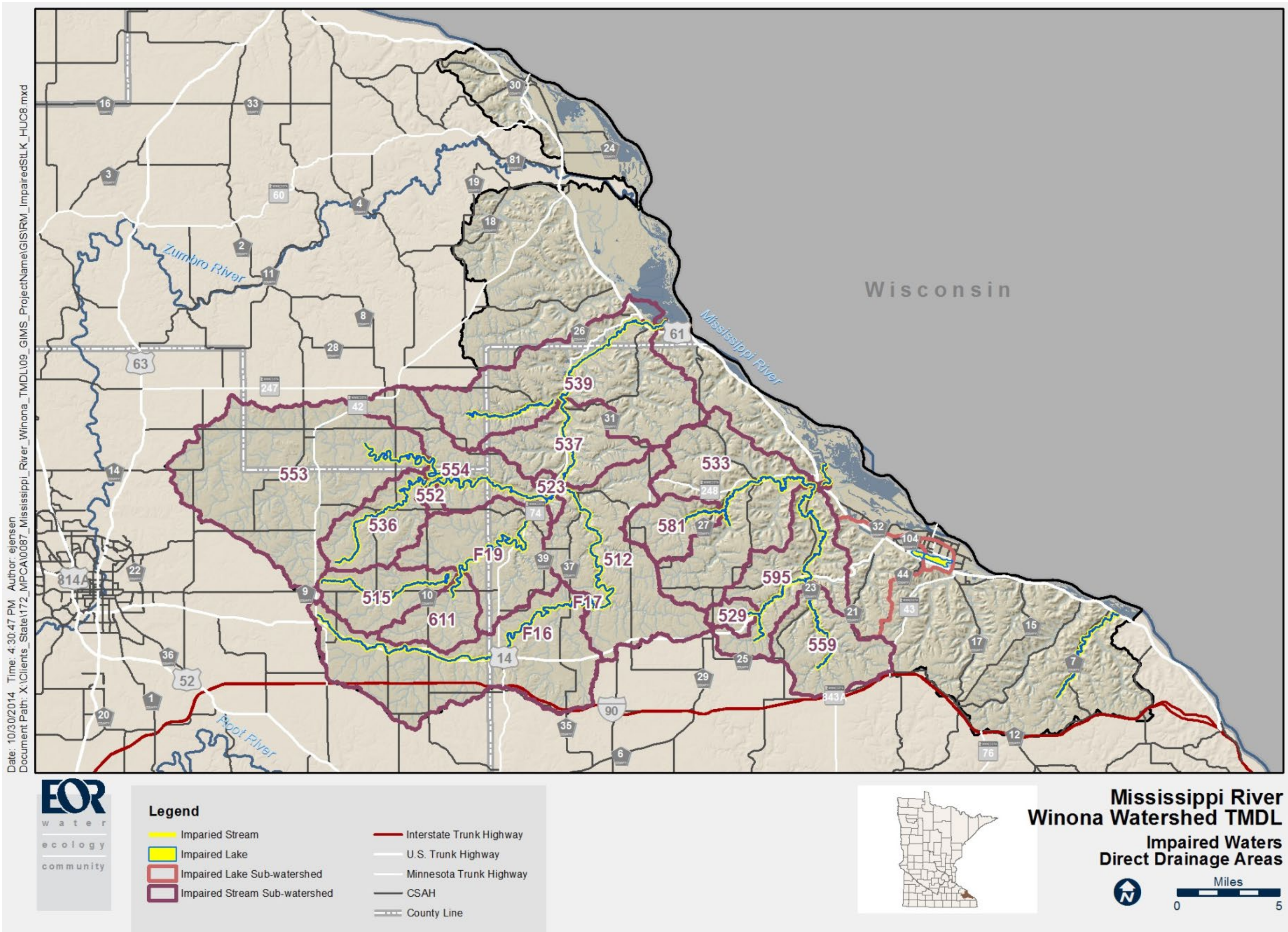

Figure 1. Impaired streams and lakes in the Mississippi River-Winona Watershed

1.3 Priority Ranking

The MPCA's projected schedule for TMDL completions, as indicated on the 303(d) impaired waters list, implicitly reflects Minnesota's priority ranking of this TMDL (see Table 1). Ranking criteria for scheduling TMDL projects include, but are not limited to: impairment impacts on public health and aquatic life; public value of the impaired water resource; likelihood of completing the TMDL in an expedient manner, including a strong base of existing data and restorability of the waterbody; technical capability and willingness locally to assist with the TMDL; and appropriate sequencing of TMDLs within a watershed or basin.

1.4 Description of the Impairments and Stressors

The following section describes the cause of stream impairments and the pollutant-based stressors that will be addressed by TMDLs in this study. A total of 7 *E. coli*, 12 TSS, 4 nitrate, and 2 phosphorus TMDLs were completed as part of this TMDL study to address impairments in the Mississippi River-Winona Watershed (Table 2).

Table 2. Pollutants addressed in this TMDL study listed by impaired stream reach or lake

AUID	Stream or Lake Name	Designated Use Class	*E. coli*	TSS	Nitrate	Phosphorus
85-0011-01	Lake Winona (Southeast Bay)	2B				●
85-0011-02	Lake Winona (Northwest Bay)	2B				●
07040003-512	Whitewater River, South Fork	1B, 2A		●	●	
07040003-515	Whitewater River, Middle Fork	2B	●			
07040003-F16	Whitewater River, South Fork	2B				
07040003-F17	Whitewater River, South Fork	1B, 2A		£	¡	
07040003-F19	Whitewater River, Middle Fork	1B, 2A		£	£	
07040003-523	Whitewater River, North Fork	1B, 2A		●		
07040003-529	Peterson Creek	1B, 2A	●			
07040003-533	Rollingstone Creek	1B, 2A	●	£		
07040003-536	Logan Branch	2B		●		
07040003-537	Whitewater River	1B, 2A		●		
07040003-539	Whitewater River	2B	●	●		
07040003-552	Logan Branch	1B, 2A	●			
07040003-553	Whitewater River, North Fork	1B, 2A		●		
07040003-554	Whitewater River, North Fork	1B, 2A		●		
07040003-559	Stockton Valley Creek	1B, 2A		●		
07040003-595	Garvin Brook	2B	●	●		
07040003-611	Crow Spring (Middle Fork Whitewater River Tributary)	1B, 2A	●		¡	
Total			**7**	**12**	**4**	**2**

● = conventional pollutant (addressing eutrophication, turbidity, bacteria, or nitrate impairments)
¡ = surrogate pollutant (identified through the stressor identification process addressing fish or macroinvertebrate bioassessment impairments)
£ = both conventional and surrogate pollutant

1.4.1 Lake Eutrophication

The lake eutrophication impairments in the Mississippi River-Winona Watershed were characterized by phosphorus and chlorophyll-a (Chl-*a)* concentrations that exceed state water quality standards and Secchi transparency depths below the state water quality standards. Excessive nutrient loads, in particular total phosphorus, lead to an increase in algae blooms and reduced transparency – both of which may significantly impair or prohibit the use of lakes for aquatic recreation. **Phosphorus lake response models were developed and TMDLs calculated for all lake eutrophication impairments**.

1.4.2 Stream *E. coli*

The stream bacteria impairments in the Mississippi River-Winona Watershed were characterized by high *E. coli* or fecal coliform concentrations during April through October. Minnesota *E. coli* water quality standards were developed to directly protect for primary (swimming and other recreation where immersion and inadvertently ingesting water is likely) and secondary (boating and wading where the likelihood of ingesting water is much smaller) body contact during the warm season months since there is very little swimming in Minnesota in the cold season months. ***E. coli* load duration curves (LDCs) and TMDLs were developed for all stream *E. coli* or fecal coliform impairments.** Stream fecal coliform data was converted to *E. coli* using an equivalence of 200 org fecal coliforms to 126 org *E. coli* based on past and current standards described in Section 2.2.1.

1.4.3 Stream Turbidity/ Suspended Sediment

The stream turbidity impairments in the Mississippi River-Winona Watershed were characterized by high turbidity levels. Turbidity is a physical characteristic of water that describes the degree to which light is scattered and absorbed in the water column (therefore reducing water clarity). Turbidity is caused by suspended sediment or impurities, such as clay, silt, fine organic matter, algae, and other organic and inorganic sources. Because turbidity is a physical characteristic of water and not a pollutant, **LDCs and TMDLs will be developed for total suspended solids (TSS)**, a measure of suspended sediment and the primary cause of turbidity in the Mississippi River-Winona Watershed.

1.4.4 Stream Nitrate

The stream nitrate impairments in the Mississippi River-Winona Watershed were characterized by high nitrate levels. The EPA regulates nitrate in drinking water to protect public health. Nitrate may cause health problems if present in public or private water supplies in amounts greater than the drinking water standard set by EPA. **Nitrate LDCs and TMDLs were developed for all stream nitrate impairments.**

1.4.5 Stream Fish and Macroinvertebrate Bioassessments

The fish or macroinvertebrate bioassessment impairments in the Mississippi River-Winona Watershed were characterized by low IBI scores for fish and/or macroinvertebrates. The presence of a healthy, diverse, and reproducing aquatic community is a good indication that the aquatic life beneficial use is being supported by a lake, stream, or wetland. The aquatic community integrates the cumulative impacts of pollutants, habitat alteration, and hydrologic modification on a waterbody over time. Monitoring of the aquatic community is accomplished using an index of biological integrity (IBI) which incorporates multiple attributes of the aquatic community, called “metrics”, to evaluate complex biological systems. For further information regarding the development of stream IBIs, refer to the MPCA *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment: 305(b) Report and 303(d) List*.

A Stressor Identification study (SID) was completed by the MPCA (2014) to determine the cause of low fish and macroinvertebrate scores that resulted in aquatic life impairments in the Mississippi River-Winona Watershed, and is summarized in Table 3.

The TMDL computations were completed for the mass pollutant based stressors of TSS and nitrate. In the case of many stressors, a mass reduction is not the appropriate means of addressing these issues, thus no TMDL is computed (i.e., habitat stressors). Dissolved oxygen (DO) and temperature stressors can sometimes be linked back to a mass pollutant, but those links were not able to be made in the Mississippi River-Winona Watershed. Therefore, a TMDL to address these stressors was not recommended at this time. It is likely that TMDL reductions and/or implementation practices to address other stressors in these reaches will have mutual benefit and may indirectly address the DO/temperature stressors. Non-pollutant stressors will be addressed through the WRAPS process.

Excess suspended sediment (turbidity) can harm aquatic life through direct, physical effects on biota such as abrasion of gills, suppression of photosynthesis, and avoidance behaviors, or through indirect effects such as loss of visibility. Suspended sediment is typically measured by the concentration of total suspended solids in the water and is an estimate of stream turbidity. Many reaches had existing turbidity impairments, which were also confirmed as TSS stressors. However, due to a shift in 2015 of the TSS standard boundary between the Central and South River Nutrient Regions, TSS concentrations in -512 and -F16 did not exceed the South River Nutrient Region TSS standard of 65 mg/L and will be considered for an aquatic life use impairment list correction.

Some species of macroinvertebrates and fish are sensitive to nitrate toxicity and biological responses have been observed in Minnesota coldwater streams to elevated nitrate concentrations. Nitrate was identified as a stressor in many reaches, but only moved forward to a TMDL computation if, 1) it was an existing nitrate (drinking water) listing, or 2) recent data suggested concentrations were >10 mg/L (for coldwater reaches, where drinking water is protected). The nitrate standard based on aquatic life is currently being developed, and until these standards exist, adequate target concentrations for coldwater and warmwater streams are not available (beyond the 10mg/L drinking water standard). In the case of 512, a nitrate stressor was not confirmed, but it exists on a stream already listed for drinking water nitrate, so the TMDL computation moved forward.

Table 3. Mississippi River-Winona Stressor Identification Study Summary

AUID	Stream Name	Designated Use Class	Biological Impairment	Stressors					
				Physical Habitat	TSS	Nitrate	Physical Connectivity	DO	Temp.
07040003-512	Whitewater River, South Fork	1B, 2A, 3B	Inverts	¡					
07040003-515	Whitewater River, Middle Fork	2B, 3C	Fish, Inverts	¡	¤	£		¡	
07040003-F16	Whitewater River, South Fork	2B, 3C	Fish, Inverts	¡	¤	£		¡	
07040003-F17	Whitewater River, South Fork	1B, 2A, 3B	Inverts		l	l			¡
07040003-F19	Whitewater River, Middle Fork	1B, 2A, 3B	Inverts		l	l			
07040003-553	Whitewater River, North Fork	1B, 2A, 3B	Fish, Inverts	¡	l	£			
07040003-566	Beaver Creek	1B, 2A, 3B	Inverts	¡					
07040003-569	Gorman Creek	2B, 3C	Inverts (proposed*)	¡			¡		
07040003-581	Bear Creek	1B, 2A, 3B	Fish, Inverts	¡		£		¡	¡
07040003-592	Big Trout Creek	1B, 2A, 3B	Inverts	¡					
07040003-609	Unnamed Creek	1B, 2A, 3B	Inverts (proposed*)	¡					

AUID	Stream Name	Designated Use Class	Biological Impairment	Stressors					
				Physical Habitat	TSS	Nitrate	Physical Connectivity	DO	Temp.
07040003-611	Crow Spring (Middle Fork Whitewater River Tributary)	1B, 2A, 3B	Inverts	¡		l			

¡ = No TMDL needed, l = TMDL needed, ¤ = TMDL needed but due to a shift in the TSS standard boundary between the Central and South River Nutrient Regions, TSS concentrations in these reaches do not exceed the South River Nutrient Region TSS standard of 65 mg/L and will be considered for an aquatic life use impairment list correction, £ = TMDL deferred while nitrate water quality standard for the protection of aquatic life is under development,

*Proposed biological impairments due to pending use class changes and/or further data collected after assessment occurred.

2 Applicable Water Quality Standards and Numeric Water Quality Targets

Each stream reach and lake has a Designated Use Classification defined by the MPCA which defines the optimal purpose for that waterbody (see Table 1). The lakes and streams addressed by this TMDL fall into one of the following two designated use classifications:

1B, 2A, 3C – drinking water use after approved disinfectant; a healthy cold water aquatic community; industrial cooling and materials transport without a high level of treatment

2B, 3C – a healthy warm water aquatic community; industrial cooling and materials transport without a high level of treatment

Class 1 waters are protected for aquatic consumption, Class 2 waters are protected for aquatic life and aquatic recreation, and Class 3 waters are protected for industrial consumption as defined by Minn. R. ch. 7050.0140. The most protective of these classes is 1B, however water bodies are not currently being assessed by the MPCA for the beneficial use of domestic consumption; therefore water quality standards for the Class 1B waters are not presented here. The next most protective of these classes is 2A and 2B, for which water quality standards are provided below. In the Mississippi River-Winona Watershed, all class 1B waters are also class 2A waters.

The Minnesota narrative water quality standard for all Class 2 waters (Minn. R. 7050.0150, subp. 3) states that "the aquatic habitat, which includes the waters of the state and stream bed, shall not be degraded in any material manner, there shall be no material increase in undesirable slime growths or aquatic plants, including algae, nor shall there be any significant increase in harmful pesticide or other residues in the waters, sediments, and aquatic flora and fauna; the normal fishery and lower aquatic biota upon which it is dependent and the use thereof shall not be seriously impaired or endangered, the species composition shall not be altered materially, and the propagation or migration of the fish and other biota normally present shall not be prevented or hindered by the discharge of any sewage, industrial waste, or other wastes to the waters".

2.1 Lakes

2.1.1 Lake Eutrophication

The lake eutrophication impairments in the Mississippi River-Winona Watershed were characterized by phosphorus and Chl-a concentrations that exceed state water quality standards and Secchi transparency depths below the state water quality standards. Excessive nutrient loads, in particular total phosphorus, lead to an increase in algae blooms and reduced transparency – both of which may significantly impair or prohibit the use of lakes for aquatic recreation.

Total phosphorus is often the limiting factor controlling primary production in freshwater lakes: as in-lake phosphorus concentrations increase, algal growth increases resulting in higher Chl-a concentrations and lower water transparency. In addition to meeting phosphorus limits, Chl-a and Secchi transparency depth standards must also be met. 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 (Heiskary and Wilson 2005). Clear relationships were established between the causal factor total phosphorus and the response variables Chl-a and Secchi transparency. Based on these relationships it is expected that by meeting the phosphorus target in each lake, the Chl-a and Secchi standards will likewise be met.

The impaired lakes within the Mississippi River-Winona Watershed were assessed against the North Central Hardwood Forests (NCHF) Ecoregion water quality standards (Table 4). A separate water quality standard was developed for shallow lakes which tend to have poorer water quality than deeper lakes in this ecoregion. According to the MPCA definition of shallow lakes, a lake is considered shallow if its maximum depth is less than 15 feet, or if the littoral zone (area where depth is less than 15 feet) covers at least 80% of the lake's surface area. Lake Winona (Northwest Bay) is shallow according to this definition.

To be listed as impaired (Minn. R. 7050.0150, subp. 5), the summer growing season (June-September) monitoring data must show that the standards for both total phosphorus (the causal factor) and either Chl-a or Secchi transparency (the response variables) were violated. If a lake is impaired with respect to only one of these criteria, it may be placed on a review list; a weight of evidence approach is then used to determine if it will be listed as impaired. For more details regarding the listing process, see the *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 303(b) Report and 303(d) List* (MPCA 2012).

Table 4. Lake Eutrophication Standards

Ecoregion	TP (ppb)	Chl-a (ppb)	Secchi (m)
North Central Hardwood Forests: General Lake Winona (Southeast Bay)	< 40	< 14	> 1.4
North Central Hardwood Forests: Shallow Lakes Lake Winona (Northwest Bay)	< 60	< 20	> 1.0

2.2 Streams

2.2.1 Bacteria

Numeric water quality standards have been developed for bacteria (Minn. R. 7050.0222), in this case *Escherichia coli* (*E. coli*), which are protective concentrations for short- and long-term exposure to pathogens in water. The past fecal coliform and current *E. coli* numeric water quality standards for Class 2 waters are shown in Table 5. *E. coli* and fecal coliform are fecal bacteria used as indicators for waterborne pathogens that have the potential to cause human illness. Although most are harmless themselves, fecal indicator bacteria are used as an easy-to-measure surrogate to evaluate the suitability of recreational and drinking waters, specifically, the presence of pathogens and probability of illness. Pathogenic bacteria, viruses, and protozoa pose a health risk to humans, potentially causing illnesses with gastrointestinal symptoms (nausea, vomiting, fever, headache, and diarrhea), skin irritations, or other symptoms. Pathogen types and quantities vary among fecal sources; therefore, human health risk varies based on the source of fecal contamination.

This Total Maximum Daily Load (TMDL) study will use the standard for *E. coli*. The change in the water quality standard from fecal coliform to *E. coli* is supported by an EPA guidance document on bacteriological criteria (EPA 1986). As of March 17, 2008, Minn. R. ch. 7050 water quality standards for *E. coli* are:

Escherichia (E.) coli - 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.

Although surface water quality standards are now based on *E. coli*, wastewater treatment facilities (WWTFs) are permitted based on fecal coliform (not *E. coli*) concentrations.

Geometric mean is used in place of arithmetic mean in order to measure the central tendency of the data, dampening the effect that very high or very low values have on arithmetic means. The MPCA's *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List* provides details regarding how waters are assessed for conformance to the *E. coli* standard (MPCA 2012).

Table 5. Past and current numeric water quality standards of bacteria (fecal coliform and *E. coli*) for the beneficial use of aquatic recreation (primary and secondary body contact).

Past Standard	Units	Current Standard	Units	Notes
Fecal coliform	200 orgs per 100 ml	*E. coli*	126 orgs per 100 ml	Geometric mean of ≥5 samples per month (April - October)
Fecal coliform	2,000 orgs per 100 ml	*E. coli*	1,260 orgs per 100 ml	<10% of all samples per month (April - October) that individually exceed

2.2.2 Nitrate

The nitrogen forms of primary concern for human health are nitrite and nitrate. Nitrite is the most toxic form of nitrogen to humans, especially infants. Nitrate is of most significance, not because of direct toxicity, but when ingested is converted to nitrite. Exposure to nitrate and in some cases nitrite contaminated water has notably contributed to methemoglobinemia or "blue baby syndrome" in infants. In addition, high levels of nitrate can be toxic to other forms of aquatic life in streams, including fish and macroinvertebrates.

Southeast Minnesota is particularly affected by nitrate contamination of its drinking water because of the prevailing karst geology and the region's rural character, including plentiful agriculture. Enhanced surface water - ground water interaction is a defining characteristic of karst that often contributes to drinking water quality problems.

The two nitrate impairments in the Mississippi River-Winona Watershed are designated as drinking water sources, as well as trout streams. The Minnesota water quality standard for nitrate in drinking water is a maximum concentration of 10 mg/L.

When assessing drinking water-protected surface waters Class 1B and 1C, the MPCA compares 24-hour average nitrate concentrations to the 10 mg/L standard. Two 24-hour averages exceeding 10 mg/L within a three-year period indicates impairment.

Single measurements of nitrate concentrations under relatively stable conditions are generally considered to be sufficiently representative of 24-hour average concentrations for the purpose of assessments. When concentrations are more variable, multiple samples or time-weighted composite samples may be necessary in order to calculate a sufficiently accurate average concentration. The necessary number and type of samples can vary considerably from one situation to another and the determination of adequacy for the purpose of assessment will necessarily involve considerable professional judgment. (Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List; 2014 Assessment and Listing Cycle; page 29-30, MPCA)

2.2.3 Turbidity

Turbidity is a measure of reduced transparency that can increase due to suspended particles such as sediment, algae, and organic matter. The Minnesota turbidity standard is 10 Nephelometric Turbidity Units (NTU) for class 2A waters and 25 NTU for class 2B waters (see the Section 2 introduction for a definition of the designated use classes). The State of Minnesota, in 2014, amended state water quality standards and replaced stream water quality standards for turbidity with standards for TSS. One component of the rationale for this change is that that turbidity unit (NTUs) is not concentration-based and therefore not well-suited to load-based studies (Markus 2011; http://www.pca.state.mn.us/index.php/view-document.html?gid=14922).

The new TSS criteria are stratified by geographic region and stream class due to differences in natural background conditions resulting from the varied geology of the state and biological sensitivity. The assessment period for these samples is April through September; any TSS data collected outside of this period was not considered for assessment purposes. The TSS standard for all class 2A streams is 10 mg/L, and the TSS standard for class 2B streams in the South River Nutrient Region is 65 mg/L. For assessment, this concentration is not to be exceeded in more than 10% of samples within a 10-year period. TSS results are available for the watershed from state-certified laboratories, and the existing data covers a large spatial and temporal scale in the watershed. Total suspended solid LDCs and TMDLs were developed for all stream turbidity impairments.

Table 6. Total suspended solids standard by stream class and river nutrient region

Stream Class (River Nutrient Region)	Total Suspended Solids (mg/L)
2A – Coldwater (Statewide)	10
2B – Coolwater or warmwater (South River Nutrient Region)	65

For more information, refer to the Aquatic Life Water Quality Standards Draft Technical Support Document for TSS (Turbidity), http://www.pca.state.mn.us/index.php/view-document.html?gid=14922, and the Minnesota Nutrient Criteria Development for Rivers report, http://www.pca.state.mn.us/index.php/view-document.html?gid=14947.

3 Watershed and Water body Characterization

The Mississippi River-Winona Watershed covers 419,200 acres in Wabasha, Winona, and Olmsted counties in southeast Minnesota. The Whitewater River falls within this watershed and is well known for its state park and trout fishing. A majority of the watershed is cropland, with forest and grassland covering large portions as well. Only a small percentage of the watershed is developed. The river discharges into the Mississippi River at Weaver Bottoms, an important Mississippi River backwater and waterfowl staging area. The largest city in the watershed is Winona (population 27,000), located on the Mississippi River.

3.1 Lakes

The physical characteristics of the impaired lakes are listed in Table 7. Lake surface areas, lake volumes, mean depths, maximum depths, and littoral areas (< 15 feet) were calculated using 2006 St. Mary's University bathymetry data; and watershed areas and watershed to surface area ratios were calculated using Mississippi River-Winona SWAT model subbasins.

From the DNR 2012 Re-Survey Report:

Lake Winona provides a good fishery for bluegill, crappie, largemouth bass, and walleye. The lake consists of two separate basins divided by Huff Street. The basins are connected by a large culvert that allows fish passage. Smaller boats can pass from one basin to the other through the culvert as well. All of the lakeshore is in public ownership providing numerous shore fishing opportunities as well as public boat access on each basin and several fishing piers. There is an outlet from the lake into the Mississippi River. This is controlled by a city owned concrete dam with 0.8 foot head. There is an electrical barrier operated by the city above the dam to impede influx of carp from the Mississippi River.

A dredging project completed in 2001 on the east basin has provided a larger area of deeper open water with less vegetation. Fish communities are similar in each basin. Largemouth bass, walleye, and bluegill are abundant, with smaller populations of northern pike, bullhead, carp, freshwater drum, and hybrid and pumpkinseed sunfish. Sand is the most common substrate in Lake Winona. The north, upper basin is dominated by muck near the inlet. Burreed, Bushy Pondweed, Cattail, Curly-leaf pondweed, Duckweed, Eurasion milfoil, coontail, purple loosestrife, sago pondweed, and water meal can all be found. In the months of May and June, curly-leaf pondweed dominates much of Lake Winona. There are a few areas in the lower basin that reach 38 feet in depth. Much of the shoreline is sandy with a gradual drop off.

Table 7. Impaired lake physical characteristics

Lake	Surface area (ac)	Littoral area (% total area)	Volume (acre-feet)	Mean depth (feet)	Maximum depth (feet)	Watershed area (incl. lake area) (ac)	Watershed area : Surface area
Winona (Southeast Bay)	223	59%	3,425	15	40	10,382	47:1
Winona (Northwest Bay)	84	89%	456	5	30	9,380	112:1

3.2 Streams

The direct drainage and total watershed areas of the impaired stream reaches are listed in Table 8. Total watershed and direct drainage areas were delineated from Mississippi River-Winona SWAT model subbasins. The direct drainage areas include only the area downstream of any impaired upstream reach.

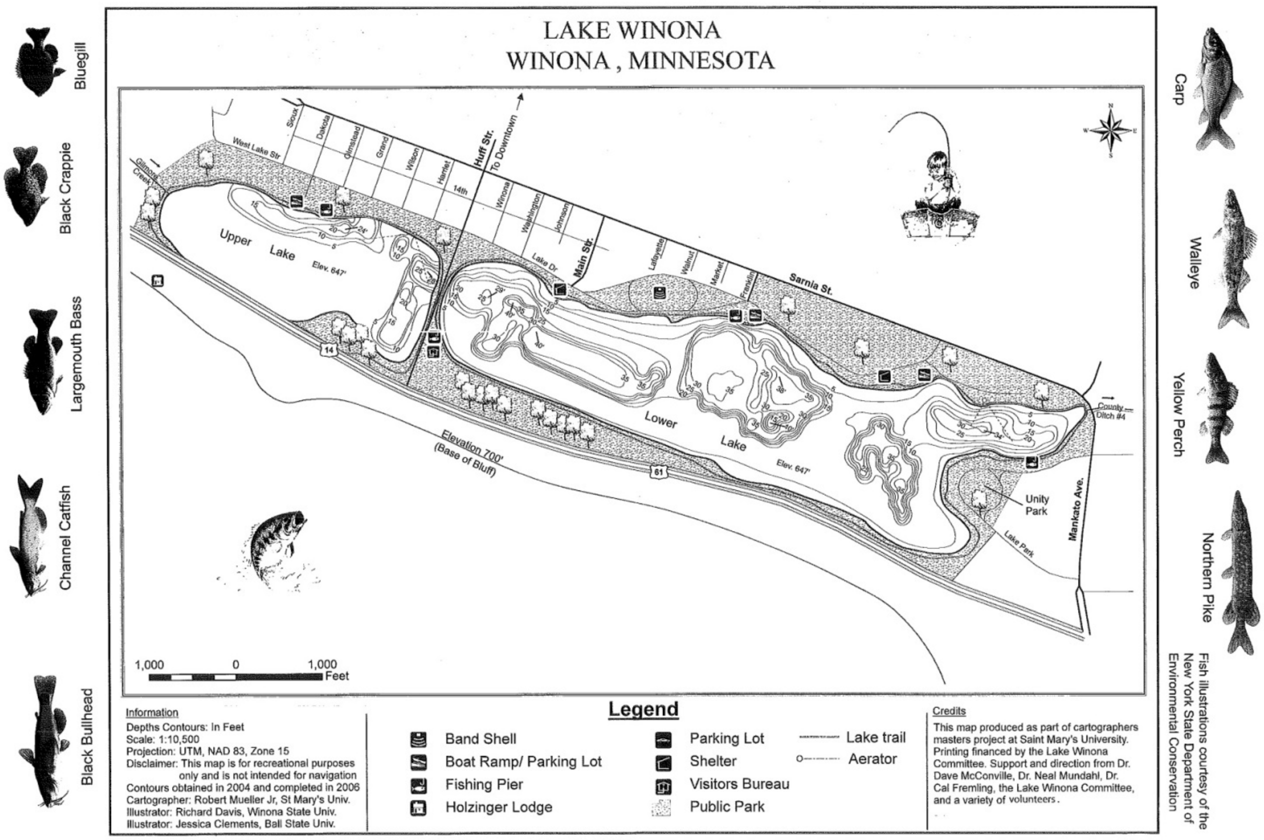

Figure 2. Lake Winona bathymetry (St. Mary's University 2006)

Table 8. Impaired stream direct drainage and total watershed areas

AUID	Name	Length (miles)	Direct Drainage Area (ac)	Total Watershed Area (ac)	Upstream Impaired Reach
07040003-512	Whitewater River, South Fork	12.08	26,022	59,043	F17
07040003-515	Whitewater River, Middle Fork	9.56	9,387	9,387	
07040003-F16	Whitewater River, South Fork	22.16	32,847	32,847	
07040003-F17	Whitewater River, South Fork	0.88	174	33,021	F16
07040003-F19	Whitewater River, Middle Fork	11.39	18,086	34,150	611, 515
07040003-523	Whitewater River, North Fork	1.64	1,090	101,530	F19, 554
07040003-529	Peterson Creek	1.60	2,061	2,061	
07040003-533	Rollingstone Creek	10.96	25,832	32,206	581
07040003-536	Logan Branch	10.67	10,113	10,113	
07040003-537	Whitewater River	6.08	12,359	172,932	523, 512
07040003-539	Whitewater River	4.72	32,523	205,455	537
07040003-552	Logan Branch	0.55	979	11,092	536
07040003-553	Whitewater River, North Fork	7.91	42,751	42,751	
07040003-554	Whitewater River, North Fork	11.37	12,447	66,290	552, 553
07040003-559	Stockton Valley Creek	7.45	12,726	12,726	
07040003-581	Bear Creek	4.37	6,374	6,374	
07040003-595	Garvin Brook	1.7	15,826	62,819	533, 529, 559
07040003-611	Crow Spring (M Fk Whitewater R Trib)	2.03	6,677	6,677	

3.3 Subwatersheds

The individual impaired lake and stream subwatersheds are illustrated in the following figures. The subwatersheds that are depicted were derived from the watershed Soil and Water Assessment Tool (SWAT) Model and do not necessarily correlate to the HUC derived subwatershed areas.

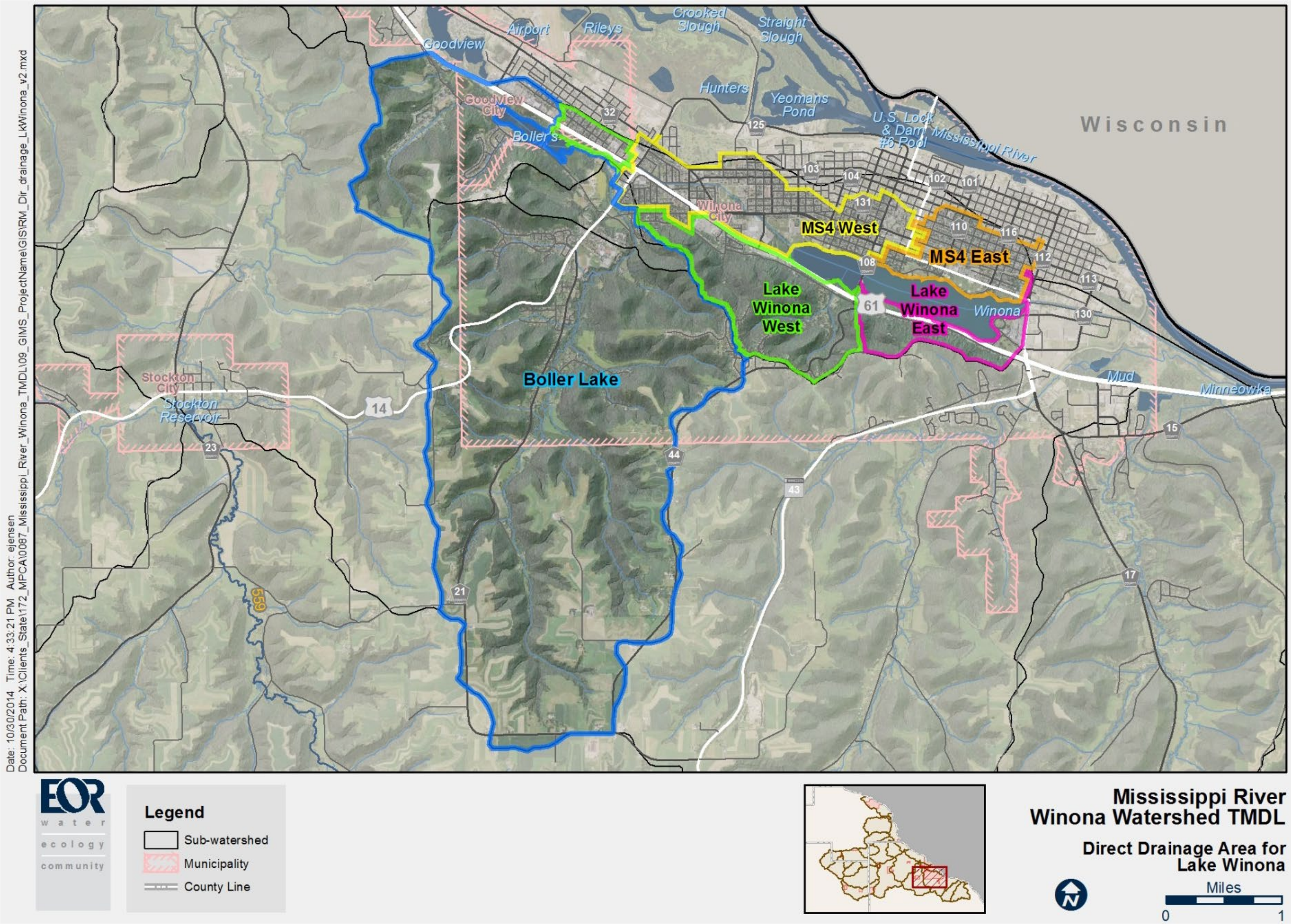

Figure 3. Lake Winona subwatersheds

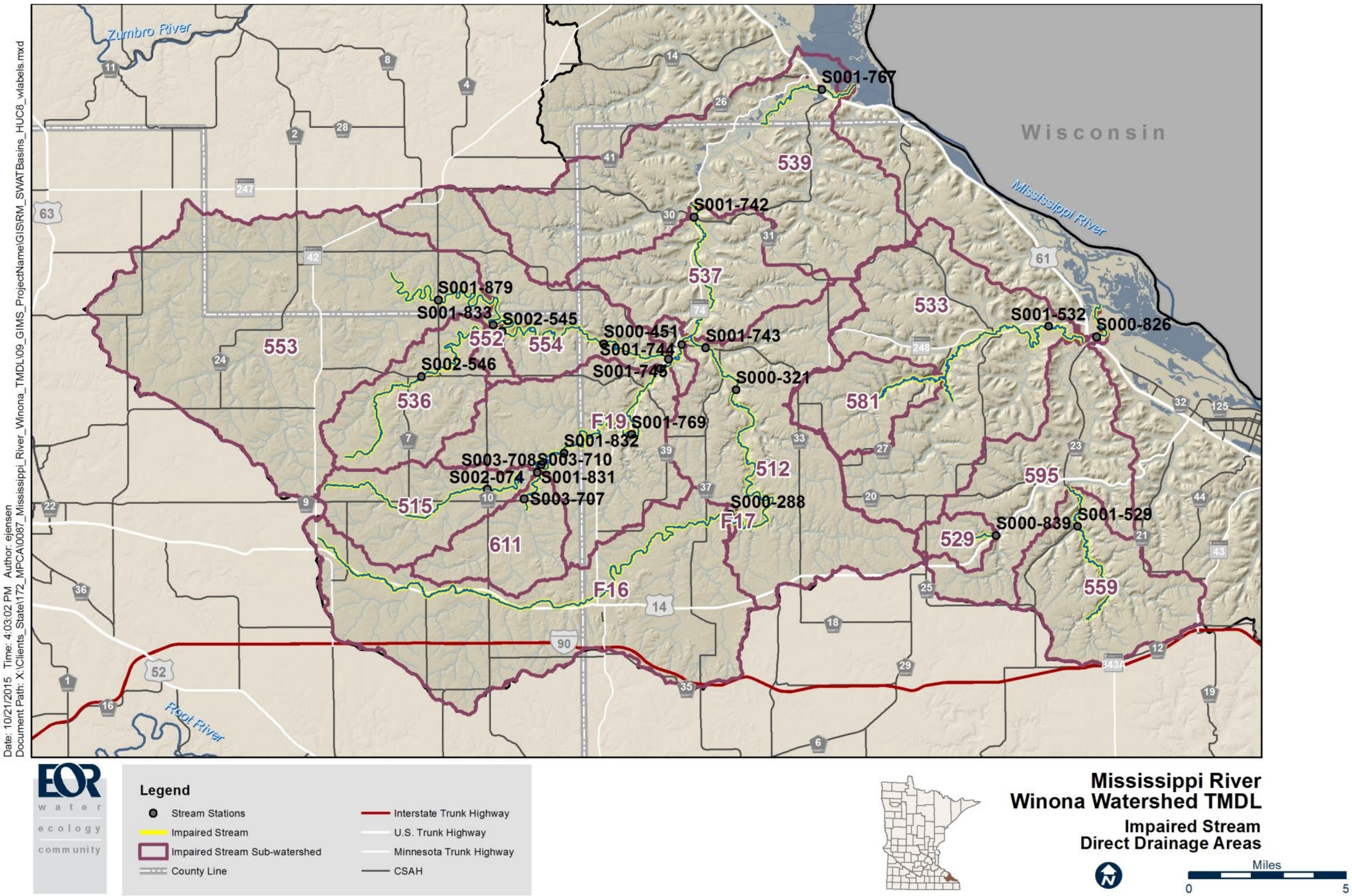

Figure 4. Impaired stream reach drainage areas

3.4 Land Use

Land cover in the Mississippi River-Winona Watershed was assessed using the Multi-Resolution Land Characteristics Consortium 2011 National Land Cover Dataset (http://www.mrlc.gov/nlcd2011.php). This information is necessary to draw conclusions about pollutant sources and best management practices (BMPs) that may be applicable within each subwatershed. The land cover distribution within impaired lake and stream watersheds is summarized in Table 9. This data was simplified to reduce the overall number of categories. Forest includes: evergreen forests, deciduous forests, mixed forests, and shrub/scrub. Developed includes: developed open space, and low, medium and high density developed areas. Grassland includes: native grass stands. Pasture includes: alfalfa, clover, long term hay, and pasture. Cropland includes: all annually planted row crops (corn, soybeans, wheat, oats, barley, etc.) and fallow crop fields. Wetland includes: wetlands and marshes. Open water includes: all lakes and rivers.

Table 9. Mississippi River - Winona Watershed and Impaired Waterbody Subwatershed Land Cover (NLCD 2011)

AUID	Stream or Lake Name	Developed	Cropland	Grassland/ Pasture	Woodland	Open Water/ Wetlands	Barren Land
85-0011-02	Lake Winona Northwest Bay	24%	3%	22%	48%	3%	<1%
85-0011-01	Lake Winona Southeast Bay	70%	<1%	1%	11%	18%	0%
07040003-F16	Whitewater River, South Fork	12%	57%	24%	7%	<1%	<1%
07040003-F17	Whitewater River, South Fork	8%	34%	14%	44%	<1%	0%
07040003-F19	Whitewater River, Middle Fork	5%	50%	27%	18%	<1%	<1%
07040003-512	Whitewater River, South Fork	5%	38%	31%	26%	<1%	<1%
07040003-515	Whitewater River, Middle Fork	4%	58%	34%	4%	<1%	<1%
07040003-523	Whitewater River, North Fork	9%	16%	23%	48%	<1%	0%
07040003-529	Peterson Creek	8%	43%	31%	18%	<1%	0%
07040003-533	Rollingstone Creek	4%	19%	38%	39%	<1%	<1%
07040003-536	Logan Branch	3%	47%	35%	15%	<1%	0%
07040003-537	Whitewater River	3%	17%	25%	49%	6%	<1%
07040003-539	Whitewater River	3%	18%	26%	45%	8%	<1%
07040003-552	Logan Branch	3%	49%	21%	27%	<1%	0%
07040003-553	Whitewater River, North Fork	5%	64%	26%	5%	<1%	<1%
07040003-554	Whitewater River, North Fork	6%	36%	28%	29%	1%	<1%
07040003-559	Stockton Valley Creek	3%	22%	42%	33%	<1%	0%
07040003-581	Bear Creek	5%	20%	48%	27%	<1%	0%
07040003-595	Garvin Brook	6%	17%	35%	42%	<1%	0%
07040003-611	Crow Spring (Middle Fork Whitewater River Tributary)	4%	70%	21%	5%	<1%	0%
Mississippi River – Winona Watershed		**7%**	**29%**	**27%**	**29%**	**8%**	**<1%**

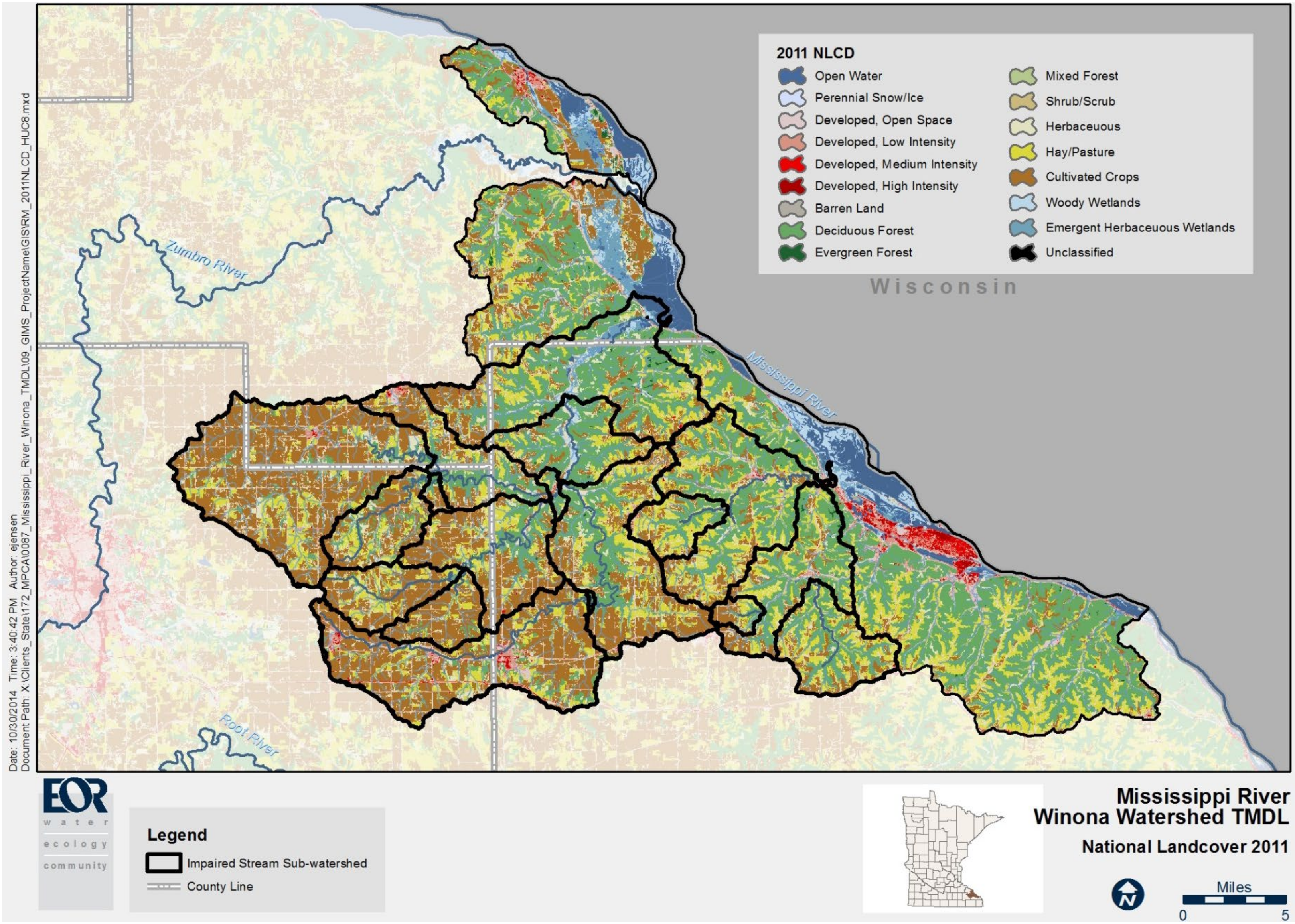

Figure 5. Mississippi River – Winona Watershed Land Cover (2011 NLCD)

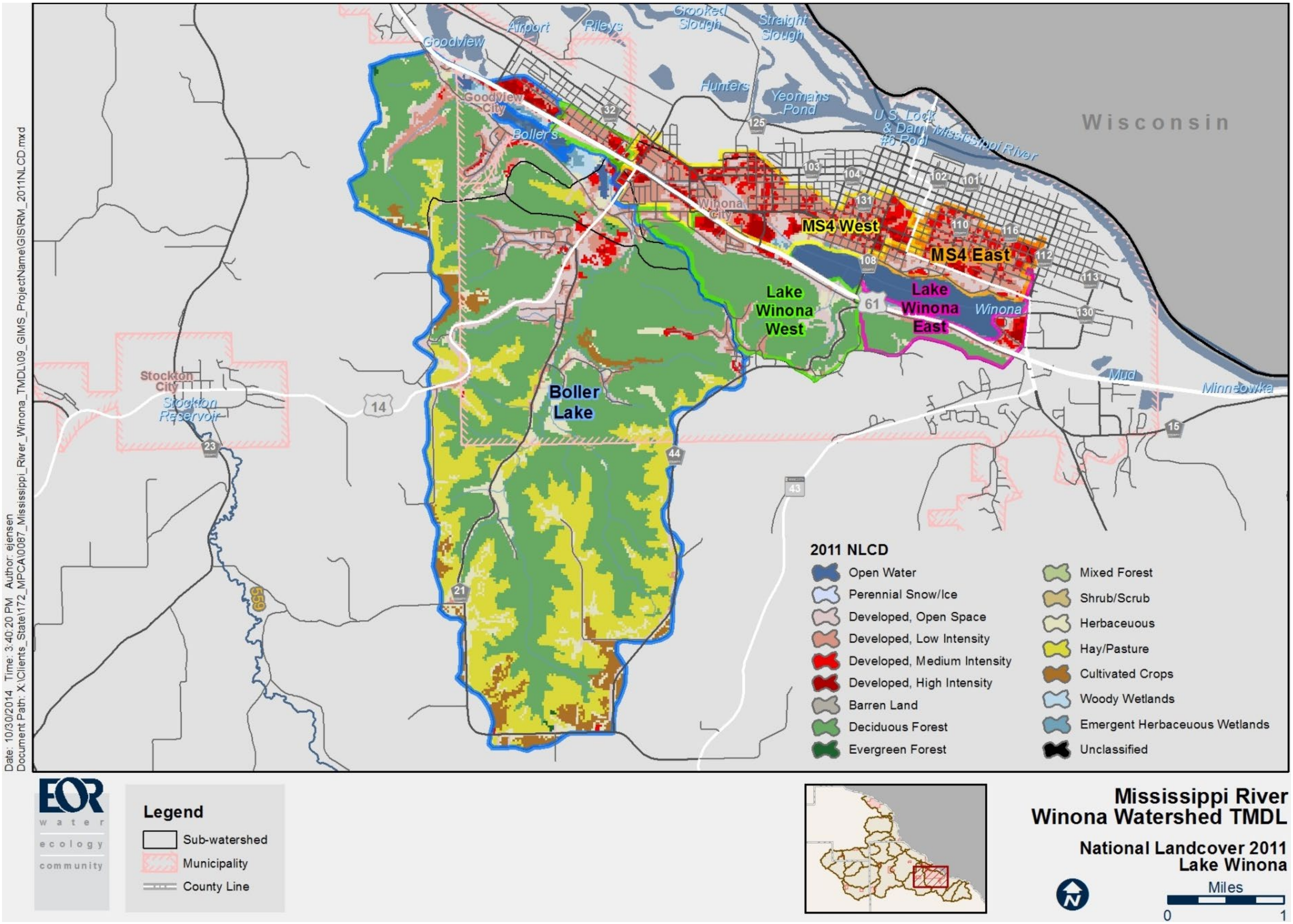

Figure 6. Winona (Northwest) and Winona (Southeast) Subwatershed Land Cover (NLCD 2011)

3.5 Current/Historic Water Quality

3.5.1 Lakes

The existing in-lake water quality conditions were quantified using data downloaded from the MPCA EQuIS database and available for the 10 year assessment period (2002-2011) used by the MPCA to identify lake impairments in the Mississippi River-Winona Watershed. Note that water quality data was only available for 2010-2011 during this 10 year assessment period. Growing season means of total phosphorus, Chl-a , and Secchi depth were calculated using monitoring data from the growing season (June through September). Information on the species and abundance of macrophyte and fish present within the lakes was compiled from DNR fisheries surveys. The 10-year growing season mean TP, Chl-a, and Secchi for each impaired lake is listed in Table 10.

Table 10. Growing season mean TP, Chl-*a*, and Secchi (2010-2011)

Lake Name	2010-2011 Growing Season Mean (June – September)					
	TP		Chl-*a*		Secchi	
	(µg/L)	CV	(µg/L)	CV	(m)	CV
North Central Hardwood Forest: General	**< 40**		**< 14**		**> 1.4**	
Lake Winona (Southeast Bay)	53	8%	52	23%	1.0	23%
North Central Hardwood Forest: Shallow Lakes	**< 60**		**< 20**		**> 1.0**	
Lake Winona (Northwest Bay)	85	11%	69	21%	0.9	35%

CV = coefficient of variation, defined in BATHTUB as the standard error divided by the mean

3.5.2 Streams

The existing stream water quality conditions were quantified using data downloaded from the MPCA EQuIS database and available for the 10 year assessment period (2002-2011) used by the MPCA to identify lake impairments in the Mississippi River-Winona Watershed. *E. coli*, nitrate, and total suspended solids were summarized for applicable streams based on the TMDLs identified to address the assessed impairments (Table 2). Additional monitoring and assessment data can be found in the Mississippi River-Winona Watershed Monitoring and Assessment report (http://www.pca.state.mn.us/index.php/view-document.html?gid=19935).

3.5.2.1 Bacteria (*E. coli*)

<u>Whitewater River-Middle Fork (07040003-515)</u>

Geometric mean *E. coli* concentrations greatly exceeded the water quality standard of 126 org/100 mL from May through September at station S002-074 of the Whitewater River-Middle Fork (07040003-515).

Table 11. 10-year geometric mean *E. coli* (org/100mL) concentrations by station and month in Whitewater River-Middle Fork (07040003-515), 2003-2012. Geometric means that exceed the water quality standard of 126 org/100mL for which there are at least 5 samples are highlighted in bold, italicized red font.

Monitoring Station	Month	Number of Samples	Geometric Mean (org/100mL)	Min – Max (org/100mL)
S002-074	May	5	***4,430***	1,467-36,540
	June	5	***6,648***	2,603-17,329
	July	6	***3,394***	1,130-26,030
	August	8	***2,211***	961-7,308
	September	5	***2,485***	1,333-3,255

<u>Peterson Creek (07040003-529)</u>

Geometric mean *E. coli* concentrations slightly exceeded the water quality standard of 126 org/100 mL in August at station S000-839 of Peterson Creek (07040003-529). No exceedances were measured in May or July.

Table 12. 12-year geometric mean *E. coli* (org/100mL) concentrations by station and month in Peterson Creek (07040003-529), 2001-2012. Geometric means that exceed the water quality standard of 126 org/100mL for which there are at least 5 samples are highlighted in bold, italicized red font.

Monitoring Station	Month	Number of Samples	Geometric Mean (org/100mL)	Min – Max (org/100mL)
S000-839	May	2	96	57-161
	July	10	125	14-2,079
	August	7	***187***	82-509

Rollingstone Creek (07040003-533)

Geometric mean *E. coli* concentrations exceeded the water quality standard of 126 org/100 mL from June through August at station S001-532 of Rollingstone Creek (07040003-533).

Table 13. 10-year geometric mean *E. coli* (org/100mL) concentrations by station and month in Rollingstone Creek (07040003-533), 2003-2012. Geometric means that exceed the water quality standard of 126 org/100mL for which there are at least 5 samples are highlighted in bold, italicized red font.

Monitoring Station	Month	Number of Samples	Geometric Mean (org/100mL)	Min – Max (org/100mL)
S001-532	June	5	***1,157***	460-2,400
	July	4	***1,526***	870-2,400
	August	5	***1,535***	440-2,400

Whitewater River (07040003-539)

Geometric mean *E. coli* concentrations slightly exceeded the water quality standard of 126 org/100 mL from June through August at station S001-767 of the Whitewater River (07040003-539).

Table 14. 10-year geometric mean *E. coli* (org/100mL) concentrations by station and month in Whitewater River (07040003-539), 2003-2012. Geometric means that exceed the water quality standard of 126 org/100mL for which there are at least 5 samples are highlighted in bold, italicized red font.

Monitoring Station	Month	Number of Samples	Geometric Mean (org/100mL)	Min – Max (org/100mL)
S001-767	June	5	***152***	65-330
	July	3	***287***	88-870
	August	5	***340***	50-2,400

Logan Branch (07040003-552)

Geometric mean *E. coli* concentrations greatly exceeded the water quality standard of 126 org/100 mL from May through September, with a maximum geometric mean concentration of 36,108 org/100mL, at station S002-545 of Logan Branch (07040003-552). No exceedances were measured in April or October.

Table 15. 10-year geometric mean *E. coli* (org/100mL) concentrations by station and month in Logan Branch (07040003-552), 2003-2012. Geometric means that exceed the water quality standard of 126 org/100mL for which there are at least 5 samples are highlighted in bold, italicized red font.

Monitoring Station	Month	Number of Samples	Geometric Mean (org/100mL)	Min – Max (org/100mL)
S002-545	April	1	15	15-15
	May	4	***355***	8-5,229
	June	2	***36,108***	28,350-45,990
	July	1	***5,166***	5,166-5,166
	August	2	***886***	113-6,930
	September	3	***1,874***	95-245,700
	October	2	13	11-15

Garvin Brook (07040003-595)

Geometric mean *E. coli* concentrations exceeded the water quality standard of 126 org/100 mL in May, July, and August at station S000-826 of Garvin Brook (07040003-595).

Table 16. 12-year geometric mean *E. coli* (org/100mL) concentrations by station and month in Garvin Brook (07040003-595), 2001-2012. Geometric means that exceed the water quality standard of 126 org/100mL for which there are at least 5 samples are highlighted in bold, italicized red font.

Monitoring Station	Month	Number of Samples	Geometric Mean (org/100mL)	Min – Max (org/100mL)
S000-826	May	2	***1,147***	754-1,743
	July	10	***1,520***	150-22,050
	August	8	***1,507***	252-37,800

Crow Spring (07040003-611)

Geometric mean *E. coli* concentrations exceeded the water quality standard of 126 org/100 mL from May through October at station S003-707 of Crow Spring (07040003-611), with geometric mean concentrations increasing from May to October. Geometric mean *E. coli* concentrations exceeded the water quality standard of 126 org/100 mL in October but not in May at station S003-708 of Crow Spring (07040003-611).

Table 17. 10-year geometric mean *E. coli* (org/100mL) concentrations by station and month in Crow Spring (07040003-611), 2003-2012. Geometric means that exceed the water quality standard of 126 org/100mL for which there are at least 5 samples are highlighted in bold, italicized red font.

Monitoring Station	Month	Number of Samples	Geometric Mean (org/100mL)	Min – Max (org/100mL)
S003-707	May	5	***233***	108-573
	June	5	***493***	225-1,986
	July	6	***557***	323-866
	August	8	***647***	299-1,625
	September	5	***1,252***	517-5,794
	October	2	***3,129***	2,646-3,700
S003-708	May	2	90	82-100
	October	2	***735***	693-780

3.5.2.2 Nitrate

Whitewater River-South Fork (07040003-512)

Nitrate concentrations exceeded the water quality standard of 10 mg/L twice in June, once in August, and once in November during the 10-year period of 2003-2012 at station S000-321 of Whitewater River-South Fork (07040003-512). No exceedances were measured at station S001-743.

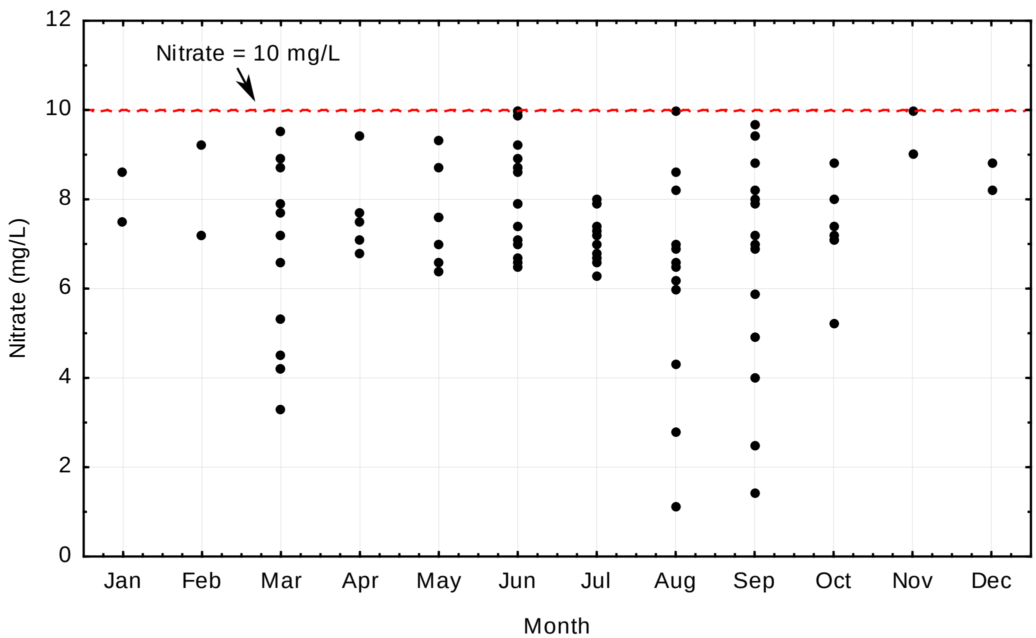

Figure 7. Nitrate (mg/L) by month in Whitewater River-South Fork (07040003-512) at monitoring station S000-321, 2003-2012. The dashed line represents the stream water quality standard (10 mg/L). Four exceedances were measured at this station during the time period represented.

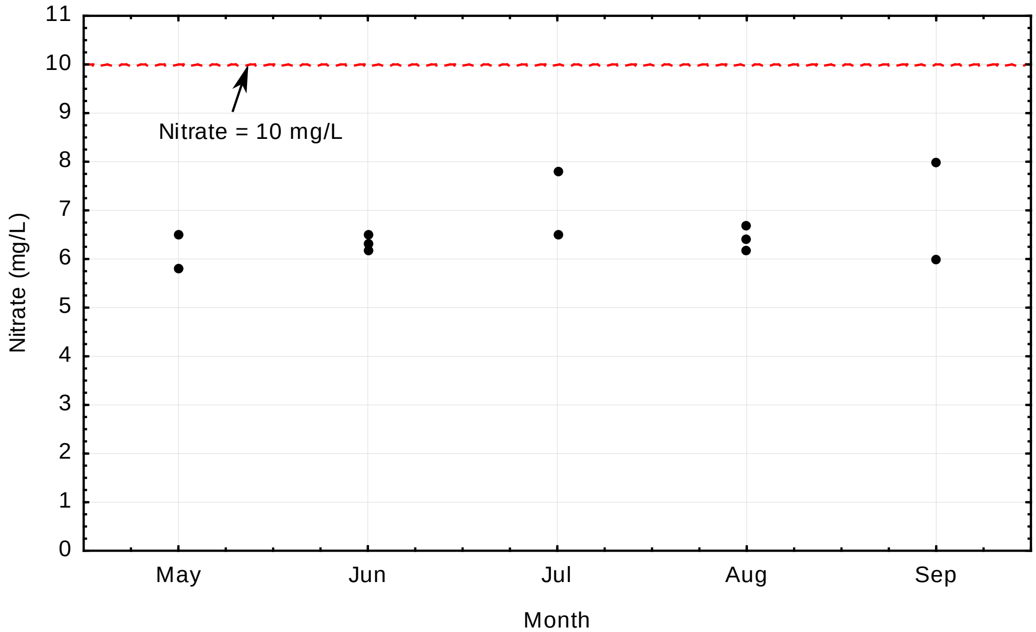

Figure 8. Nitrate (mg/L) by month in Whitewater River-South Fork (07040003-512) at monitoring station S001-743, 2003-2012. The dashed line represents the stream water quality standard (10 mg/L). No exceedances were measured at this station during the time period represented.

Whitewater River-South Fork (07040003-F17)

Nitrate concentrations exceeded the water quality standard of 10 mg/L two to three times per month in all months but March between January and November during the 10-year period of 2003-2012 at station S000-288 of Whitewater River-South Fork (07040003-F17).

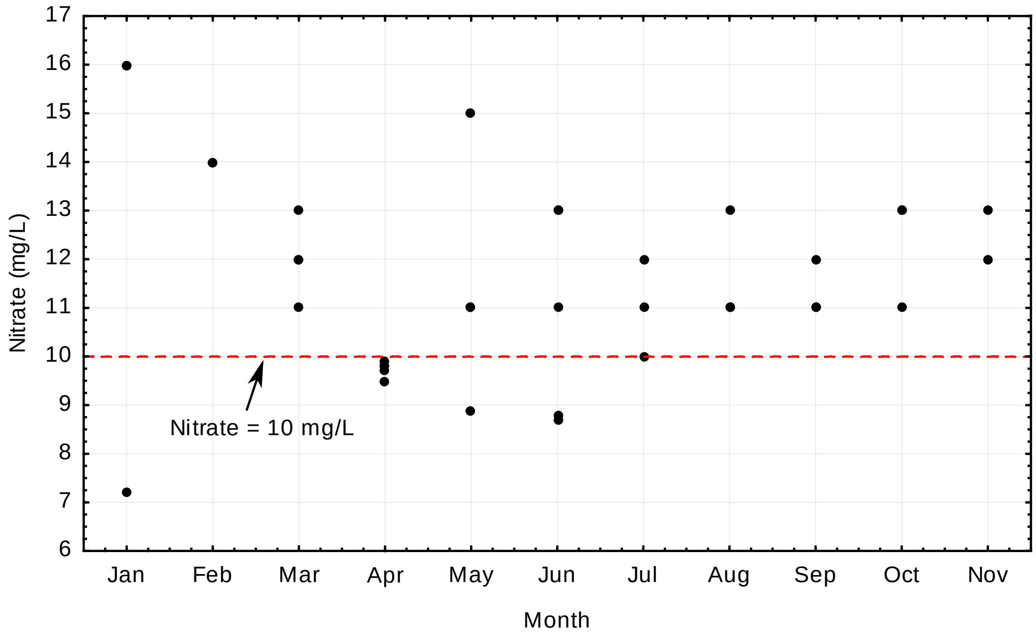

Figure 9. Nitrate (mg/L) by month in Whitewater River-South Fork (07040003-F17) at monitoring station S000-288, 2003-2012. The dashed line represents the stream water quality standard (10 mg/L).

Whitewater River-Middle Fork (07040003-F19)

Nitrate concentrations exceeded the water quality standard of 10 mg/L one to two times per month from September through March and in July during the 10-year period of 2003-2012 at station S001-831 of Whitewater River-Middle Fork (07040003-F19). No exceedances were observed at stations S001-769, S001-825, S003-710, and S007-086.

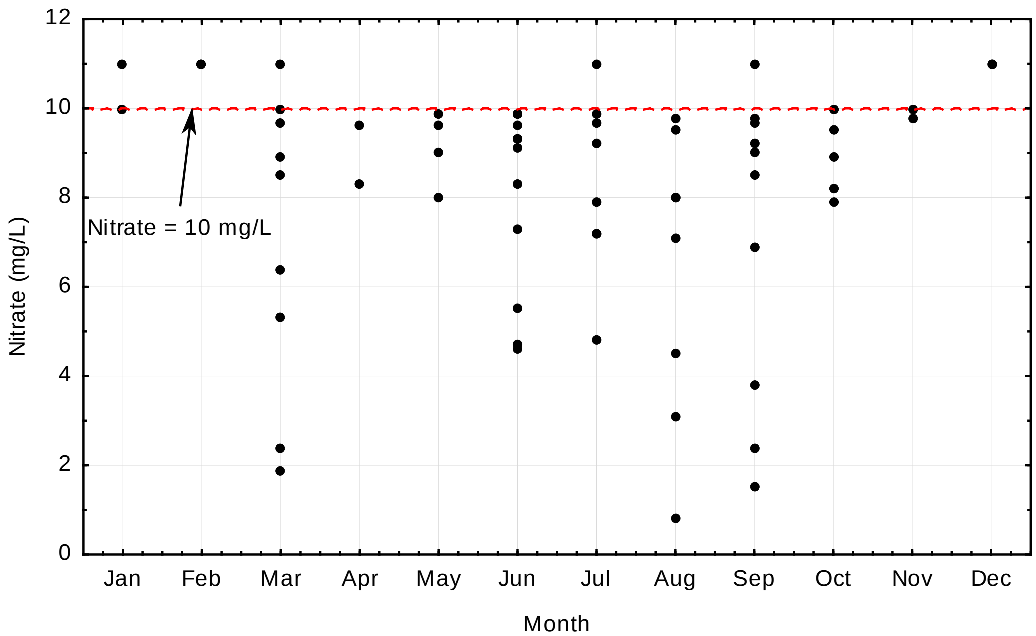

Figure 10. Nitrate (mg/L) by month in Whitewater River-Middle Fork (07040003-F19) at monitoring station S001-831, 2003-2012. The dashed line represents the stream water quality standard (10 mg/L).

Crow Spring (07040003-611)

Nitrate concentrations exceeded the water quality standard of 10 mg/L once in May and July during the 10-year period of 2003-2012 at station S003-707 of Crow Spring (07040003-611). No exceedances were measured at station S003-708.

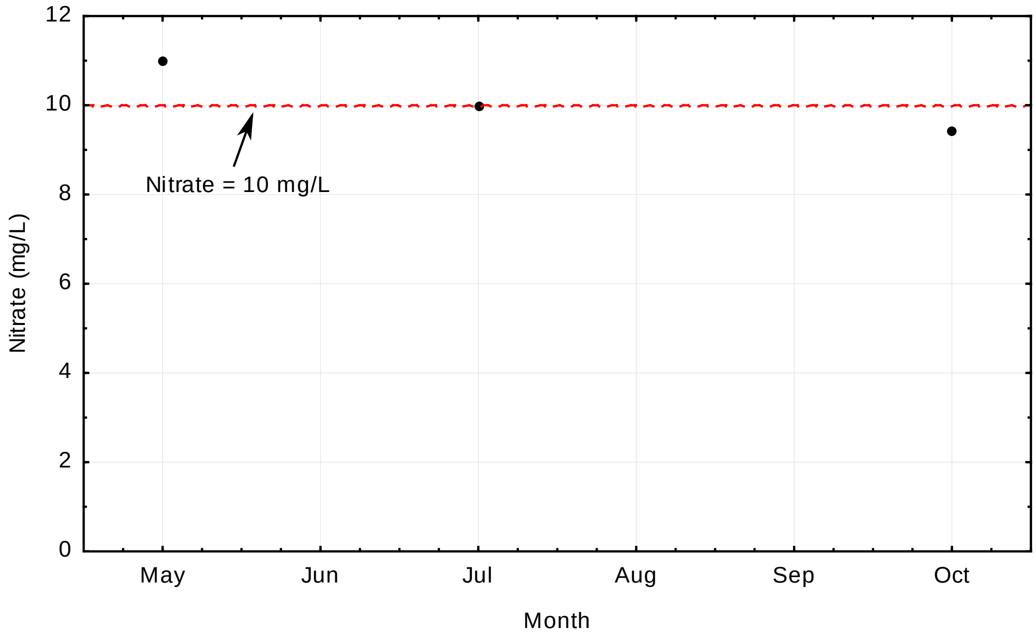

Figure 11. Nitrate (mg/L) by month in Crow Spring at monitoring station S003-707, 2003-2012. The dashed line represents the stream water quality standard (10 mg/L).

3.5.2.3 Total Suspended Solids

Whitewater River-South Fork (07040003-512)

50% (38 out of 76) of TSS samples exceeded the class 2A water quality standard of 10 mg/L during the 10-year period of 2003-2012. Exceedances were measured in April through September at station S000-321, and in June, August and September at station S001-743 of Whitewater River-South Fork (07040003-512).

Table 18. Average, minimum and maximum total suspended solids concentration by station and month in Whitewater River-South Fork (07040003-512), 2003-2012.

Monitoring Station	Month	Number of Samples	Average TSS (mg/L)	Minimum TSS (mg/L)	Maximum TSS (mg/L)
S000-321	**April**	5	14	2	42
	May	6	42	2	120
	June	17	33	3	100
	July	7	33	4	88
	August	12	631	1	3,500
	September	13	443	2	3,000
S001-743	**May**	2	3	2	4
	June	3	14	1	38
	July	2	4	4	5
	August	6	25	1	78
	September	3	16	4	39

Whitewater River-South Fork (07040003-F17)

36% (9 out of 25) of TSS samples exceeded the class 2A water quality standard of 10 mg/L in April through September at station S000-288 of Whitewater River-South Fork (07040003-F17) during the 10-year period of 2003-2012.

Table 19. Average, minimum and maximum total suspended solids concentration by station and month in Whitewater River-South Fork (07040003-F17), 2003-2012.

Monitoring Station	Month	Number of Samples	Average TSS (mg/L)	Minimum TSS (mg/L)	Maximum TSS (mg/L)
S000-288	April	4	39	2	150
	May	3	12	4	26
	June	3	19	6	41
	July	4	11	8	16
	August	7	19	3	66
	September	4	14	4	40

Whitewater River-Middle Fork (07040003-F19)

59% (40 out of 68) of TSS samples in April through September exceeded the class 2A water quality standard of 10 mg/L in the Whitewater River-Middle Fork (07040003-F19) during the 10-year period of 2003-2012. Exceedances were measured in June, August and September at station S001-825, in April through September at station S001-831, and in September at station S001-832.

Table 20. Average, minimum and maximum total suspended solids concentration by station and month in Whitewater River-Middle Fork (07040003-F19), 2003-2012.

Monitoring Station	Month	Number of Samples	Average TSS (mg/L)	Minimum TSS (mg/L)	Maximum TSS (mg/L)
S001-769	**August**	2	2	2	2
	September	2	1	1	1
S001-825	**May**	2	2	1	3
	June	2	31	2	60
	July	3	5	4	6
	August	5	6	2	18
	September	4	10	4	29
S001-831	**April**	2	9	3	16
	May	2	28	15	41
	June	11	169	14	1,100
	July	7	47	1	130
	August	8	613	12	2,800
	September	10	184	2	780
S001-832	**August**	4	4	2	6
	September	4	10	0	22

Whitewater River-North Fork (07040003-523)

20% (1 out of 5) of TSS samples exceeded the class 2A water quality standard of 10 mg/L in the Whitewater River-North Fork (07040003-523) during the 10-year period of 2003-2012. The exceedance was measured in September at station S001-744.

Table 21. Average, minimum and maximum total suspended solids concentration by station and month in Whitewater River-North Fork (07040003-523), 2003-2012.

Monitoring Station	Month	Number of Samples	Average TSS (mg/L)	Minimum TSS (mg/L)	Maximum TSS (mg/L)
S001-744	August	3	4	1	6
	September	2	20	1	39

Rollingstone Creek (07040003-533)

88% (60 out of 68) of TSS samples exceeded the class 2A water quality standard of 10 mg/L in Rollingstone Creek (07040003-533) during the 10-year period of 2003-2012. Exceedances were measured in April through September at station S001-532.

Table 22. Average, minimum and maximum total suspended solids concentration by station and month in Rollingstone Creek (07040003-533), 2003-2012.

Monitoring Station	Month	Number of Samples	Average TSS (mg/L)	Minimum TSS (mg/L)	Maximum TSS (mg/L)
S001-532	April	7	89	8	390
	May	11	64	20	150
	June	17	253	14	2,500
	July	8	128	20	570
	August	11	32	10	120
	September	14	146	4	1,800

Logan Branch (07040003-536)

42% (10 out of 24) of TSS samples exceeded the class 2B water quality standard of 65 mg/L in Logan Branch (07040003-536) during the 10-year period of 2003-2012. Exceedances were measured in May, June, and September at station S002-546.

Table 23. Average, minimum and maximum total suspended solids concentration by station and month in Logan Branch (07040003-536), 2003-2012.

Monitoring Station	Month	Number of Samples	Average TSS (mg/L)	Minimum TSS (mg/L)	Maximum TSS (mg/L)
S002-546	**April**	2	24	3	45
	May	8	2,163	6	5,600
	June	3	303	110	500
	July	3	22	4	52
	August	4	5	4	6
	September	4	75	3	270

Whitewater River (07040003-537)

83% (65 out of 78) of TSS samples exceeded the class 2A water quality standard of 10 mg/L in the Whitewater River (07040003-537) during the 10-year period of 2003-2012. Exceedances were measured in April through September at station S001-742.

Table 24. Average, minimum and maximum total suspended solids concentration by station and month in Whitewater River (07040003-537), 2003-2012.

Monitoring Station	Month	Number of Samples	Average TSS (mg/L)	Minimum TSS (mg/L)	Maximum TSS (mg/L)
S001-742	**April**	16	52	6	280
	May	12	44	10	220
	June	14	36	8	77
	July	11	45	16	150
	August	12	33	2	200
	September	13	518	3	4,300

Whitewater River (07040003-539)

27% (3 out of 11) of TSS samples exceeded the class 2B water quality standard of 65 mg/L in the Whitewater River (07040003-539) during the 10-year period of 2003-2012. Exceedances were measured in August and September at station S001-767.

Table 25. Average, minimum and maximum total suspended solids concentration by station and month in Whitewater River (07040003-539), 2003-2012.

Monitoring Station	Month	Number of Samples	Average TSS (mg/L)	Minimum TSS (mg/L)	Maximum TSS (mg/L)
S001-767	**May**	2	18	17	19
	June	2	35	15	54
	July	2	19	13	24
	August	3	152	36	230
	September	2	60	41	78

Whitewater River-North Fork (07040003-553)

17% (1 out of 6) of TSS samples exceeded the class 2A water quality standard of 10 mg/L in the Whitewater River-North Fork (07040003-553) during the 10-year period of 2003-2012. The exceedance was measured in September at station S001-879.

Table 26. Average, minimum and maximum total suspended solids concentration by station and month in Whitewater River-North Fork (07040003-553), 2003-2012.

Monitoring Station	Month	Number of Samples	Average TSS (mg/L)	Minimum TSS (mg/L)	Maximum TSS (mg/L)
S001-879	**August**	4	5	3	8
	September	2	20	3	37

Whitewater River-North Fork (07040003-554)

41% (34 out of 83) of TSS samples exceeded the class 2A water quality standard of 10 mg/L in the Whitewater River-North Fork (07040003-554) during the 10-year period of 2003-2012. Exceedances were measured in April through September at stations S000-451, S001-745, and S001-833.

Table 27. Average, minimum and maximum total suspended solids concentration by station and month in Whitewater River-North Fork (07040003-554), 2003-2012.

Monitoring Station	Month	Number of Samples	Average TSS (mg/L)	Minimum TSS (mg/L)	Maximum TSS (mg/L)
S000-451	**April**	5	14	1	53
	May	8	52	2	390
	June	18	32	2	370
	July	11	22	2	68
	August	14	68	2	490
	September	16	279	2	2,000
S001-745	**August**	4	7	1	19
	September	1	52	52	52
S001-833	**August**	4	6	2	17
	September	2	11	9	13

Stockton Valley Creek (07040003-559)

43% (13 out of 30) of TSS samples exceeded the class 2A water quality standard of 10 mg/L in Stockton Valley Creek (07040003-559) during the 12-year period of 2001-2012. Exceedances were measured in May through August at station S001-529.

Table 28. Average, minimum and maximum total suspended solids concentration by station and month in Stockton Valley Creek (07040003-559), 2001-2012.

Monitoring Station	Month	Number of Samples	Average TSS (mg/L)	Minimum TSS (mg/L)	Maximum TSS (mg/L)
S001-529	May	2	17	6	27
	June	10	91	2	801
	July	10	13	2	59
	August	8	8	2	15

Garvin Brook (07040003-595)

37% (11 out of 30) of TSS samples exceeded the class 2B water quality standard of 65 mg/L in Garvin Brook (07040003-595) during the 12-year period of 2001-2012. Exceedances were measured in June and July at station S000-826.

Table 29. Average, minimum and maximum total suspended solids concentration by station and month in Garvin Brook (07040003-595), 2001-2012.

Monitoring Station	Month	Number of Samples	Average TSS (mg/L)	Minimum TSS (mg/L)	Maximum TSS (mg/L)
S000-826	May	2	37	33	41
	June	10	339	27	2,417
	July	10	63	24	116
	August	8	29	2	56

3.6 Pollutant Source Summary

3.6.1 Lake Phosphorus

This section provides a brief description of the potential sources in the watershed contributing to excess nutrients in the impaired lakes. Phosphorus in lakes often originates on land. Phosphorus from sources such as phosphorus-containing fertilizer, manure, and the decay of organic matter can adsorb to soil particles. Wind and water action erode the soil, detaching particles and conveying them in stormwater runoff to nearby waterbodies where the phosphorus becomes available for algal growth. Organic material such as leaves and grass clippings can leach dissolved phosphorus into standing water and runoff or be conveyed directly to waterbodies where biological action breaks down the organic matter and releases phosphorus.

3.6.1.1 Permitted Sources

The regulated sources of phosphorus within the watersheds of the eutrophication impairments addressed in this TMDL study include MS4 stormwater, construction sites, and industrial sites. Phosphorus loads from MS4, construction, and industrial stormwater runoff were accounted for using the methods described in Section 4.1.3 below.

3.6.1.2 Non-permitted Sources

The following sources of phosphorus not requiring National Pollutant Discharge Elimination System (NPDES) Permit coverage were evaluated:

- Watershed runoff
- Atmospheric deposition
- Lake internal loading

Watershed runoff

The Mississippi River-Winona SWAT model (EOR 2014) and total phosphorus export coefficients (TPECs) were used to calculate direct watershed runoff volumes and TP loads to the impaired lakes (Table 30). The Lake Winona subwatersheds are located outside of but adjacent to the Garvin Brook subwatershed that was included in the calibrated SWAT model. An average annual runoff depth of 8.9 inches derived from SWAT model outputs was used in the absence of modeled or continuous flow monitoring records in the Lake Winona subwatersheds.

The TPECs are the phosphorus runoff yield (i.e., loading rate) for a given land use, applicable in a given region having common surface features and a comparable climate record. The Lake St. Croix Total Phosphorus Loading Study summarized TPECs from published reports of runoff studies conducted by natural scientists and water resource managers in Minnesota, Wisconsin, and/or Upper Midwest landscapes. The Basin Team's Implementation Committee pooled their collective knowledge of runoff behavior within in the St. Croix basin to develop a customized list of dry-, average-, and wet-condition TPECs for six land cover groupings (Table 31). TPECs are higher for developed land uses primarily because of the volume of flow generated from impervious surfaces. These were customized to the Mississippi River-Winona region based on SWAT modeled average subbasin yields for cropland and developed areas. Summary tables of watershed runoff volumes and TP loads by land cover type for each tributary are provided in Appendix A.

In addition, phosphorus reductions from several existing BMPs identified by the city of Winona were subtracted from the total direct drainage loads. In the Boller's Lake direct drainage area, the Crestview stormwater pond was estimated to reduce 2.62 lb phosphorus/year. In the Lake Winona (Northwest Bay) direct drainage area, the three Woodlawn stormwater ponds were estimated to reduce 15.78 lb phosphorus/ year.

Table 30. SWAT model annual average runoff flow and phosphorus loads for impaired lakes and unmonitored upstream lakes (in italics).

Lake	Tributary	Drainage Area excluding lake surface (ac)	Flow (ac-ft/yr)	TP Conc. (µg/L)	TP Load (lb/yr)
Boller's Lake	*Direct drainage area*	*7,350*	*5,451*	*89.53*	***1,327****
Winona (Northwest Bay)	Direct drainage area	972	721	107.8	**211****
	City of Winona MS4 stormwater	917	680	215.68	**399**
Winona (Southeast Bay)	Direct drainage area	334	248	126.72	**85**
	City of Winona MS4 stormwater	445	330	219.82	**197**

* Includes a 2.62 lb/yr reduction from the Crestview pond
** Includes a 15.78 lb/yr reduction from the Woodlawn ponds

Table 31. TPECs by 2011 NLCD Land Cover Type

NLCD 2011 Land Cover Type	TPEC (lb/ac/yr)
Barren Land	0.04
Cultivated Crops	0.39
Deciduous Forest	0.09
Developed, High Intensity	0.45
Developed, Medium Intensity	0.45
Developed, Low Intensity	0.45
Developed, Open Space	0.45
Emergent Herbaceous Wetlands	0.09
Evergreen Forest	0.09
Herbaceous	0.09
Mixed Forest	0.09
Open Water	0.04
Hay/Pasture	0.22
Shrub/Scrub	0.09
Woody Wetlands	0.09

Upstream lakes

Upstream lakes can contribute significant phosphorus loads to downstream impaired lakes and streams. Because lakes remove phosphorus from its upstream contributing watershed load through sedimentation, watershed load models that do not account for phosphorus removal of lakes overestimate watershed loads from upstream lakes. Therefore, water quality monitoring data and flow from upstream lakes were used to estimate their phosphorus loads to downstream impaired waters and are summarized in Table 32. No water quality monitoring data was available for Boller's Lake. In-lake phosphorus concentration was estimated using an uncalibrated BATHTUB model for this lake. Estimated uncertainty in these loads was predicted to be 10% based on the model development dataset. In addition, flow out of the upstream lakes was based on total advective outflow from the BATHTUB model to account for evaporative losses of watershed runoff in the lake.

Table 32. Existing upstream phosphorus loads to impaired lakes and streams

Impaired Lake	Upstream Lake	TP (µg/L)	Flow (ac-ft/yr)	TP Load (lb/yr)
Winona (Northwest)	Boller's Lake	72.9*	5,442	**1,070**
Winona (Southeast)	Winona (Northwest)	84.9	6,828	**1,563**

*Estimated using an uncalibrated BATHTUB model using phosphorus load and flow listed in Table 30

Atmospheric Deposition

Atmospheric deposition represents the phosphorus that is bound to particulates in the atmosphere and is deposited directly onto surface waters. Average phosphorus atmospheric deposition loading rates were 0.386 lb/ac/yr of TP per year for an average rainfall year for the Lower Mississippi River Basin (Barr 2007 addendum to MPCA 2004). This rate was applied to the lake surface area to determine the total atmospheric deposition load per year to the impaired lakes.

Table 33. Atmospheric deposition phosphorus loads to impaired lakes [MPCA 2004]

Impaired Lake	Atmospheric Deposition Phosphorus Load (lb/yr)
Winona (Northwest)	**32.4**
Winona (Southeast)	**85.3**

Internal Loading

Internal loading in lakes refers to the phosphorus load that originates in the bottom sediments or macrophytes and is released back into the water column. Internal loading can occur via:

1. *Chemical release from the sediments:* Caused by anoxic (lack of oxygen) conditions in the overlying waters or high pH (>9). If a lake's hypolimnion (bottom area) remains anoxic for a portion of the growing season, the phosphorus released due to anoxia will be mixed throughout the water column when the lake loses its stratification at the time of fall mixing. In shallow lakes, the periods of anoxia can last for short periods of time and occur frequently.
2. *Physical disturbance of the sediments*: Caused by bottom-feeding fish behaviors (such as carp and bullhead), motorized boat activity, and wind mixing. This is more common in shallow lakes than in deeper lakes.

No sediment samples were available to estimate internal loading rates of phosphorus due to anoxic release from the sediments using the statistical regression equations developed from measured release rates and sediment P concentrations for a large set of North American lakes (Nürnberg 1988; Nürnberg 1996). Internal loading due to physical disturbance is difficult to estimate reliably and was therefore not included in the lake phosphorus analyses.

Some amount of internal loading is implicit in the BATHTUB lake water quality model, therefore internal loading rates added to the BATHTUB model during calibration represents the excess sediment release rate beyond the average background release rate accounted for by the model development lake dataset. The implicit amount of internal loading in BATHTUB is typically smaller than the calibrated BATHTUB rates for shallow lakes because the BATHTUB model development lake dataset is less representative of this lake type and therefore accounts for less implicit internal loading in shallow lakes. Shallow lake sediments can easily be disturbed by wind-driven mixing of the water column, or physical disturbance from boats and carp.

Winona (Northwest) has a long recorded history of filling in with mud and debris from Gilmore Creek beginning as early as 1887, occasional winter fish kills, and is known to support carp and curly-leaf pondweed (WSU 1986). High internal sediment load is expected in this lake basin. Winona (Southeast) was dredged in 1999-2000 to remove accumulated sediment and increase lake depths. Lower internal sediment load is expected in this lake basin compared to the Northwest basin.

Table 34. Internal phosphorus load assumptions and summary

Lake	% Littoral (< 15 feet deep)	BATHTUB Calibrated Excess Phosphorus Release Rate (mg/m^2-calendar day)	BATHTUB Calibrated Excess Phosphorus Internal Load (lb/yr)
Winona (Northwest)	89%	1.32	**364**
Winona (Southeast)	59%	0.06	**44**

3.6.2 Stream Bacteria

Bacteria sources have been identified within the Mississippi River-Winona Watershed through several previous studies, including the 1996 Agricultural Nonpoint Source Pollution Model developed by Nick Gervino and the Revised Regional TMDL Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota (MPCA 2006). In addition, numerous subsequent implementation efforts are underway to reduce bacteria sources, including the February 2007 Lower Mississippi River Basin Fecal Coliform Implementation Plan, Section 319 Nonpoint Source Pollution Control Program: 2005-2009 South Branch Bacteria Reduction Project, and the CWP Phase II 2009-2013 Whitewater River Watershed Bacteria Reduction Continuation Project.

Major permitted and non-permitted sources of bacteria in the Mississippi River-Winona Watershed include WWTFs, livestock facilities with NPDES Permits, individual sewage treatment systems (ISTSs), livestock manure, and urban and rural stormwater. Information included in this section was obtained from Section 4.2 of the Revised Regional TMDL Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota (MPCA 2006), and from the MPCA NPDES permitted facility and registered feedlot database (November 2014).

Certain types of bacteria pose a potential health risk to those who come into contact with surface water. These bacteria come from a variety of sources, including agricultural runoff, inadequately treated domestic sewage, and even wildlife. Some of these bacteria may cause disease. Other potential pathogens (disease-causing agents) from these sources include viruses, protozoa, and worms. Perhaps of greatest concern are bacteria from human feces.

The limitations of available monitoring tools make it difficult to determine whether bacterial contamination in a water body is from human or animal sources. It is, however, possible to determine whether the bacteria originated in the intestinal tract of a mammal. These kinds of bacteria are called fecal coliforms. If fecal coliform bacteria levels exceed state water quality standards, it's an indication that fecal matter is entering the stream in quantities that pose a potential threat to public health.

There are many types of fecal coliform bacteria, and not all of them cause disease in humans, but where there are coliform bacteria there may be pathogens of concern. Thus, widespread violation of the fecal coliform standard in the Lower Mississippi River Basin indicates serious pollution and a possible health concern, but it doesn't necessarily mean there is an immediate health threat in any particular area.

Bacterial contamination of surface and ground water by antibiotic-resistant micro-organisms has been expressed as a public concern in southeastern Minnesota; however, this issue has not been widely studied and is not addressed in this report. Further work is needed in this area.

The relationship between land use and fecal coliform concentrations found in streams is complex, involving both pollutant transport and rate of survival in different types of aquatic environments. Intensive sampling at several of the sites listed above in southeastern Minnesota shows a strongly positive correlation between stream flow, precipitation, and fecal coliform bacteria concentrations. In the Vermillion River Watershed, storm-event samples often showed concentrations in the thousands of organisms per 100 milliliters, far above non-storm-event samples. A study of the Straight River Watershed divided sources into continuous (failing ISTSs, unsewered communities, industrial and institutional sources, WWTFs) and weather-driven (feedlot runoff, manured fields, urban stormwater categories). The study hypothesized that when precipitation and stream flows are high; the influence of continuous sources is overshadowed by weather-driven sources, which generate extremely high fecal coliform concentrations. However, during drought, low-flow conditions continuous sources can generate high concentrations of fecal coliform, the study indicated. Besides precipitation and flow, factors such as temperature, livestock management practices, wildlife activity, fecal deposit age, and channel and bank storage also affect bacterial concentrations in runoff (Baxter-Potter and Gilliland 1988).

Several studies have found a strong correlation between livestock grazing and fecal coliform levels in streams running through pastures. Several samples taken in the Grindstone River in the St. Croix River Basin, downstream of cattle observed to be in the stream, were found to contain a geometric mean of 11,000 organisms/100 ml, with individual samples ranging as high as 110,000/100ml. However, carefully managed grazing can be beneficial to stream water quality. A study of southeastern Minnesota streams by Sovell, et. al., found that fecal coliform, as well as turbidity, were consistently higher at continuously grazed sites than at rotationally grazed sites where cattle exposure to the stream corridor was greatly reduced. This study and several others indicate that sediment-embededness, turbidity, and fecal coliform concentrations are positively related. Fine sediment particles in the streambed can serve as a substrate harboring fecal coliform bacteria. "Extended survival of fecal bacteria in sediment can obscure the source and extent of fecal contamination in agricultural settings," (Howell et. al. 1996).

Hydrogeologic features in southeastern Minnesota may favor the survival of fecal coliform bacteria. Cold ground water, shaded streams, and sinkholes may protect fecal coliform from light, heat, drying, and predation (MPCA 1999).

Sampling in the South Branch of the Root River Watershed showed concentrations of up to 2,000 organisms/100 ml coming from springs, pointing to a strong connection between surface water and ground water (Fillmore

County 1999 and 2000). The presence of fecal coliform bacteria has been detected in private well water in southeastern Minnesota. However, many such detections have been traced to problems of well construction, wellhead management, or flooding, not from widespread contamination of the deeper aquifers used for drinking water. One study from Kentucky showed that rainfall on well-structured soil with a sod surface could generate fecal coliform contamination of the shallow ground water through preferential flow (McMurry et. al. 1998).

Finally, fecal coliform survival appears to be shortened through exposure to sunlight. This is purported to be the reason why, at several sampling sites downstream of reservoirs, fecal coliform concentrations were markedly lower than at monitoring sites upstream of the reservoirs. This has been demonstrated at Lake Byllesby on the Cannon River and the Silver Creek Reservoir on the South Branch of the Zumbro River in Rochester.

Despite the complexity of the relationship between sources and in-stream concentrations of fecal coliform, the following can be considered major source categories:

3.6.2.1 Permitted

Wastewater Treatment Facilities

The WWTFs are required to test fecal coliform bacteria levels in effluent on a weekly basis. Dischargers to Class 2 waters are required to disinfect from April through October. Wastewater disinfection is required during all months for dischargers within 25 miles of a water intake for a potable water supply system (Minn. R. ch. 7053.0215, subp. 1). The geometric mean for all samples collected in a month must not exceed 200 cfu/ 100 mL fecal coliform bacteria. There are a total of seven NPDES permitted WWTFs located within the drainage area of an *E. coli* impaired stream. In addition to these, a WLA was written for the Crystal Springs State Fish Hatchery. Discharges from this facility are regulated under NPDES Permitting. The WLA for the Fish Hatchery was set equal to the permitted discharge volume multiplied by the *E. coli* water quality standard (126 organisms/ 100 ml). Bacteria loads from NPDES-permitted WWTFs was estimated based on the design flow and permitted bacteria effluent limit of 200 org/ 100 mL (Table 35).

Table 35. WWTF design flows and permitted bacteria loads

Facility NAME	NPDES Permit #	Impaired Stream	Design flow (MGD)	Permitted Bacteria Load as Fecal Coliform: 200 org/ 100 mL [billion org/day]	Equivalent Bacteria Load as *E. coli*: 126 org / 100 mL[1] [billion org/day]
Rollingstone WWTP	MNG580078	Rollingstone Creek (07030004-533)	0.80	6.03	3.80
Utica WWTP	MN0022055	Whitewater River (07040003-539)	0.23	1.73	1.09
Whitewater Region WWTP	MN0046868		1.12	8.48	5.34
DNR Crystal Springs State Fish Hatchery	MN0004421		3.20	24.23	15.26
Altura WWTP	MN0021831		0.36	2.72	1.71
Plainview Elgin WWTP	MN0055361		2.67	20.21	12.74
Stockton WWTP	MNG580079	Garvin Brook (07090003-595)	0.61	4.65	2.93
Minnesota City WWTP	MN0069817		0.03	0.23	0.14

[1] WWTF permits are regulated for fecal coliform, not *E. coli*. The MPCA surface water quality standard for *E. coli* (126 org / 100 ml) was used in place of the fecal coliform permitted limit of 200 org / 100 ml, which was also the MPCA surface water quality standard prior to the March 2008 revisions to Minn. R. ch. 7050.

Livestock Facilities with NPDES Permits

Animal waste containing fecal bacteria can be transported in watershed runoff to surface waters. The MPCA regulates animal feedlots in Minnesota though counties may be delegated by the MPCA to administer the program for feedlots that are not under federal regulation. The primary goal of the state program for AFO is to ensure that surface waters are not contaminated by the runoff from feeding facilities, manure storage or stockpiles, and cropland with improperly applied manure. Livestock also occur at hobby farms, small-scale farms that are not large enough to require registration but may have small-scale feeding operations and associated manure application or stockpiles.

Livestock manure is often either surface applied or incorporated into farm fields as a fertilizer and soil amendment. This land application of manure has the potential to be a substantial source of fecal contamination, entering waterways from overland runoff and drain tile intakes. Research being conducted in southern Minnesota shows high concentrations of fecal bacteria leaving fields with incorporated manure and open tile intakes (Scott Matteson, personal communication). Minn. R. ch. 7020 contains manure application setback requirements based on research related to phosphorus transport, and not bacterial transport, and the effectiveness of these current setbacks on bacterial transport to surface waters is not known.

There are nine active NPDES permitted feedlot operations in the Mississippi River-Winona Watershed, five of which are CAFOs. The MPCA currently uses the federal definition of a CAFO in its regulation of animal feedlots. In Minnesota, the following types of livestock facilities are issued, and must operate under, a NPDES Permit: a) all federally defined CAFOs, some of which are under 1000 animal units (AUs) in size; and b) all CAFOs and non-CAFOs which have 1000 or more AUs. These feedlots must be designed to totally contain runoff, and manure management planning requirements are more stringent than for smaller feedlots. In accordance with the State of Minnesota's agreement with EPA, CAFOs with state-issued General NPDES Permits must be inspected twice during every five year permitting cycle and CAFOs with state issued Individual NPDES Permits are inspected annually. The number of AUs by animal type registered with the MPCA feedlot database (November 2014) is summarized in Table 43.

Table 36. NPDES permitted feedlot operation number of animals (MPCA feedlot database November 2014)

Impaired Stream	Facility NAME	NPDES Permit #	Cow AU	Pig AU	CAFO
Whitewater River (07040003-539)	Daley Farms of Lewiston LLP	MN0067652	1,996		ü
	Diamond K Dairy Inc.	MN0064629	1,498		ü
	Gar-Lin Dairy Site 1	MNG440496	2,852		ü
	Gar-Lin Dairy Site 2	MNG440496	56		
	Gar-Lin Dairy Site 3	MNG440496	182		
	Holden Farms Inc., St. Charles	MNG440331		960	ü
	Schell's Pine Grove Farm	MNG440040	605		
	Shea Dairy Inc.	MN0070181	1,255		ü

3.6.2.2 Non-permitted

Individual Sewage Treatment Systems

Of the rural population of the Lower Mississippi River basin, an estimated 65,314 – or 44%– have inadequate treatment of their household wastewater. This includes individual residences and unsewered communities, both incorporated and unincorporated. Nonconforming septic systems are considered to be an important source of fecal coliform bacteria, particularly during periods of low precipitation and runoff when this continuous source may dominate fecal coliform loads. Unsewered or undersewered communities include older individual systems that are generally failing, and/or collection systems that discharge directly to surface water. This may result in locally high concentations of wastewater contaminants in surface water, including fecal coliform bacteria, in locations close to population centers where risk of exposure is relatively high.

The court decision leading to the revised Regional TMDL Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota (MPCA 2006) included the following language related to septic systems that discharge directly to surface waters:

"MCEA describes a straight pipe septic system as a system of disposing untreated sewage directly via a pipe to rivers, lakes, drain tiles, or ditches. Such systems are illegal pursuant to Minn. Stat. §§ 115.55 and 115.56."

The MPCA concurs that these are illegal and un-permitted systems and would expand the definition slightly to include partially treated, as well as untreated, sewage. The majority of these systems likely have some form of rudimentary settling which may provide partial, but inadequate, treatment. The Minn. R. ch. 7080 definition of septic systems posing an imminent threat to public health or safety (ITPHSS) includes "surface or surface water discharges and sewage backup into a dwelling or other establishment." Straight pipe septic systems clearly meet this definition.

An estimate of ITPHSS in each impaired stream subwatershed was based on 2010 U.S. Census population data by county and percent of ITPHSS by county (MPCA 2012 SSTS Annual Report) area-weighted to the fraction of the impaired reach subwatershed area in Olmstead, Wabasha, and Winona Counties. A total of 86 ITPHSS are estimated to be located in the seven impaired stream subwatersheds.

An MPCA evaluation for the Minnesota River Basin suggests that improper ISTS may be responsible for approximately 74 fecal coliform bacteria organisms per 100 milliliter sample within larger rivers (David Morrison, "Contributions from Septic Systems and Undersewered Communities," presented at Bacteria in the Minnesota River, Mankato, Minnesota, Feb 16, 1999). However, transport and survival of fecal coliform bacteria are not well understood, particularly as they are affected by the interaction of surface and ground water flows in the karst geology found throughout the Lower Mississippi Basin.

Livestock Manure

Runoff from livestock feedlots, pastures, and land application areas has the potential to be a significant source of fecal coliform bacteria and other pollutants. There is considerable spatial variation in the type and density of livestock across the Mississippi River-Winona Watershed. There are 79,841 cow (Figure 12), 6,088 pig, 3,121 poultry, 1,152 horse, 150 goat, 125 bison, and 99 sheep AUs registered in the MPCA feedlot database (November 2014) for the Mississippi River-Winona Watershed (Figure 13). Very small numbers of elk, llama, deer, and duck are also registered in the watershed. Within the 7 impaired stream subwatersheds there are an estimated 27,538 AUs.

Dairy and beef cattle predominates the livestock numbers in the Mississippi River-Winona Watershed. While many of the non-permitted dairy and beef cattle operations have manure management practices in place, the majority of these operations are relatively small, with open feedlots, presenting the potential for polluted runoff much of the year. Considerable grazing of cattle still occurs. Where over-grazing occurs, serious erosion and manure runoff can result. This includes grazing of woodland, which can result in severe erosion. However, properly managed pasture can increase infiltration of precipitation into the soil profile, reducing runoff and improving water quality.

Swine facilities tend to confine livestock under a roof, with a pit for liquid manure beneath a slated floor. Thus, feedlot runoff tends not to be a common occurrence with most facilities, but land application of manure can be a major source of nonpoint pollution runoff. Liquid swine manure is commonly incorporated into the soil during, or shortly after, land application. While this has the potential to greatly reduce the pollution for bacteria runoff.

While there is little runoff potential from enclosed poultry facilities themselves, open stockpiling of poultry manure is a common practice. These stockpiles, as well as land application areas, are potential sources of bacteria runoff research has shown that fields where manure is incorporated can still be a source of bacteria when there are open tile intakes.

Urban and Rural Stormwater

Untreated stormwater from cities, small towns, and rural residential or commercial areas can be a source for many pollutants including fecal coliform bacteria and associated pathogens. Fecal coliform concentrations in urban runoff can be as great as or greater than those found in cropland runoff, and feedlot runoff (EPA 2001). Sources of fecal coliform in urban and residential stormwater include pet and wildlife waste that can be directly conveyed to streams and rivers via impervious surfaces and storm sewer systems. Newer urban development often includes stormwater treatment in the form of such practices as sedimentation basins, infiltration areas, and vegetated filter strips. None of the communities within the watersheds of the impaired reaches included in this report are required to obtain Municipal Separate Storm Sewer System (MS4) Permits (Permits). These Permits require a range of actions that will ultimately reduce the impact of stormwater from these communities on downstream water bodies. However, the smaller communities or even rural residences not covered under MS4 Permits located in the watersheds of the impaired reaches may still need to take action to reduce stormwater, and associated bacteria, runoff.

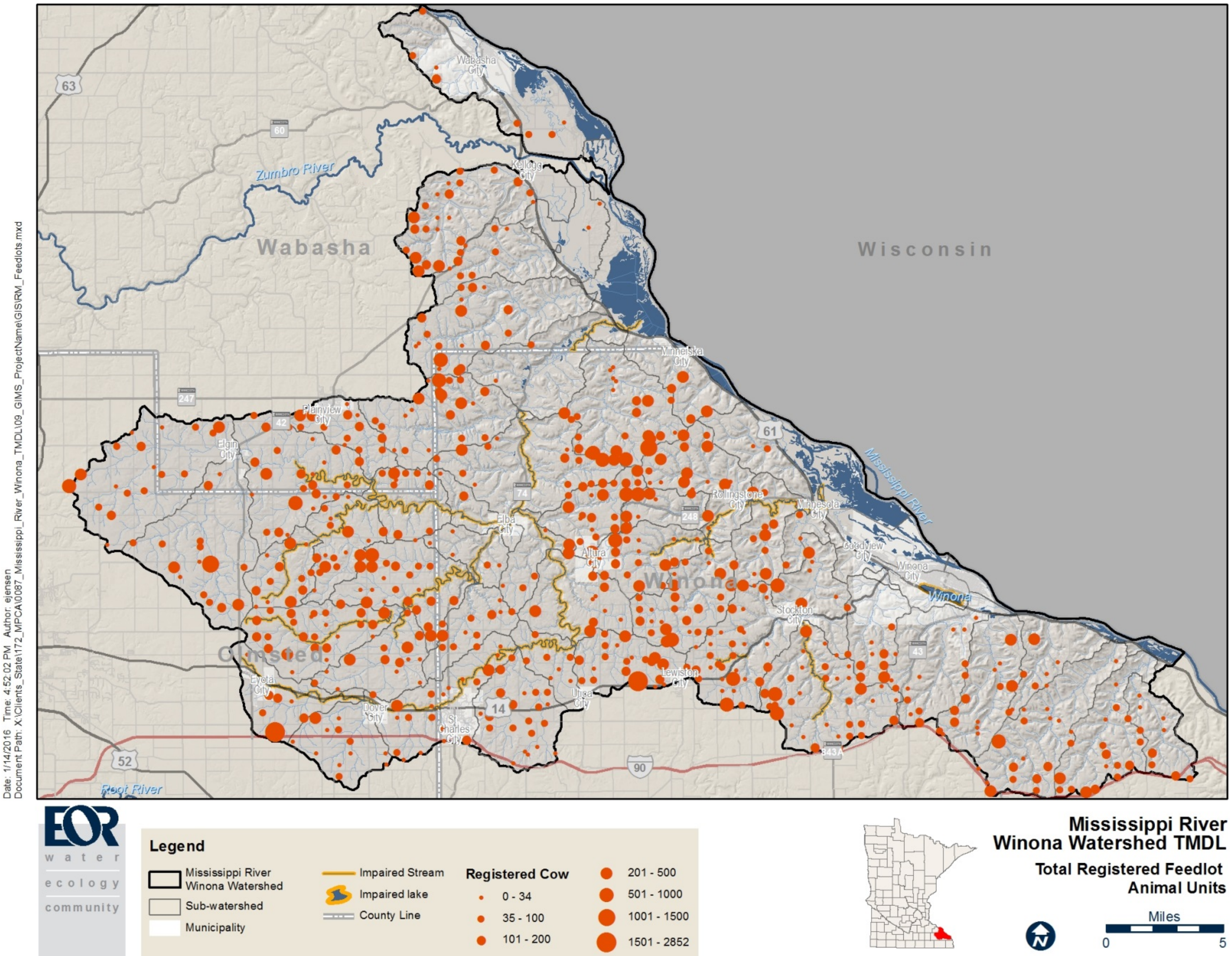

Figure 12. Registered feedlot cow animal units in the Mississippi River-Winona Watershed (MPCA, November 2014). Feedlot locations are based on addresses provided to the feedlot database; feedlots with known inaccurate locations have been removed from the map.

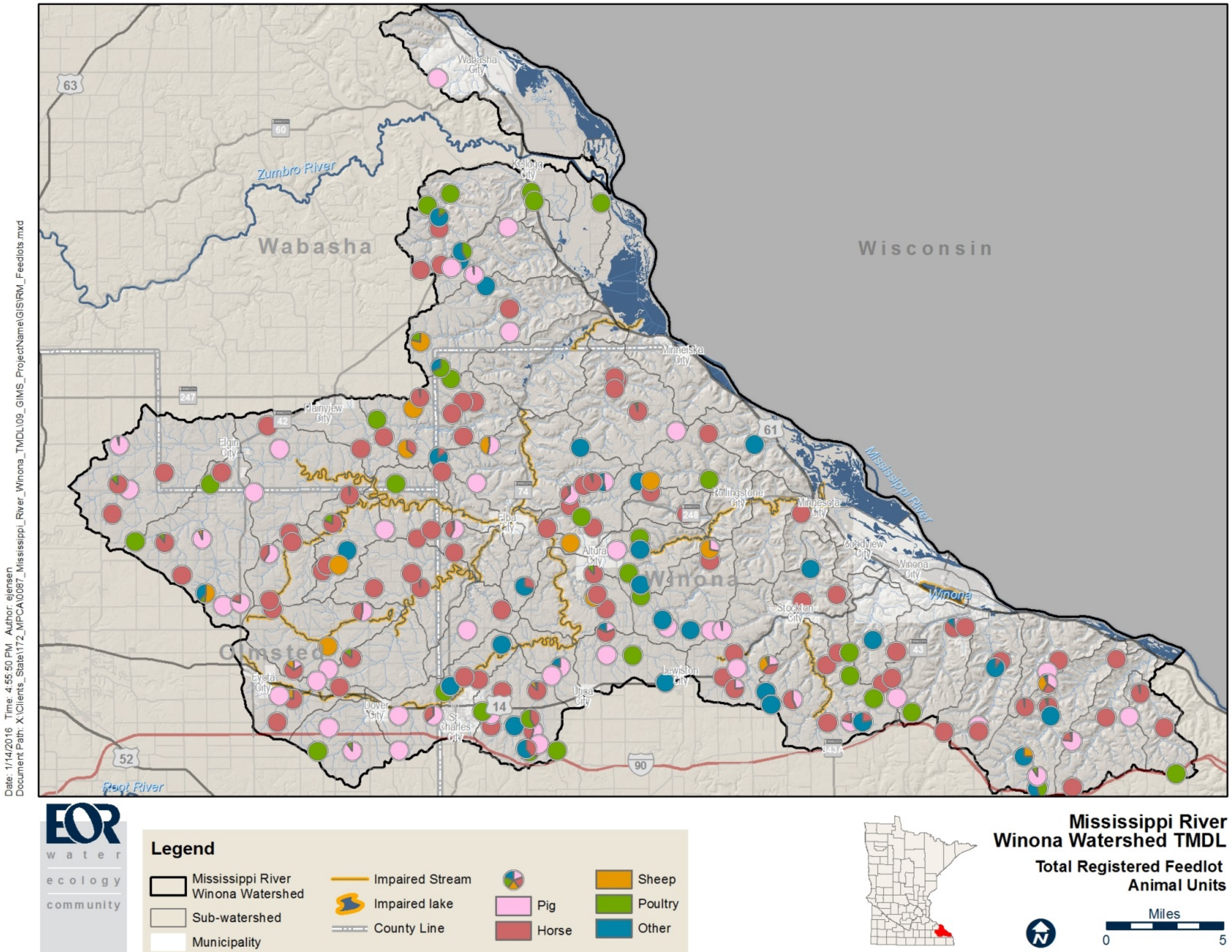

Figure 13. Registered feedlot animal units by animal type, excluding cows (MPCA, November 2014). Feedlot locations are based on addresses provided to the feedlot database; feedlots with known inaccurate locations have been removed from the map.

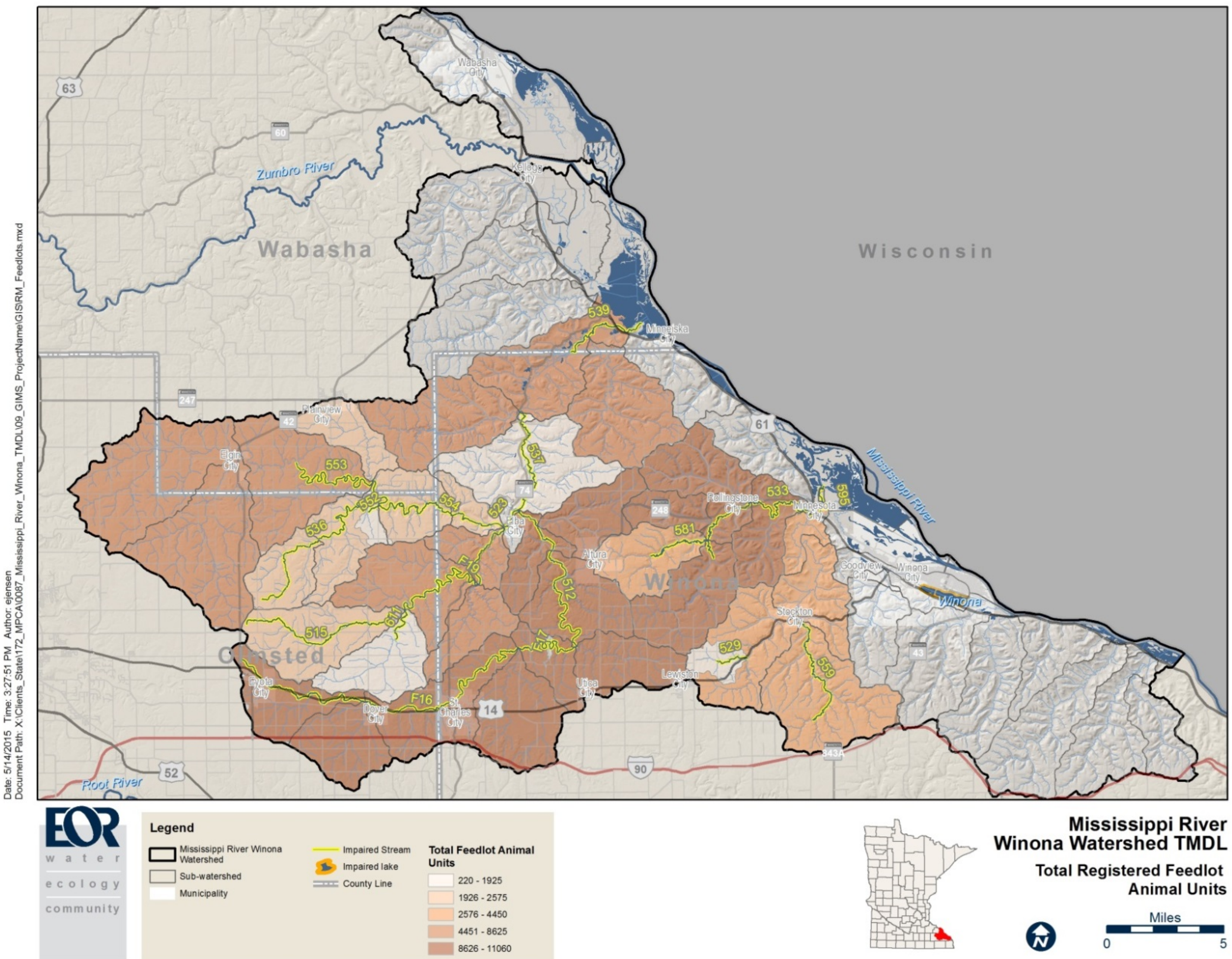

Figure 14. Total registered feedlot animal units by impaired stream subwatershed (MPCA, November 2014).

3.6.3 Stream Nitrate

The major sources of nitrate in the Mississippi River-Winona Watershed are leaching loss from manure and fertilizer applied to row crop acres, WWTF effluent, and atmospheric deposition (MPCA 2014a).

The MPCA and MDA monitor nitrate in surface waters. The MPCA uses this data to determine if all water quality standards are being met. In 2011, 15 cold-water streams in Minnesota were listed as not meeting the nitrate water quality standards (listed as impaired). Twelve of the fifteen were located in southeastern Minnesota. Two of those twelve are located in the Mississippi-River Winona Watershed.

In a targeted study of southeastern Minnesota private well drinking water nitrate concentrations, the percent of wells exceeding 10 mg/l nitrate-N ranged between 9.3% and 14.6% during the years 2008 to 2011 (MDA 2013).

The MDA report titled: Commercial Nitrogen and Manure Fertilizer Applications on Minnesota Corn Acres Compared to the University of Minnesota Nitrogen Guidelines Crop Year 2010. This is a companion report to the 2010 Survey of Fertilizer and Manure Selection and Management Practices on Corn and Wheat in Minnesota comparing the rates of nitrogen applications on fertilized corn acres to the University of Minnesota (U of M) guidelines for nitrogen fertilizer. Figure 8 of that report details the distribution of nitrogen fertilizer rates in the SE BMP region for corn following soybeans using a “nitrogen to corn price ratio” of 0.05. This gives insight on nitrogen fertilizer use in Southeast Minnesota, a major source of nitrogen in the region (MDA 2015).

Minnesota recently initiated two state-level efforts related to nitrogen in surface waters: 1) development of nitrate river nutrient standards, and the 2) state-level Nutrient Reduction Strategy (MPCA 2014a).

The MPCA is developing water quality standards to protect aquatic life from the toxic effects of high nitrate concentrations. The standards development effort, which is required under a 2010 Legislative directive, draws upon recent scientific studies that identify the concentrations of nitrate harmful to fish and other aquatic life (MPCA 2013).

Also in development is a state-level Nutrient Reduction Strategy (MPCA 2014a), as called for in the 2008 Gulf of Mexico Hypoxia Action Plan. Minnesota contributes the sixth highest N load to the Gulf and is one of 12 member states serving on the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force. The cumulative N and phosphorus (P) contributions from several states are largely the cause of a hypoxic (low oxygen) zone in the Gulf of Mexico. This hypoxic zone affects commercial and recreational fishing and the overall health of the Gulf, since fish and other aquatic life cannot survive with low oxygen levels. Minnesota is developing a strategy which will identify how further progress can be made to reduce N and P entering both in-state and downstream waters (MPCA 2013).

The Minnesota Department of Agriculture's (USDA) updated Nitrogen Fertilizer Management Plan will be implemented in southeast Minnesota; associated activities within at-risk townships and wellhead protection areas, in addition to prevention activities intended to promote nitrogen fertilizer BMPs across southeast Minnesota, will assist toward the reduction of agricultural leaching losses within the watershed.

The scientific foundation of information for these efforts is represented in the 2013 report, *Nitrogen in Minnesota Surface Waters* (MPCA 2013, http://www.pca.state.mn.us/index.php/view-document.html?gid=19622). This document will be useful as the MPCA and other state and federal organizations further their nitrogen-related work, and also as local governments consider how high N levels might be reduced in their watersheds.

3.6.3.1 Permitted

The regulated sources of nitrate within the watersheds of the nitrate impairments addressed in this TMDL study include NPDES permitted WWTF effluent, construction stormwater, and industrial stormwater. Nitrate loads from stormwater runoff were accounted for using the methods described in Section 4.3.3 below.

Justification for nitrate stormwater allocations:

For industrial stormwater, some permitted industrial sectors have benchmark monitoring requirements for total nitrogen as nitrite plus nitrate-nitrogen. If one of these industrial sectors is currently in the watershed or comes into the watershed in the future, it would have the potential to be a source of nitrate.

For construction stormwater, nitrate is not currently covered in the construction permit, but if it becomes more prevalent in stormwater it could be. It was included to avoid potential need for transfers in the future. While sediment itself generally is not associated with nitrate, particulate nitrogen can be 30-40% of total nitrogen loads during urban runoff events. Therefore, indirectly, sediment could transport total nitrogen that could later transform to nitrate.

The WWTFs tend to discharge high concentrations of nitrate which is produced from the conversion of ammonia in waste. Limited discharge monitoring records exist for WWTFs that discharge to nitrate impaired streams. Available average monthly flow, nitrate concentration, and nitrate load data for WWTFs are summarized in Table 37. Altura WWTP existing nitrate loads are well below its nitrate WLA based on 10 mg/L and facility design flow. However, Whitewater Regional WWTP existing nitrate loads often exceed its nitrate WLA based on 10 mg/L and facility design flow. No nitrate discharge monitoring data was available for Utica WWTP between 2003 and 2012.

Table 37. WWTP nitrate discharge monitoring record summary (2003-2012)

Facility Name	DMR Range	DMR Frequency	Nitrate Load (kg/day)			Nitrate WLA (kg/day)
			Minimum	Average	Maximum	
Altura WWTP	9/2010 – 9/2012	Twice a year	0.04	1.84	3.97	13.6
Whitewater River Regional WWTP	10/2011 – 12/2012	Monthly	28.99	60.03	127.36	42.4
Utica WWTP	n/a	n/a	n/a	n/a	n/a	n/a

3.6.3.2 Non-permitted

Nitrate yields were estimated for the Mississippi River-Winona Watershed from 2007-2011 monitoring data as part of the MPCA Watershed Pollutant Load Monitoring Network (Figure 15). Nitrate-nitrite yields in the Mississippi River-Winona Watershed range from 2.58 to 16.5 lb/ac/yr.

Atmospheric deposition

The Lower Mississippi River Basin has the highest wet and dry deposition rates of nitrogen (12.1-14.6 lb/ac/yr) of all Minnesota Basins (Wall and Pearson 2013). However, atmospheric deposition nitrogen loads are relatively small compared to WWTF effluent or agricultural runoff nitrogen loads.

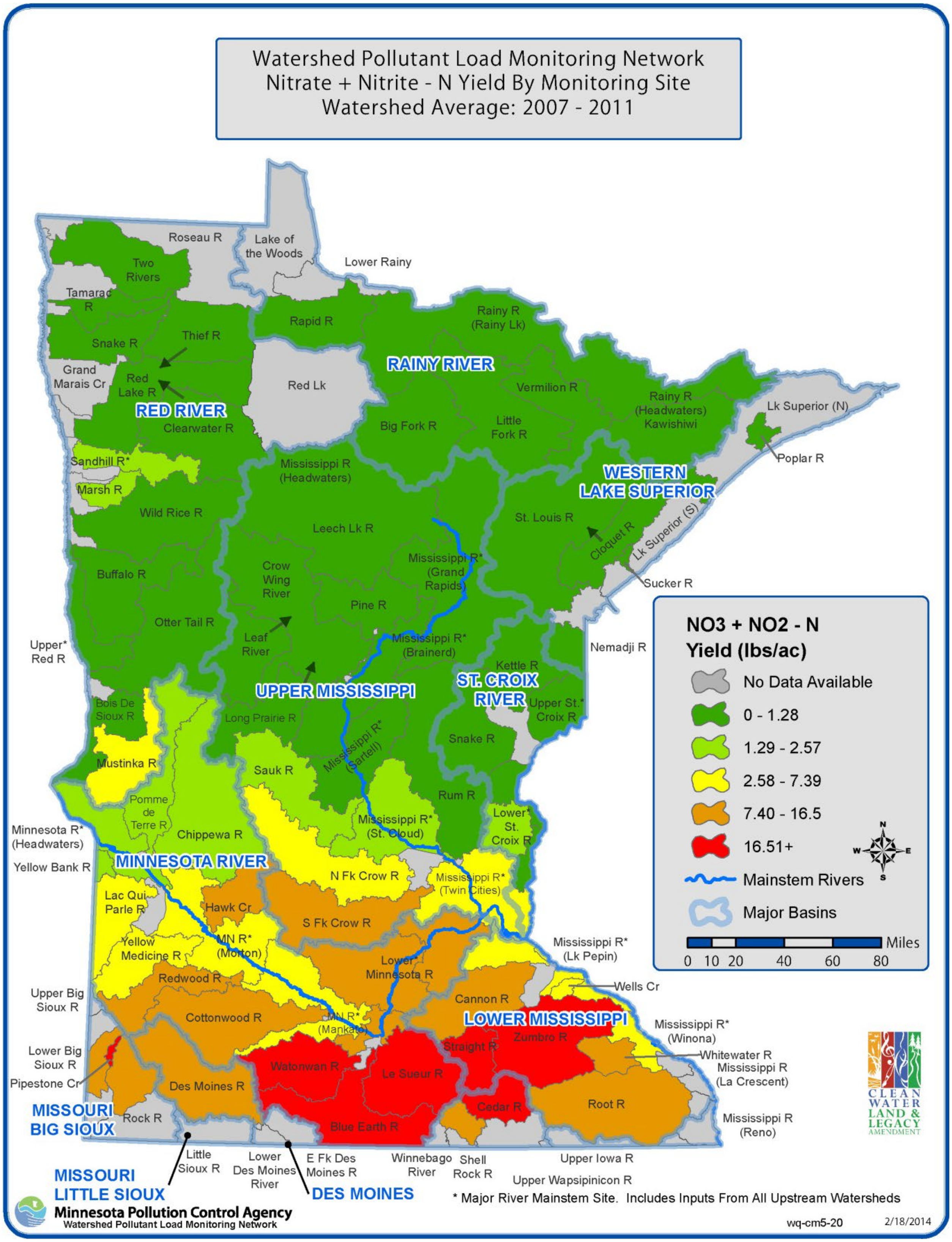

Figure 15. Nitrate-nitrite yields by Minnesota Major Watersheds (HUC 8)

Agricultural runoff

The major non-permitted source of nitrate in the Mississippi River-Winona Watershed is crop fertilizer. Fertilizer nitrogen is applied to cropland which is rapidly converted to nitrate. Nitrate is the most mobile form of nitrogen in waters, which easily dissolves in water and moves with the water. In the coarse soils and underlying karst geology of the Mississippi River-Winona Watershed, nitrate can rapidly move through the thin layers of soils and reach fractures in bedrock, where fast flow rates can transport nitrate to stream without much opportunity for denitrification losses to occur within the groundwater (GW) (Figure 16 and Figure 17).

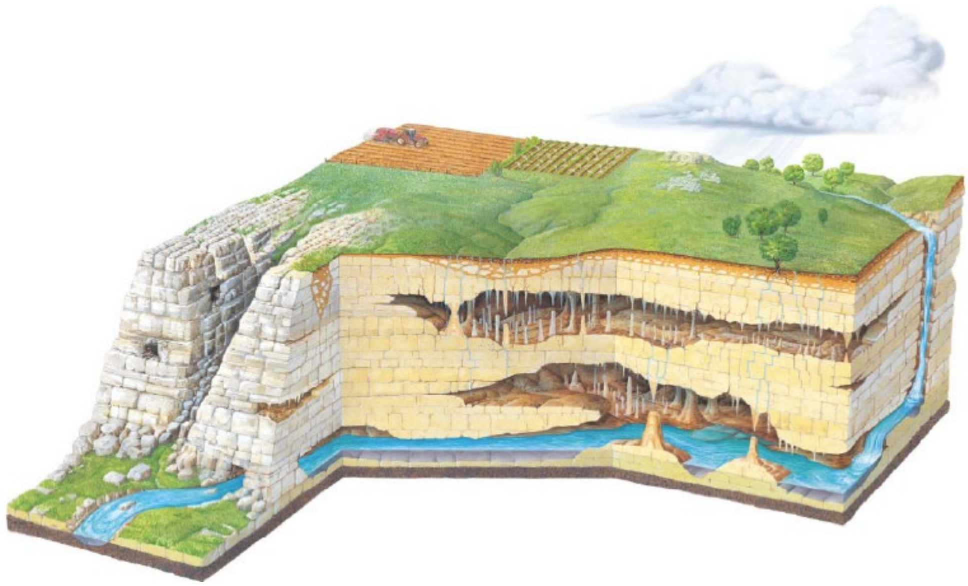

Figure 16. Karst topography

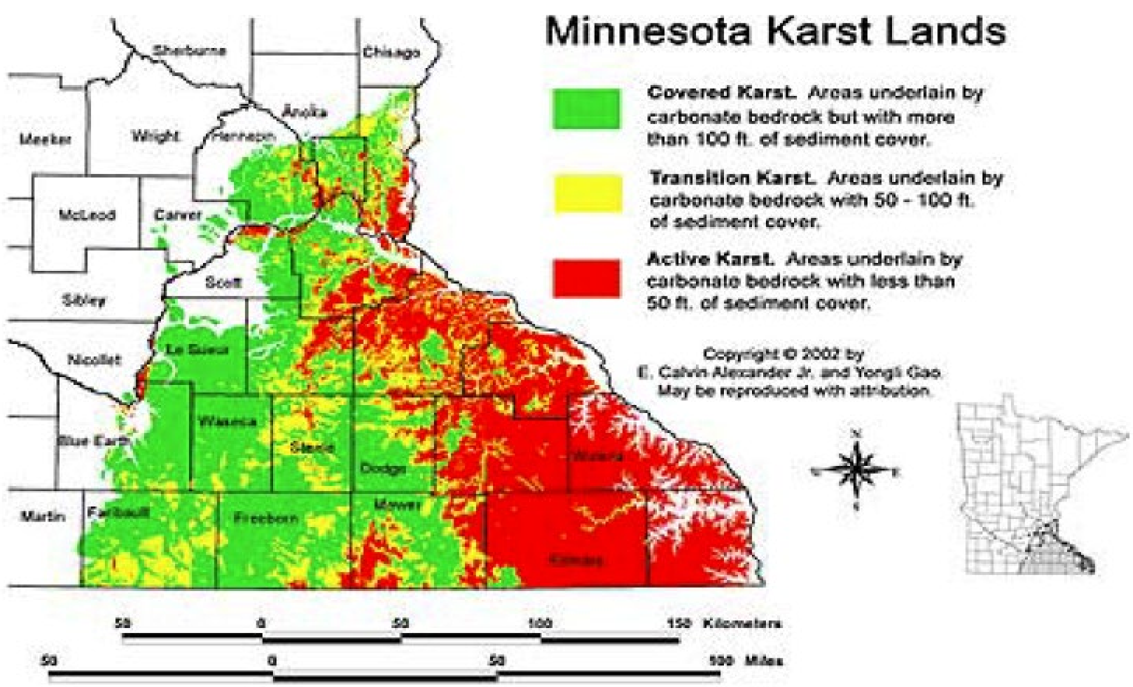

Figure 17. Minnesota Karst Lands (Calvin Alexander Jr. and Yongi Gao, 2002)

Baseflow mean nitrate-nitrogen concentrations and corresponding watershed land use were summarized for 100 sampling stations located on trout streams (although not all are on *designated* trout streams) mostly in the Driftless Area ecoregion of southeast Minnesota. Of the 100 sites examined, 22 were located within the Mississippi River-Winona Watershed (Figure 18 and Figure 19). Baseflow is the condition that conducts the majority of nitrate through Driftless Area ecoregion streams (Masarik et al. 2007). The row crop land use area of each sampling site watershed was determined using the 2009 National Agricultural Statistics Service (NASS) *corn* and *soybean* classifications. Results indicate that baseflow nitrate-nitrogen concentration in trout streams of southeast Minnesota, including the Mississippi River-Winona Watershed, are directly related to the percentage of row crop in the watershed (Figure 19).This regression analysis indicates that a watershed of approximately 60% corn and soybean acres corresponds to exceedances of Minnesota's drinking water nitrate-nitrogen standard of 10 mg/L at the point of sample in the stream (trout streams in Minnesota are protected as drinking water sources). This conclusion is supported by the findings of Nitrogen in Minnesota Surface Waters, which describe similar relationships between nitrogen in surface waters and "leaky soils below row crops," which include areas of shallow depth to bedrock such as the trout stream region of Southeast Minnesota (MPCA 2013). The natural background level of nitrate in streams appears to be very low given that the base flow concentrations of streams with undisturbed (very little row crop land use and little or no other human impact) watersheds were less than 1 mg/L. Statistical analysis also suggested that in the absence of human disturbance in a watershed, the base flow nitrate concentration at the point of sample in the stream could approach 0 mg/L (Watkins, Rasmussen, Streitz et al. 2013).

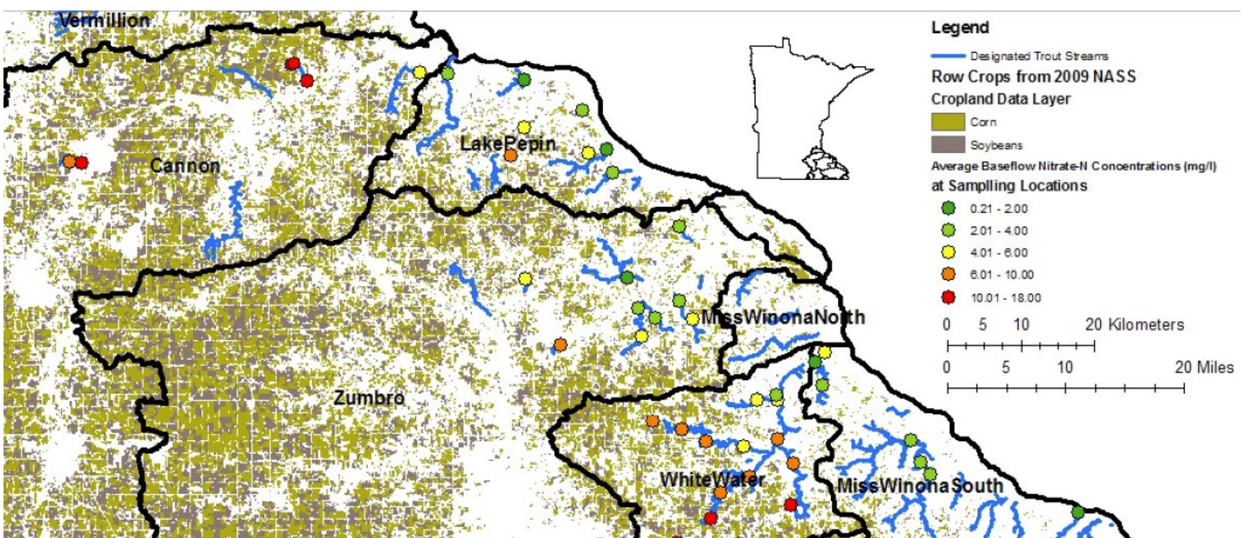

Figure 18. Current baseflow nitrate-nitrogen concentrations from all available data

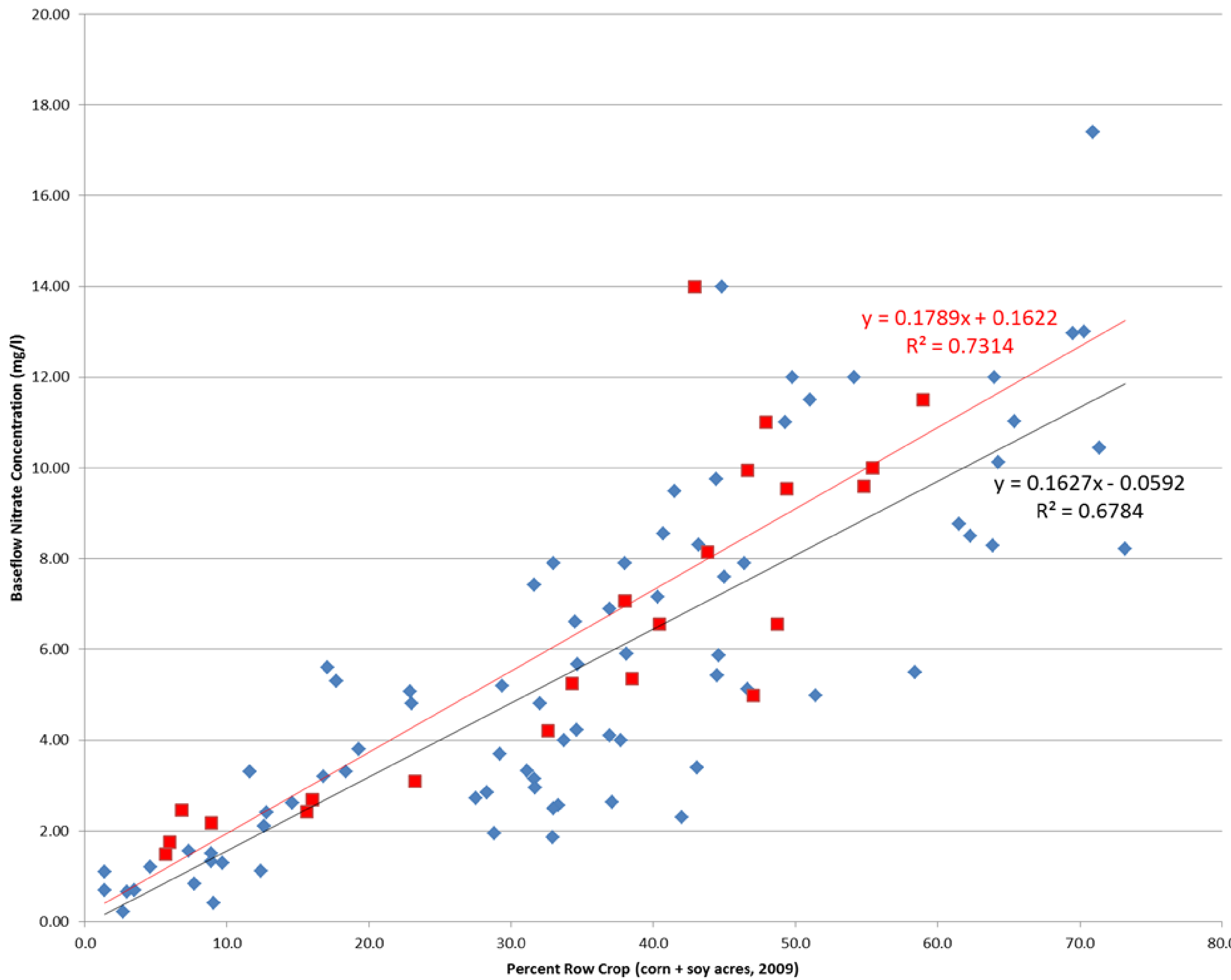

Figure 19. Percent row crop versus baseflow nitrate concentration in bedrock-dominated watersheds of SE MN; N = 100 (Watkins, Rasmussen, Streitz et al. 2013). All baseflow nitrate concentration data points from southeast Minnesota are plotted in blue, while the data points specific to the Mississippi River-Winona are plotted in red. The black linear trend line is associated with all southeast Minnesota data points while the red linear regression line is associated with the watershed specific points.

Given that the primary transport mechanism for loading nitrate to the trout streams of the Mississippi River-Winona Watershed is leaching loss from agricultural lands to GW, it follows that the response time of nitrate concentrations to changes in land use practices will likely vary in different hydrogeological settings (MGS 2013). Studies outside of southeastern Minnesota have concluded that some hydrogeological systems function in a manner whereby changes in base flow nitrate concentrations lag changes in land use practices by decades (e.g. Tesoriero et al 2013). The most significantly lagged response in southeastern Minnesota should be expected in the deep valleys incised into the Prairie du Chien Plateau, where significant baseflow is derived from deep, siliciclastic-dominated bedrock sources with one or more overlying aquitards (MGS 2013).

3.6.4 Stream Total Suspended Sediment

3.6.4.1 Permitted

The regulated sources of TSS within the watersheds of the TSS impairments addressed in this TMDL study include NPDES permitted WWTF effluent, construction stormwater, and industrial stormwater. TSS loads from wastewater and stormwater runoff were accounted for using the methods described in Section 4.4.3 below.

3.6.4.2 Non-permitted

A Soil and Water Assessment Tool (SWAT) watershed model was constructed to set TMDL targets and development of management strategies with scenarios designed to improve and protect water resources (Figure 20). The project focused on two areas within the Mississippi River Winona Watershed; the Middle and Logan Branches of the Whitewater River System (Figure 21), chosen because of an active Farmer-led council (FLC) in this area, and the Garvin Brook Watershed (Figure 22), which is a direct tributary to the Mississippi River. Scenarios were developed and simulated for these areas and then extrapolated to areas of the Mississippi River Winona Watershed with similar geology, hydrology, land uses, topography, and meteorology.

The FLC was instrumental in the development of scenarios in the Middle Branch of the Mississippi River Winona Watershed. Those scenarios were simulated in the rest of the Whitewater River System. This project also focused on identifying critical pollutant source areas, areas that contribute a disproportionate amount of nonpoint source pollution, so their effects on water quality can be mitigated or minimized with the installation of BMPs. This was done through LiDAR analysis and ground truthing in FLC subwatersheds and the Garvin Brook Watershed and then extrapolated to the remaining portions of the Mississippi River Winona Watershed.

Total Suspended Sediment

During model calibration, total sediment loads were assumed to be a mix of field and nonfield sediment components, where nonfield includes material from bank, bluff, and ravine erosion. From sediment fingerprinting studies in the Root River watershed in similar karst terrain (Stout et al. 2013), the field component may constitute about 40% of the total sediment load. Clearly nonfield erosion is important, since it is the dominant source, but SWAT's strength lies in its field runoff and erosion algorithms, and not channel erosion. Hence model calibration focused on the field component of erosion alone, which will lead to implementation of upland BMPs in SWAT to reduce these loads. Baseflow loads amounted to about 12% of the total loads, and the remaining 88% of the loads -- all occurring during stormflows -- was split between nonfield (54%) and field (46%) components such that, of the total sediment load, 40% was attributed to field, and 60% to nonfield (channel).

The total sediment load during selected periods was underpredicted by 25% during 2008-2010 and over predicted by 16% during 1975-1985. Loads during the poor-fit period of 1993-1999 were vastly overpredicted, by a factor of four. We did not find a robust method of parameterizing the model that could improve the 1993-1999 fit without simultaneously ruining the fits during the earlier and later periods. We see no obvious reason for why sediment loads were so overestimated during the 1990s by the model. Massive loads during March 1997 accounted for much of the mis-fit, but even there, modeled flows were overestimated by only a factor of two, whereas sediment loads were overestimated by nearly a factor of 10.

A probable factor in the relatively poor sediment fits is the 40%/60% field to non-field assumption. While the assumption is reasonable it is an uncertain estimate. Further, the split would most likely not be constant but would be expected to vary storm-to-storm, season-to-season, and year-to-year based on flow conditions and the moisture and vegetated conditions of streambanks. Further work is likely necessary to improve understanding of the extent and timing of this field/non-field split, and how it affects total stream sediment load.

No suspended sediment data was available from the Garvin Brook watershed and therefore no calibration was attempted. We simply applied the same parameterization (USLE_P = 0.68) to Garvin Brook as was determined for the Whitewater.

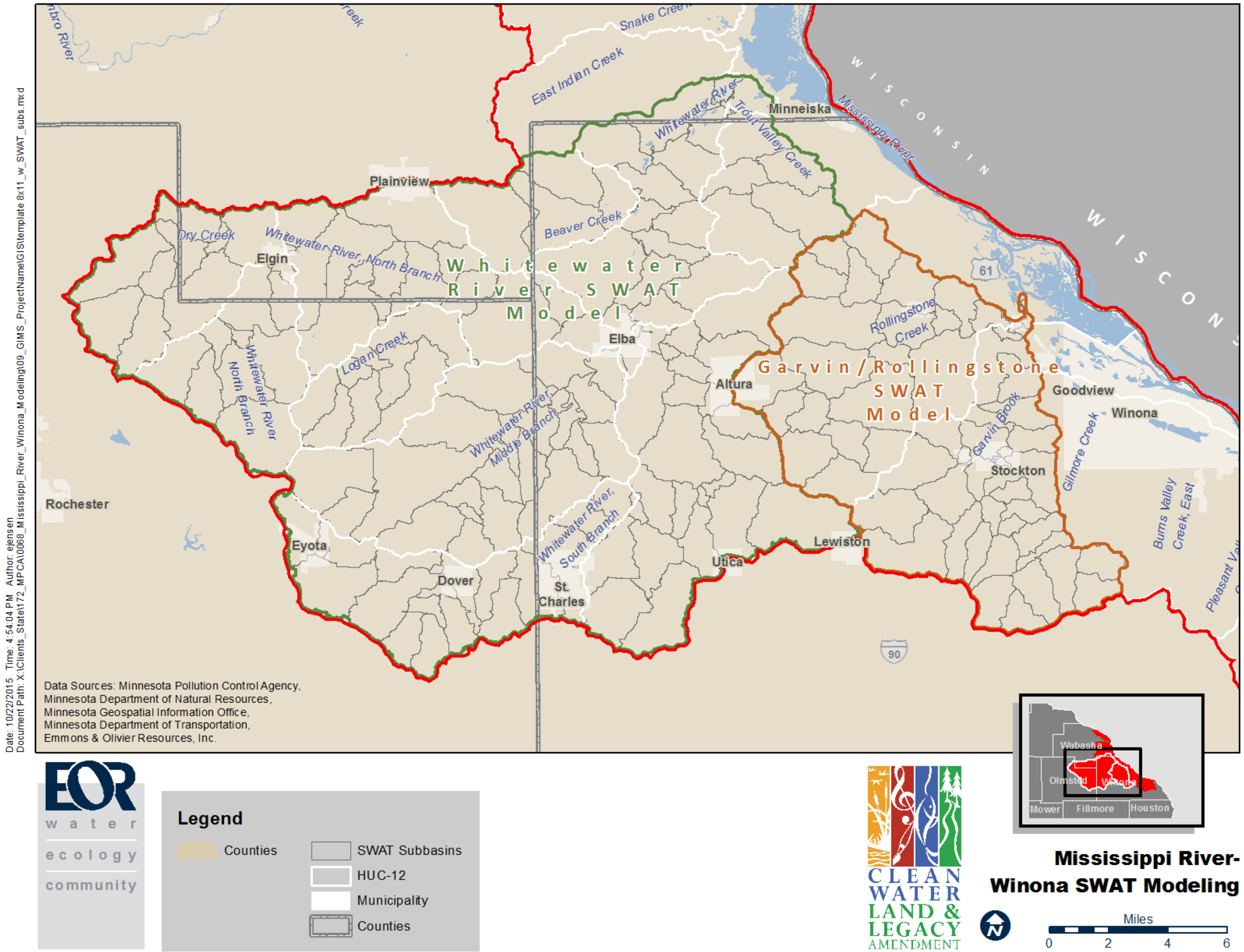

Figure 20. Whitewater River and Garvin/Rollingstone SWAT Model boundaries within the Mississippi River-Winona Watershed

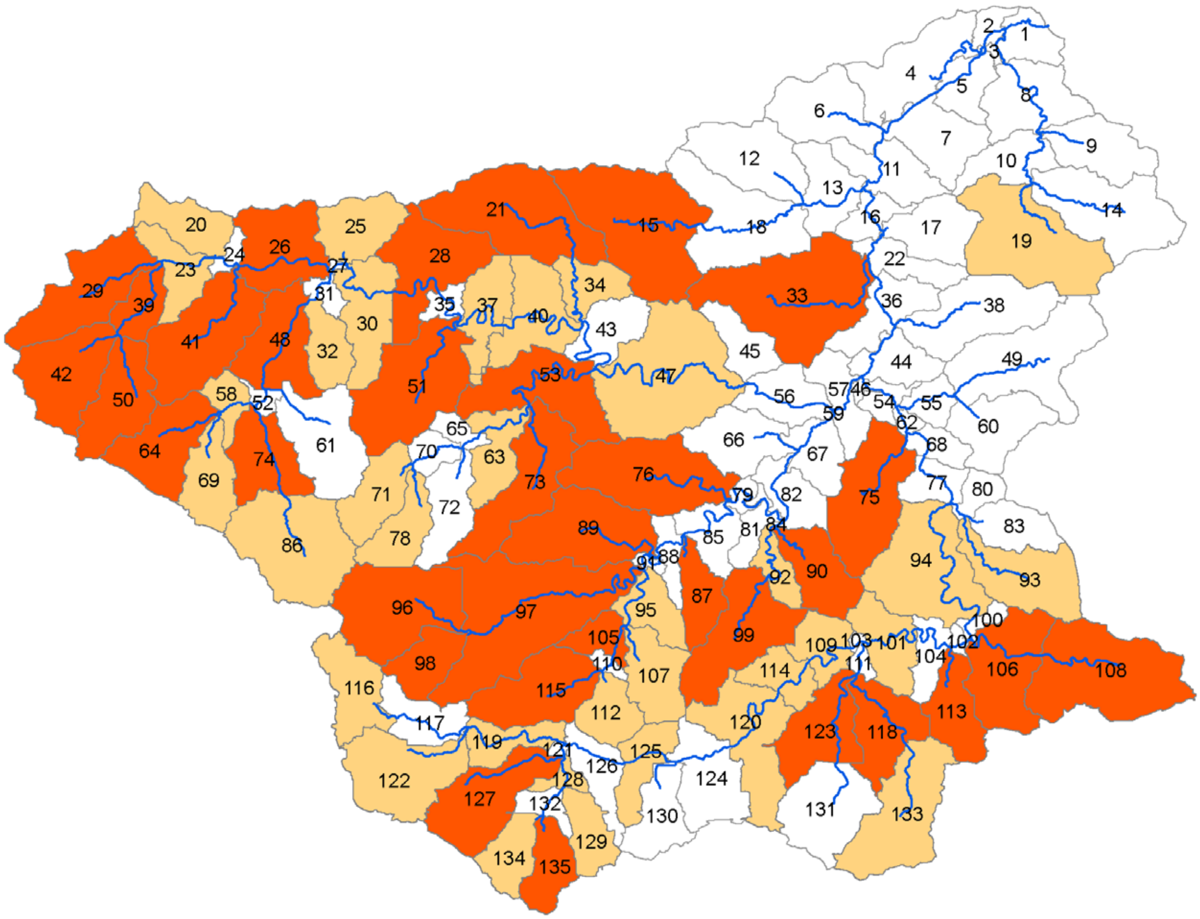

Figure 21. Whitewater watershed showing top 25% (dark orange) and 50% (dark + light orange) sediment loading SWAT subwatersheds (by SWAT index number)

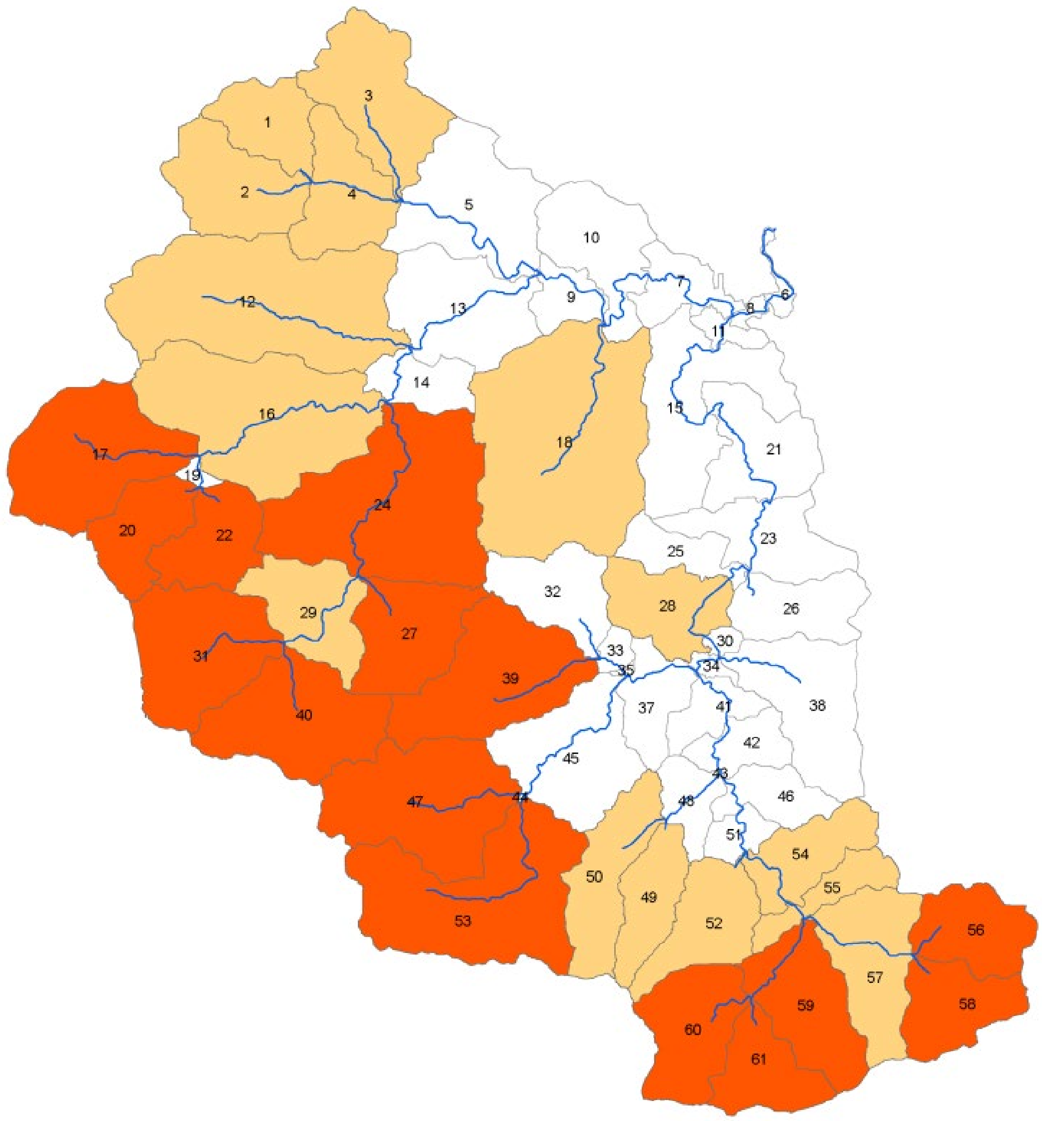

Figure 22. Garvin Brook/Rollingstone Creek watershed showing top 25% (dark orange) and 50% (dark + light orange) sediment loading SWAT subwatersheds (by SWAT index number)

4 TMDL Development

This section presents the overall approach to estimating the components of the TMDL. The pollutant sources were first identified and estimated in the pollutant source assessment. The loading capacity (TMDL) of each lake or stream was then estimated using an in-lake water quality response model or stream load duration curve and was divided among WLAs and LAs. A TMDL for a waterbody that is impaired as the result of excessive loading of a particular pollutant can be described by the following equation:

$$\text{TMDL} = \text{LC} = \sum \text{WLA} + \sum \text{LA} + \text{MOS} + \text{RC}$$

Where:

Loading capacity (LC): the greatest pollutant load a waterbody can receive without violating water quality standards;

Wasteload allocation (WLA): the pollutant load that is allocated to point sources, including WWTFs, regulated construction stormwater, and regulated industrial stormwater, all covered under NPDES permits for a current or future permitted pollutant source;

Load allocation (LA): the pollutant load that is allocated to sources not requiring NPDES permit coverage, including non-regulated stormwater runoff, atmospheric deposition, and internal loading;

Margin of Safety (MOS): an accounting of uncertainty about the relationship between pollutant loads and receiving water quality;

Reserve Capacity (RC): the portion of the loading capacity attributed to the growth of existing and future load sources.

4.1 Phosphorus

4.1.1 Loading Capacity

4.1.1.1 Lake Response Model

The modeling software BATHTUB (Version 6.1) was selected to link phosphorus loads with in-lake water quality. A publicly available model, BATHTUB was developed by William W. Walker for the U.S. Army Corps of Engineers (Walker 1999). It has been used successfully in many lake studies in Minnesota and throughout the United States. BATHTUB is a steady-state annual or seasonal model that predicts a lake's summer (June through September) mean surface water quality. BATHTUB's time-scales are appropriate because watershed phosphorus loads are determined on an annual or seasonal basis, and the summer season is critical for lake use and ecological health. BATHTUB has built-in statistical calculations that account for data variability and provide a means for estimating confidence in model predictions. The heart of BATHTUB is a mass-balance phosphorus model that accounts for water and phosphorus inputs from tributaries, watershed runoff, the atmosphere, sources internal to the lake, and GW; and outputs through the lake outlet, water loss via evaporation, and phosphorus sedimentation and retention in the lake sediments.

System Representation in Model

In typical applications of BATHTUB, lake and reservoir systems are represented by a set of segments and tributaries. Segments are the basins (lakes, reservoirs, etc.) or portions of basins for which water quality parameters are being estimated, and tributaries are the defined inputs of flow and pollutant loading to a particular segment. For the Winona (Northwest Bay) model, outflow from Boller's Lake, the direct drainage area, and the city of Winona MS4 stormwater were defined as separate tributaries. For the Winona (Southeast Bay) model, the direct drainage area and outflow from the upstream Northwest Bay were defined as separate tributaries.

Model Inputs

The input required to run the BATHTUB model includes lake geometry, climate data, and water quality and flow data for runoff contributing to the lake. Observed lake water quality data are also entered into the BATHTUB program in order to facilitate model verification and calibration. Lake segment inputs are listed in Table 38, and tributary inputs are listed in Table 30 and Table 32 from Section 3.6.1.2. Precipitation rates were estimated at 0.89 m per year based on the average 2000-2009 annual water year precipitation reported for the city of Winona in the cli-MATE database (http://mrcc.isws.illinois.edu/CLIMATE/). Evaporation rates were estimated to be 0.94 m per year based on data from the Minnesota Hydrology Guide (SCS 1992). Precipitation and evaporation rates apply only to the lake surface areas. Average phosphorus atmospheric deposition loading rates were estimated to be 0.386 lb/ac/yr for the Lower Mississippi River Basin (Barr 2007), applied over each lake's surface area. See discussion titled *Atmospheric Deposition* in *Section 3.6.1.2* for more details.

Table 38. BATHTUB segment input data for impaired lakes and unmonitored upstream lakes (italics)

Lake	Surface area (sq km)	Lake fetch (km)	Mean depth (m)	Total Phosphorus	
				(µg/L)	CV (%)
Boller's	*0.2327*	*1.2832*	*1.52**	--	--
Winona (Northwest Bay)	0.3412	0.9845	1.65	84.9	11%
Winona (Southeast Bay)	0.9008	2.1994	4.69	52.8	8%

* Unknown, estimated using best professional judgment

Model Equations

BATHTUB allows a choice among several different phosphorus sedimentation models. The Canfield-Bachmann phosphorus sedimentation model (Canfield and Bachmann 1981) best represents the lake water quality response of Minnesota lakes, and is the model used by the majority of lake TMDLs in Minnesota. In order to perform a uniform analysis it was selected as the standard equation for the study. However, the Canfield-Bachmann phosphorus sedimentation model tends to underpredict the amount of internal loading in shallow, frequently mixing lakes. Therefore, an explicit internal load is added to shallow lakes to improve the lake water quality response of the Canfield-Bachmann phosphorus sedimentation model.

Model Calibration

The models were calibrated to existing water quality data according to Table 39, and then were used to determine the phosphorus loading capacity (TMDL) of each lake. When the predicted in-lake total phosphorus concentration was *lower* than the average observed (monitored) concentration, an explicit additional load was added to calibrate the model. It is widely recognized that Minnesota lakes in agricultural and urban regions have histories of high phosphorus loading and/or very poor water quality. For this reason, it is reasonable that internal loading may be higher than that of the lakes in the data set used to derive the Canfield-Bachmann lakes formulation.

Table 39. Model calibration summary for the impaired lakes

Impaired Lake	P Sedimentation Model	Calibration Mode	Calibration Value
Winona (Northwest Bay)	Canfield & Bachman, Lakes	Added internal load	1.32 mg/m^2-day
Winona (Southeast Bay)	Canfield & Bachman, Lakes	Added internal load	0.06 mg/m^2-day

Determination of Lake Loading Capacity

Using the calibrated existing conditions model as a starting point, the phosphorus concentrations associated with tributaries were reduced until the model indicated that the total phosphorus state standard was met, to the nearest tenth of a whole number. First, upstream lake phosphorus concentrations were assumed to meet lake water quality standards. Next, the direct drainage flow weighted mean TP concentration was reduced to no less than 100 ppb for undeveloped and 150 ppb for developed areas until the in-lake phosphorus concentration met the lake water quality standard. These concentrations were chosen to represent reasonable baseline loading conditions from the mostly urban and agricultural watershed. If further reductions were needed, any added internal loads were reduced until the in-lake phosphorus concentration met the lake water quality standard.

Minnesota lake water quality standards assume that once the total phosphorus goals are met, the Chl-a and Secchi transparency standards will likewise be met (see *Section 2.1 Applicable Water Quality Standards*). With this process, a series of models were developed that included a level of phosphorus loading consistent with lake water quality state standards, or the TMDL goal. Actual load values are calculated within the BATHTUB software, so loads from the TMDL goal models could be compared to the loads from the existing conditions models to determine the amount of load reduction required.

4.1.2 Load Allocation Methodology

The LA includes all sources of phosphorus that do not require NPDES Permit coverage: watershed runoff, internal loading, atmospheric deposition, and upstream lakes described in Section 3.6.1. The LA for watershed runoff was calculated based on the flow from the unregulated watershed area that discharges to each Bay and an event mean runoff phosphorus concentration goal of 90 and 86 µg/L for the Northwest and Southeast Bays, respectively. The LA for atmospheric deposition was set to the existing load estimated in Section 3.6.1. The LA for Boller's Lake and Lake Winona (Northwest) Bay was calculated based on the BATHTUB modeled outflow and a phosphorus concentration of 54 and 60 µg/L, respectively. The remainder of the loading capacity (TMDL) after subtraction of the MOS, WLAs, and watershed runoff, upstream lake, and atmospheric LAs was used to determine the internal load LA.

4.1.3 Wasteload Allocation Methodology

All regulated stormwater and wastewater were assigned a WLA based on the methods described in the following section. The remainder of the loading capacity (TMDL) after subtraction of the MOS, atmospheric deposition, and internal loading was used to determine the WLA for each impaired lake or stream on an areal basis. Note that the MOS was distributed proportionately among internal loading and watershed runoff based on existing loads relative to the loading capacity, but not to atmospheric deposition and lake outflow from an upstream impaired lake.

4.1.3.1 Regulated Construction 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 is construction activities reflects the number of construction sites > 1 acre expected to be active in the impaired lake or stream subwatershed at any one time.

A categorical WLA was assigned to all construction activity in each impaired lake subwatershed. First, the average annual fraction of the impaired subwatershed area under construction activity over the past 5 years was calculated based on the MPCA Construction Stormwater Permit data from January 1, 2007 to October 6, 2012 (Table 40), area weighted based on the fraction of the subwatershed located in each county. This percentage was multiplied by the watershed runoff load component to determine the construction stormwater WLA. The watershed runoff load component is equal to the total TMDL (loading capacity) minus the sum of the non-watershed runoff load components (atmospheric load, upstream lake loads, internal loads, and MOS).

Table 40. Average Annual NPDES/SDS Construction Stormwater Permit Activity by County (1/1/2007-10/6/2012)

County	Total Area (ac)	Average Annual Construction Activity (% Total Area)
Winona	410,324	0.04%

4.1.3.2 Regulated Industrial Stormwater

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. The WLA for stormwater discharges from sites where there is industrial activity reflects the number of sites in an impaired stream subwatershed for which NPDES Industrial Stormwater Permit coverage is required.

A categorical WLA was assigned to all industrial activity in each impaired stream subwatershed. The industrial stormwater WLA was set equal to the construction stormwater WLA because industrial activities make up a very small fraction of the watershed area.

4.1.3.3 MS4 Regulated Stormwater

Stormwater from MS4s - a conveyance or system of conveyances (roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, storm drains) - is regulated by NPDES Permits for all mandatory, designated, or petition MS4s. All MS4s in the project area are mandatory MS4s, which is based on the U.S. Census definition of an urbanized area: a land area comprising one or more places ("central places") and the adjacent densely settled surrounding area ("urban fringe") that together have a residential population of at least 50,000 and a density of at least 1,000 people per square mile. The definition also includes any other public storm sewer system located fully or partially within an urbanized area.

The city of Winona is a regulated MS4 stormwater community and discharges to both bays of Lake Winona. A storm sewer drainage map was provided by the city of Winona in September of 2014 (Figure 22). A total regulated MS4 area of 1,362 acres was delineated from this map based on storm sewer mains with the following receiving waters: County Ditch and Lake Winona (Figure 3), with approximately 917 acres discharging to Lake Winona Northwest Bay and 445 acres discharging to Lake Winona Southeast Bay.

An individual WLA for the city of Winona MS4 was calculated based on the flow from the MS4 regulated area that discharges to each Bay and an event mean runoff concentration goal of 135 and 129 for the Northwest and Southeast Bays, respectively.

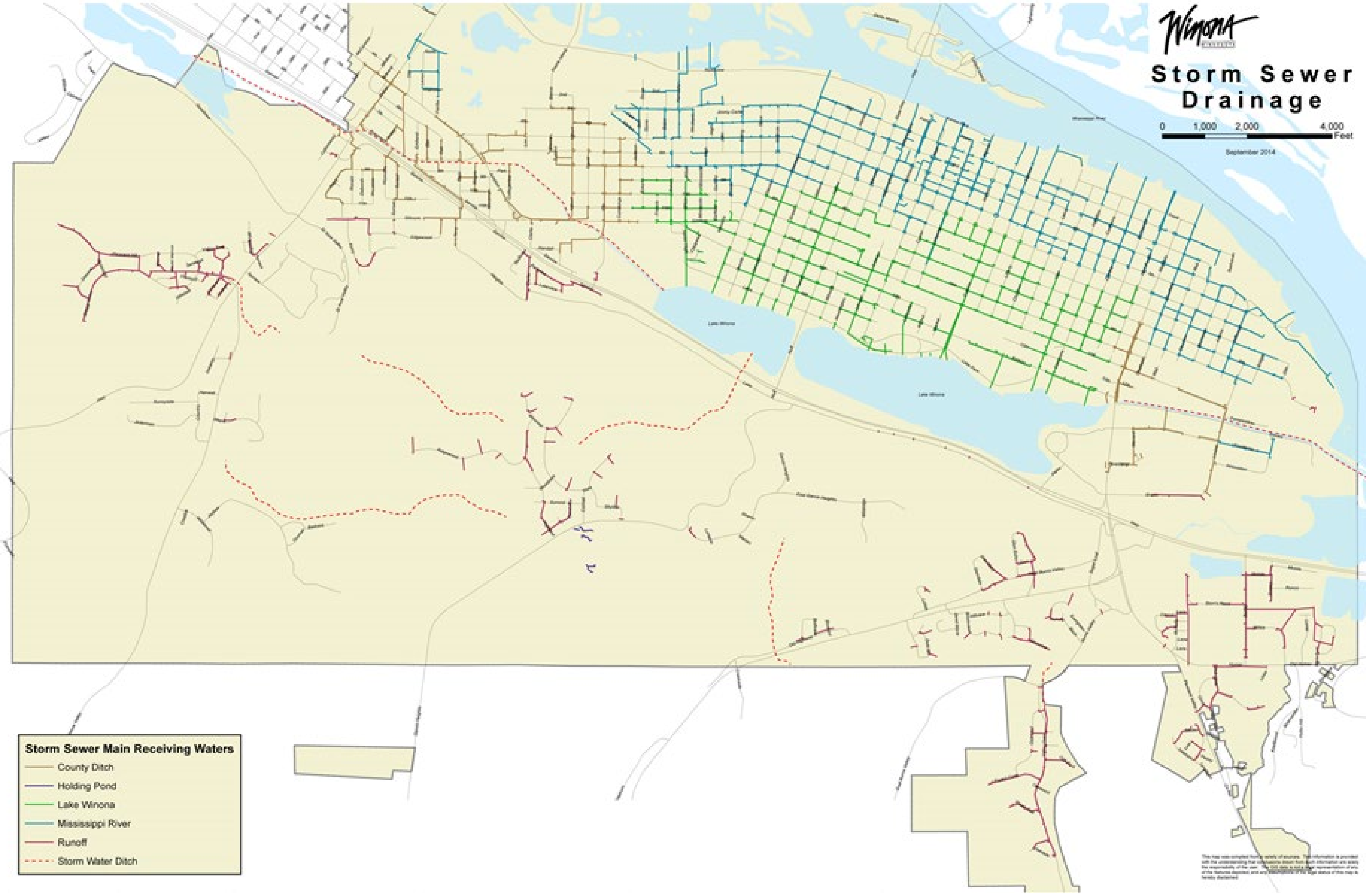

Figure 23. City of Winona Storm Sewer Drainage, September 2014

4.1.4 Margin of Safety

An explicit 10% margin of safety (MOS) was accounted for in the TMDL for each impaired lake. This MOS is sufficient to account for uncertainties in predicting phosphorus loads to lakes and predicting how lakes respond to changes in phosphorus loading. This explicit MOS is considered to be appropriate based on

- precedence for using an explicit 10% MOS in most other lake TMDLs in Minnesota
- the generally good agreement between BATHTUB model predicted and observed values indicating that the models reasonably reflect the conditions in the lakes and their subwatersheds
- BATHTUB model calibration using added internal load with values typical of shallow, eutrophic lakes, with less added internal load to the Southeast Bay which was dredged in 2001 to provide a larger area of deeper open water
- two years of in-lake water quality data and decades of water quality observations and lake history collected in the 1986 book: *A Lake Winona Compendium: Information Concerning the Reclamation of an Urban Winter-kill Lake at Winona, Minnesota* by Calvin Fremling and Glenn Heins (Winona State University)

4.1.5 Seasonal Variation

In-lake water quality varies seasonally. In Minnesota lakes, the majority of the watershed phosphorus load often enters the lake during the spring. During the growing season months (June through September), phosphorus concentrations may not change drastically if major runoff events do not occur. However, Chl-a concentration may still increase throughout the growing season due to warmer temperatures fostering higher algal growth rates. In shallow lakes, the phosphorus concentration more frequently increases throughout the growing season due to the additional phosphorus load from internal sources. This can lead to even greater increases in Chl-a since not only is there more phosphorus but temperatures are also higher. This seasonal variation is taken into account in the TMDL by using the eutrophication standards (which are based on growing season averages) as the TMDL goals. The eutrophication standards were set with seasonal variability in mind. The load reductions are designed so that the lakes and streams will meet the water quality standards over the course of the growing season (June through September).

Critical conditions in these lakes occur during the growing season, which is when the lakes are used for aquatic recreation. Similar to the manner in which the standards take into account seasonal variation, since the TMDL is based on growing season averages, the critical condition is covered by the TMDL.

4.1.6 TMDL Summary

Table 41. Winona (Northwest) phosphorus TMDL and allocations

Winona (Northwest) Load Component		Existing (kg/yr)	Goal (kg/yr)	Goal (kg/day)	Reduction (kg/yr)	Reduction (%)
Wasteload Allocations	Construction stormwater (MNR100001)	0.08	0.08	0.0002	0.0	0%
	Industrial stormwater (MNR50000)	0.08	0.08	0.0002	0.0	0%
	Winona MS4 stormwater (MS400247)	180.7	112.8	0.309	67.9	38%
	Total WLA	**180.9**	**113.0**	**0.309**	**67.9**	**38%**
Load Allocations	*Direct Drainage*	*95.7*	*79.6*	*0.218*	*16.1*	*17%*
	Boller's Lake	*475.0*	*361.4*	*0.989*	*113.6*	*24%*
	Total Watershed	570.7	441.0	1.207	129.7	23%
	Internal Load	180.7	10.1	0.028	170.6	94%
	Atmospheric Deposition	14.7	14.7	0.040	0.0	0%
	Total LA	**766.1**	**465.8**	**1.275**	**300.3**	**39%**
	MOS		**64.3**	**0.176**		
	TOTAL	**947.0**	**643.1**	**1.760**	**368.2**	**39%**

Table 42. Winona (Southeast) phosphorus TMDL and allocations

Winona (Southeast) Load Component		Existing (kg/yr)	Goal (kg/yr)	Goal (kg/day)	Reduction (kg/yr)	Reduction (%)
Wasteload Allocations	Construction stormwater (MNR100001)	0.04	0.04	0.0001	0.0	0%
	Industrial stormwater (MNR50000)	0.04	0.04	0.0001	0.0	0%
	Winona MS4 stormwater (MS400247)	89.4	52.3	0.143	37.1	41%
	Total WLA	**89.5**	**52.4**	**0.143**	**37.1**	**41%**
Load Allocations	Direct Drainage Runoff	38.7	26.2	0.072	12.5	32%
	Internal Load	19.7	0.0	0.000	19.7	100%
	Atmospheric Deposition	38.7	38.7	0.106	0.0	0%
	Total LA	**97.1**	**64.9**	**0.178**	**32.2**	**33%**
	MOS		**13.0**	**0.036**		
	Direct Drainage Subtotal	**186.6**	**130.3**	**0.357**	**69.3**	**37%**
Boundary Condition: Lake Winona (Northwest)*		714.8	505.2	1.383	209.6	29%
	TOTAL	**901.4**	**635.5**	**1.741**	**278.9**	**31%**

* MOS for the Boundary Condition is included in the Lake Winona (Northwest) TP TMDL (see Table 41)

4.1.7 TMDL Baseline

The lake TMDLs are based on data from the 10 year period 2002-2011. Any activities implemented during or after 2011 that lead to a reduction in loads or an improvement in an impaired lake or stream water quality may be considered as progress towards meeting a WLA or LA.

4.2 Bacteria (*E. coli*)

4.2.1 Loading Capacity Methodology

The loading capacities for impaired stream reaches receiving a TMDL as a part of this study were determined using LDCs. Flow and LDCs are used to determine the flow conditions (flow regimes) under which exceedances occur. Flow duration curves provide a visual display of the variation in flow rate for the stream. The x-axis of the plot indicates the percentage of time that a flow exceeds the corresponding flow rate as expressed by the y-axis. LDCs take the flow distribution information constructed for the stream and factor in pollutant loading to the analysis. A standard curve is developed by applying a particular pollutant standard or criteria to the stream flow duration curve and is expressed as a load of pollutant per day. The standard curve represents the upper limit of the allowable in-stream pollutant load (loading capacity) at a particular flow. Monitored loads of a pollutant are plotted against this curve to display how they compare to the standard. Monitored values that fall above the curve represent an exceedance of the standard.

For the stream TMDL derivation, flow records generated from the Whitewater and Garvin SWAT models for the period 2001-2010 were used to develop flow duration curves. The loading capacities were determined by applying the *E. coli* water quality standard (126 org/ 100 mL) to the flow duration curve to produce a bacteria standard curve. Loading capacities were calculated as the median value of the *E. coli* load (in billion org/day) along the bacteria standard curve within each flow regime. A bacteria load duration curve with monitored data and a TMDL summary table are provided for each stream in Section 4.2.7.

The LDC method is based on an analysis that encompasses the cumulative frequency of historic flow data over a specified period. Because this method uses a long-term record of daily flow volumes virtually the full spectrum of allowable loading capacities is represented by the resulting curve. In the TMDL equation tables of this report (Table 45 - Table 52) only five points on the entire loading capacity curve are depicted (the midpoints of the designated flow zones). However, it should be understood that the entire curve represents the TMDL and is what is ultimately approved by EPA.

4.2.2 Load Allocation Methodology

The LAs represent the portion of the loading capacity that is designated for non-regulated sources of *E. coli*, as described in Section 3.6.2, that are located downstream of any other impaired waters with TMDLs located in the watershed. The remainder of the loading capacity (TMDL) after subtraction of the MOS and calculation of the WLA was used to determine the LA for each impaired stream, on an areal basis.

4.2.3 Wasteload Allocation Methodology

4.2.3.1 MS4 Regulated Stormwater

Stormwater from MS4s - a conveyance or system of conveyances (roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, storm drains) - is regulated by NPDES Permits for all mandatory, designated, or petition MS4s. All MS4s in the project area are mandatory MS4s, which is based on the U.S. Census definition of an urbanized area: a land area comprising one or more places ("central places") and the adjacent densely settled surrounding area ("urban fringe") that together have a residential population of at least 50,000 and a density of at least 1,000 people per square mile. The definition also includes any other public storm sewer system located fully or partially within an urbanized area.

There are no regulated MS4 communities that discharge within the drainage area of a bacteria impaired stream reach.

4.2.3.2 Regulated Wastewater

An individual WLA was provided for all NPDES-permitted WWTFs that have fecal coliform discharge limits (200 org/100mL, April 1 through October 31) and whose surface discharge stations fall within an impaired stream subwatershed (Table 43). The WLA was calculated as the pollutant effluent limit multiplied by the permitted facility design flow. Continuously discharging municipal WWTF 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.

Municipal controlled (pond) discharge WWTF WLAs were calculated based on the maximum daily volume that may be discharged in a 24-hour period.

The WLAs are based on *E. coli* loads even though the facilities' discharge limits are based on fecal coliform. If a discharger is meeting the fecal coliform limits of their permit, it is assumed that they are also meeting the *E. coli* WLA in these TMDLs. Expanding and new dischargers permitted at the fecal coliform limit will be added to the *E. coli* WLA via the NPDES Permit public notice process (see Section 4.2.6).

There are a total of seven NPDES permitted WWTFs located within the drainage area of an *E. coli* impaired stream. In addition to these, a WLA was written for the Crystal Springs State Fish Hatchery. Discharges from this facility are regulated under NPDES permitting. The WLA for the Fish Hatchery was set equal to the permitted discharge volume multiplied by the *E. coli* water quality standard (126 organisms/ 100 ml). NPDES permitted WWTFs and WLAs are summarized in Table 43.

Table 43. Individual NPDES permitted facilities within the drainage area of *E. coli* impaired streams

Facility NAME	NPDES Permit #	Impaired Stream	Design flow (MGD)	*E. coli* WLA (billions org/day)
Utica WWTP	MN0022055	Whitewater River (07040003-539)	0.23	1.09
Whitewater Region WWTP	MN0046868		1.12	5.34
DNR Crystal Springs State Fish Hatchery	MN0004421		3.20	15.26
Altura WWTP	MN0021831		0.36	1.71
Plainview Elgin WWTP	MN0055361		2.67	12.74
Stockton WWTP	MNG580079	Garvin Brook (07090003-595)	0.61	2.93
Minnesota City WWTP	MN0069817		0.03	0.14
Rollingstone WWTP	MNG580078	Rollingstone Creek (07030004-533)	0.80	3.80

4.2.3.3 Feedlots Requiring NPDES/SDS Permit Coverage

An AFO is a general term for an area intended for the confined holding of animals, where manure may accumulate, and where vegetative cover cannot be maintained within the enclosure due to the density of animals. AFOs that either (a) have a capacity of 1,000 AUs or more, or (b) meet or exceed the EPA's CAFO threshold and discharge to Waters of the United States, are required to apply for permit coverage through the MPCA. If item (a) is triggered, the permit can be an SDS or NPDES/SDS Permit; if item (b) is triggered, the permit must be an NPDES Permit. These permits require that the feedlots have zero discharge to surface water.

There are a total of nine NPDES permitted feedlots located within the drainage area of an *E. coli* impaired stream (Table 44). Because they are required to have zero discharge to surface water, their WLA is 0.

Table 44. NPDES permitted feedlots located within the drainage area of *E. coli* impaired streams

Facility NAME	NPDES Permit #	Impaired Stream	*E. coli* WLA (billions org/day)
Gar-Lin Dairy Site 3	MNG440496	Whitewater River (07040003-539)	0.0
Daley Farms of Lewiston LLP	MN0067652		
Schell's Pine Grove Farm	MNG440040		
Diamond K Dairy Inc.	MN0064629		
Holden Farms Inc., St. Charles	MNG440331		
Shea Dairy Inc.	MN0070181		
Gar-Lin Dairy Site 2	MNG440496		
Gar-Lin Dairy Site 1	MNG440496		

4.2.4 Margin of Safety

An explicit MOS equal to 10% of the loading capacity was used for the stream TMDLs based on the following considerations:

- Most of the uncertainty in flow is a result of extrapolating flows from the hydrologically-nearest stream gage. The explicit MOS, in part, accounts for this.
- Allocations are a function of flow, which varies from high to low flows. This variability is accounted for through the development of a TMDL for each of five flow regimes.
- With respect to the *E. coli* TMDLs, the load duration analysis does not address bacteria re-growth in sediments, die-off, and natural background levels. The MOS helps to account for the variability associated with these conditions.

4.2.5 Seasonal Variation

Use of these water bodies for aquatic recreation occurs from April through October, which includes all or portions of the spring, summer and fall seasons. *E. coli* loading varies with the flow regime and season. Spring is associated with large flows from snowmelt, the summer is associated with the growing season as well as periodic storm events and receding streamflows, and the fall brings increasing precipitation and rapidly changing agricultural landscapes.

Critical conditions and seasonal variation are addressed in this TMDL through several mechanisms. The *E. coli* standard applies during the recreational period, and data was collected throughout this period. The water quality analysis conducted on these data evaluated variability in flow through the use of five flow regimes: from high flows, such as flood events, to low flows, such as baseflow. Through the use of LDCs and monthly summary figures, *E. coli* loading was evaluated at actual flow conditions at the time of sampling (and by month), and monthly *E. coli* concentrations were evaluated against precipitation and streamflow.

4.2.6 TMDL Summary

4.2.6.1 Whitewater River, Middle Fork (07040003-515) *E. coli* TMDL and allocations

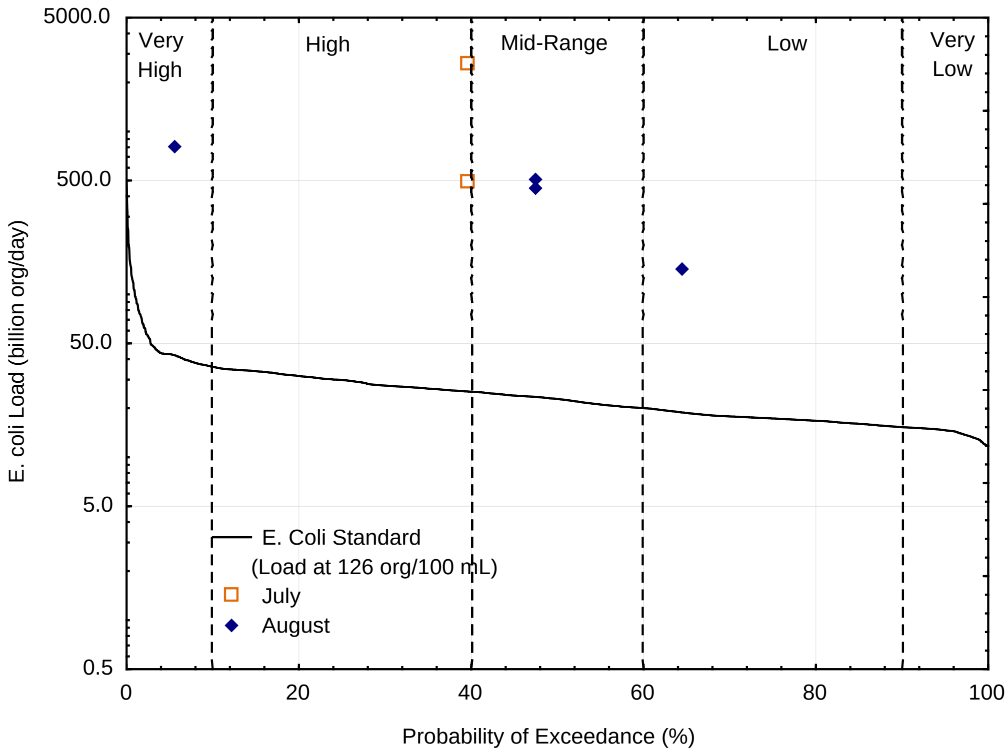

Figure 24. *E. coli* load duration curve for Whitewater River, Middle Fork (07040003-515)

Table 45. Whitewater River, Middle Fork (07040003-515) *E. coli* TMDL and allocations

Whitewater River, Middle Fork 07040003-515 Load Component		Flow Regime				
		Very High	High	Mid	Low	Very Low
		Billion organisms per day				
Existing Load[§]		*811.2*	*1,127.3*	*479.4*	*143.7*	*no data*
Wasteload Allocations	*NPDES Permitted Facilities*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*
	Total WLA	0.0	0.0	0.0	0.0	0.0
Load Allocations	*Watershed load*	*38.7*	*26.8*	*20.6*	*15.6*	*13.2*
	Total LA	38.7	26.8	20.6	15.6	13.2
10% MOS		4.3	3.0	2.3	1.7	1.5
Total Loading Capacity		43.0	29.8	22.9	17.3	14.7
Estimated Load Reduction		*768.2* *95%*	*1,097.5* *97%*	*456.5* *95%*	*126.4* *88%*	*no data*

[§]Limited monitoring data overlapped with continuous flow monitoring records. See Appendix C for data sources.

4.2.6.2 Peterson Creek (07040003-529) *E. coli* TMDL and allocations

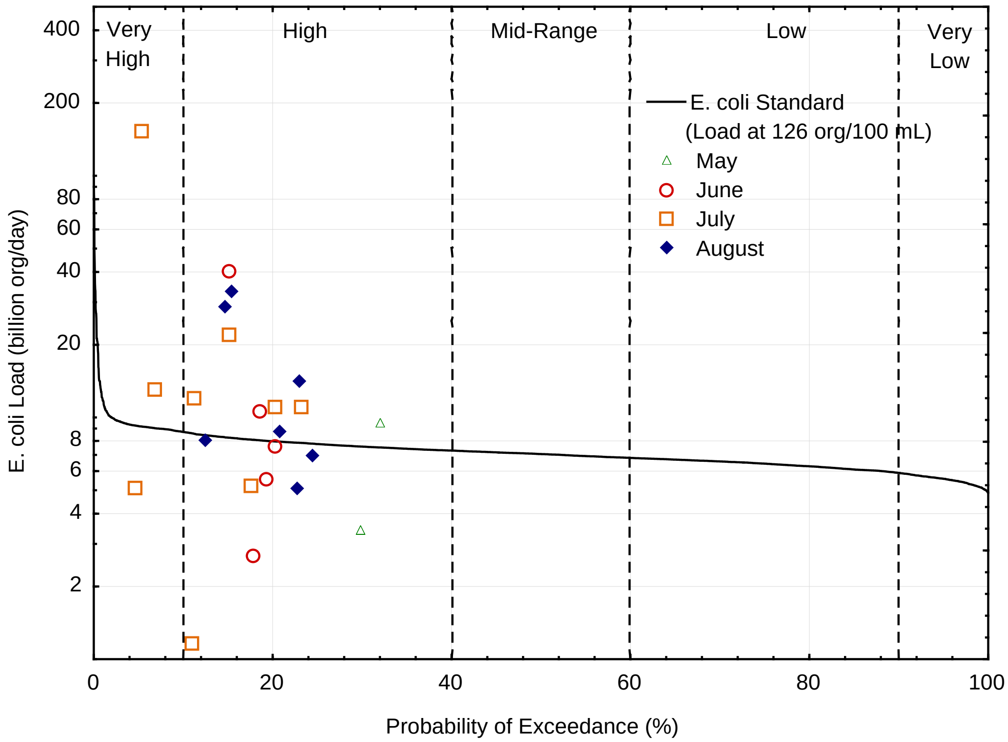

Figure 25. *E. coli* load duration curve for Peterson Creek (07040003-529)

Table 46. Peterson Creek (07040003-529) *E. coli* TMDL and allocations

Peterson Creek 07040003-529 Load Component		Flow Regime				
		Very High	High	Mid	Low	Very Low
		Billion organisms per day				
Existing Load[§]		***21.6***	***8.0***	***no data***	***no data***	***no data***
Wasteload Allocations	*NPDES Permitted Facilities*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*
	Total WLA	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Load Allocations	*Watershed load*	*8.3*	*7.0*	*6.4*	*5.8*	*5.0*
	Total LA	**8.3**	**7.0**	**6.4**	**5.8**	**5.0**
10% MOS		**0.9**	**0.8**	**0.7**	**0.6**	**0.6**
Total Loading Capacity		**9.2**	**7.8**	**7.1**	**6.4**	**5.6**
Estimated Load Reduction		*12.4* *57%*	*0.2* *3%*	*no data*	*no data*	*no data*

[§]Limited monitoring data overlapped with continuous flow monitoring records. See Appendix C for data sources.

4.2.6.3 Rollingstone Creek (07040003-533) *E. coli* TMDL and allocations

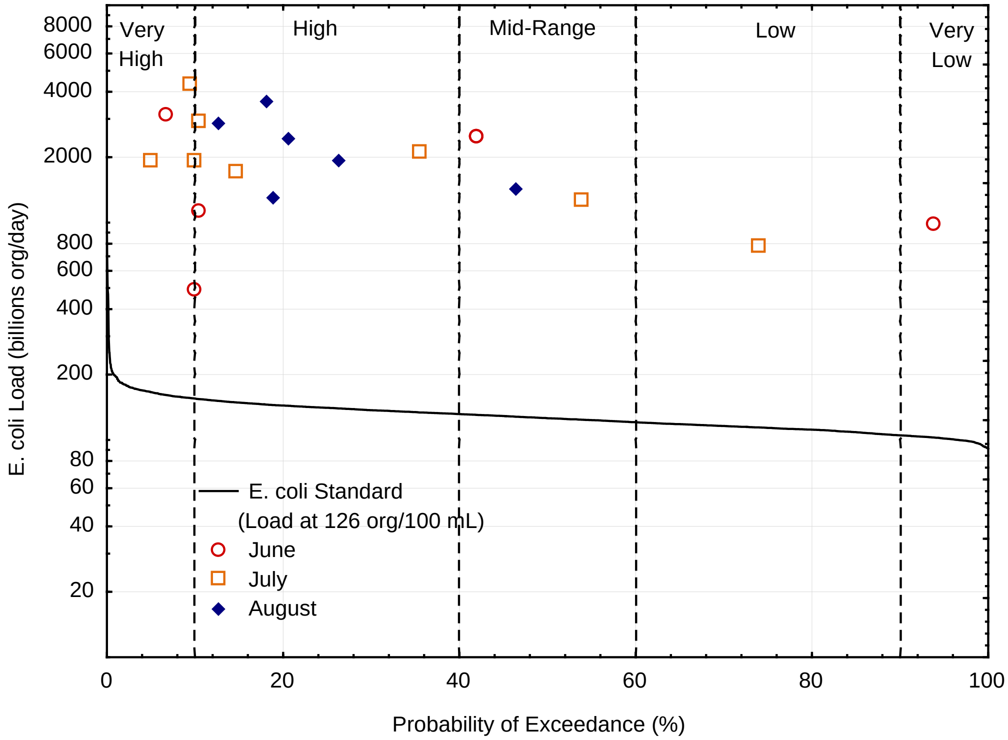

Figure 26. *E. coli* load duration curve for Rollingstone Creek (07040003-533)

Table 47. Rollingstone Creek (07040003-533) *E. coli* TMDL and allocations

Rollingstone Creek 07040003-533 Load Component		Flow Regime: Very High	High	Mid	Low	Very Low
		Billion organisms per day				
Existing Load[§]		***1,893.3***	***2,080.5***	***1,829.6***	***788.4***	***976.9***
Wasteload Allocations	*Rollingstone WWTP, MNG580078*	*3.8*	*3.8*	*3.8*	*3.8*	*3.8*
	Total WLA	**3.8**	**3.8**	**3.8**	**3.8**	**3.8**
Load Allocations	*Watershed load*	*145.6*	*122.7*	*109.5*	*98.5*	*87.6*
	Total LA	**145.6**	**122.7**	**109.5**	**98.5**	**87.6**
10% MOS		**16.6**	**14.1**	**12.6**	**11.4**	**10.2**
Total Loading Capacity		**166.0**	**140.6**	**125.9**	**113.7**	**101.6**
Estimated Load Reduction		*1,727.3* *91%*	*1,940.0* *93%*	*1,703.7* *93%*	*674.7* *86%*	*875.3* *90%*

[§]Limited monitoring data overlapped with continuous flow monitoring records. See Appendix C for data sources.

4.2.6.4 Whitewater River (07040003-539) *E. coli* TMDL and allocations

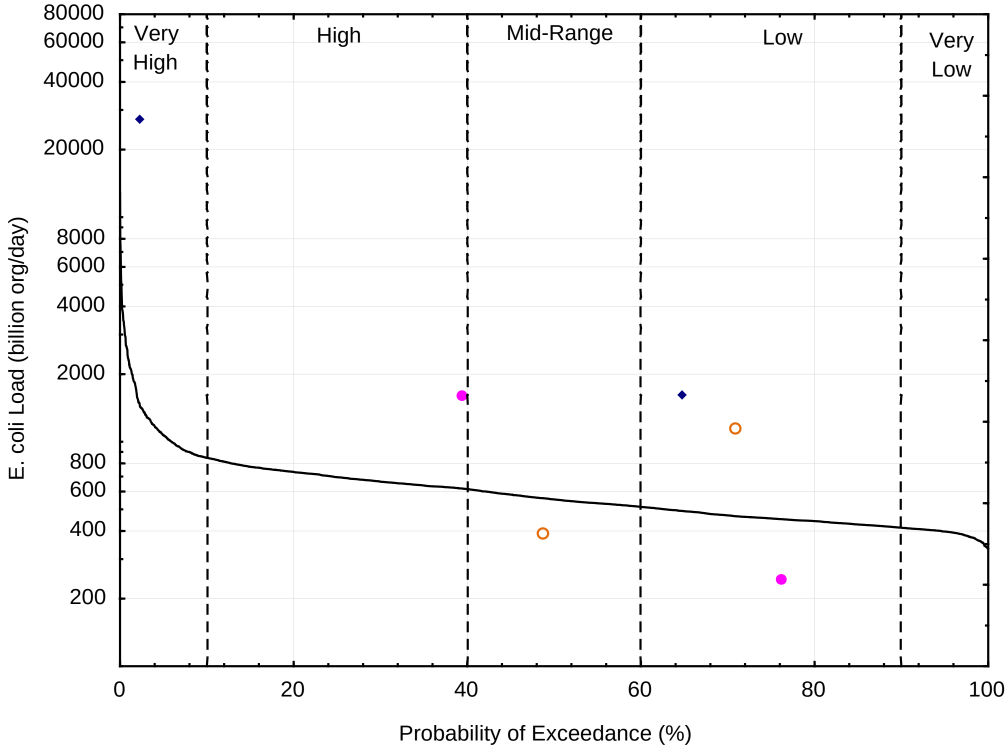

Figure 27. *E. coli* load duration curve for Whitewater River (07040003-539)

Table 48. Whitewater River (07040003-539) *E. coli* TMDL and allocations

Whitewater River 07040003-539 Load Component		Flow Regime: Very High	High	Mid	Low	Very Low
		Billion organisms per day				
Existing Load§		*27,036.1*	*1,621.1*	*391.6*	*765.3*	*no data*
Wasteload Allocations	*NPDES Permitted Facilities**	*36.1*	*36.1*	*36.1*	*36.1*	*36.1*
	Total WLA	36.1	36.1	36.1	36.1	36.1
Load Allocations	*Whitewater R, Middle Fork (-515)*	*38.7*	*26.8*	*20.6*	*15.6*	*13.2*
	Logan Branch (-552)	*42.0*	*27.1*	*21.7*	*16.2*	*13.1*
	Crow Spring (-611)	*18.5*	*14.1*	*11.1*	*9.2*	*8.1*
	Watershed load	*826.5*	*521.5*	*408.3*	*332.6*	*287.6*
	Total LA	925.7	589.5	461.7	373.6	322.0
10% MOS		106.9	69.5	55.3	45.5	39.8
Total Loading Capacity		1,068.7	695.1	553.1	455.2	397.9
Estimated Load Reduction		*25,967.4*	*926.0*	*0*	*310.1*	*no data*
		96%	*57%*	*0%*	*41%*	

§Limited monitoring data overlapped with continuous flow monitoring records. See Appendix C for data sources.

*See Table 49 for individual facility WLAs

Table 49. NPDES permitted facilities included in the Whitewater River (07040003-539) *E. coli* TMDL

Facility Name	Permit	WLA (billions org/day)
Utica WWTP	MN0022055	1.09
Whitewater Region WWTP	MN0046868	5.34
DNR Crystal Springs State Fish Hatchery	MN0004421	15.26
Altura WWTP	MN0021831	1.71
Plainview Elgin WWTP	MN0055361	12.74
NPDES Permitted Feedlots		
Gar-Lin Dairy Site 3	MNG440496	0.0
Daley Farms of Lewiston LLP	MN0067652	0.0
Schell's Pine Grove Farm	MNG440040	0.0
Diamond K Dairy Inc	MN0064629	0.0
Holden Farms Inc, St. Charles	MNG440331	0.0
Shea Dairy Inc	MN0070181	0.0
Gar-Lin Dairy Site 2	MNG440496	0.0
Gar-Lin Dairy Site 1	MNG440496	0.0
TOTAL		**36.1**

4.2.6.5 Logan Branch Creek (07040003-552) *E. coli* TMDL and allocations

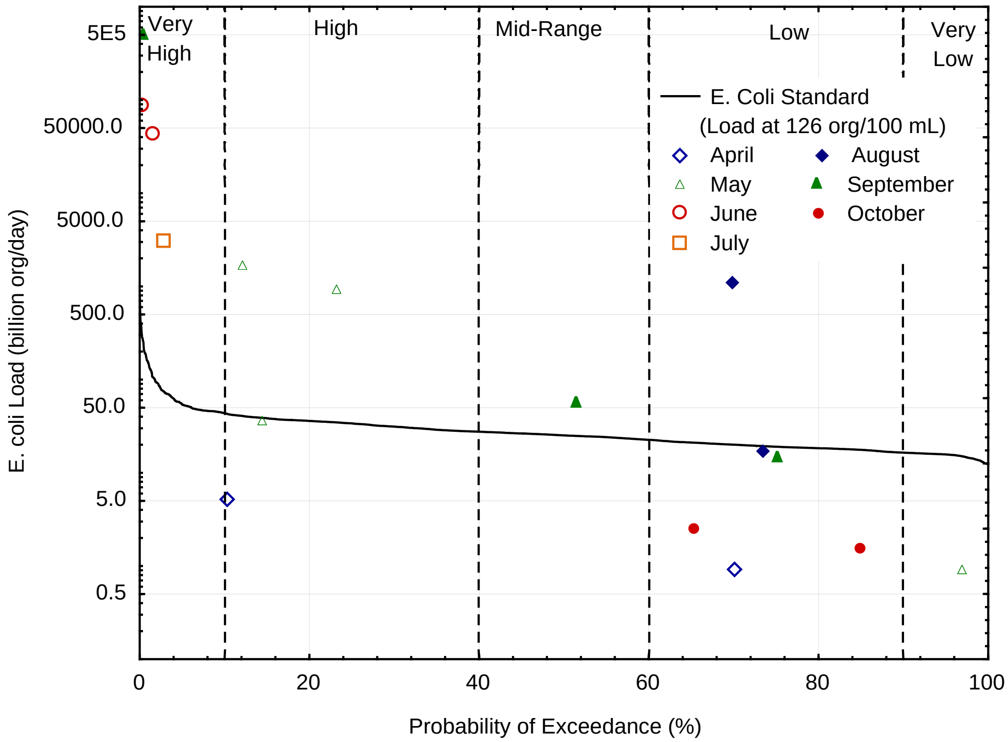

Figure 28. *E. coli* load duration curve for Logan Branch Creek (07040003-552)

Table 50. Logan Branch Creek (07040003-552) *E. coli* TMDL and allocations

Logan Branch Creek 07040003-552 Load Component		Flow Regime				
		Very High	High	Mid	Low	Very Low
		Billion organisms per day				
Existing Load§		***49,272.1***	***146.5***	***55.9***	***3.8***	***0.9***
Wasteload Allocations	*NPDES Permitted Facilities*	n/a	n/a	n/a	n/a	n/a
	Total WLA	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Load Allocations	*Watershed load*	*42.0*	*27.1*	*21.7*	*16.2*	*13.1*
	Total LA	**42.0**	**27.1**	**21.7**	**16.2**	**13.1**
10% MOS		**4.7**	**3.0**	**2.4**	**1.8**	**1.5**
Total Loading Capacity		**46.7**	**30.1**	**24.1**	**18.0**	**14.6**
Estimated Load Reduction		*49,225.4*	*116.4*	*31.8*	*0*	*0*
		>99%	*79%*	*57%*	*0%*	*0%*

§Limited monitoring data overlapped with continuous flow monitoring records. See Appendix C for data sources.

4.2.6.6 Garvin Brook (07040003-595) *E. coli* TMDL and allocations

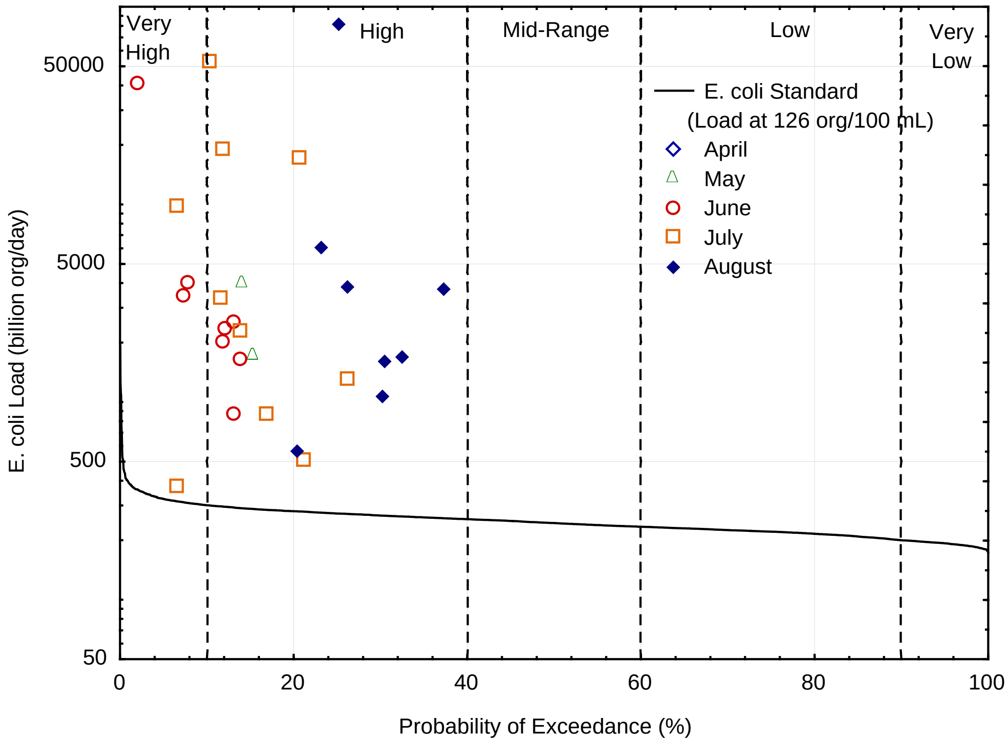

Figure 29. *E. coli* load duration curve for Garvin Brook (07040003-595)

Table 51. Garvin Brook (07040003-595) *E. coli* TMDL and allocations

Garvin Brook 07040003-595 Load Component		Flow Regime: Very High	High	Mid	Low	Very Low
		Billion organisms per day				
Existing Load[§]		*4,596.7*	*3,024.5*	*no data*	*no data*	*no data*
Wasteload Allocations	*Stockton WWTP, MNG580079*	*2.9*	*2.9*	*2.9*	*2.9*	*2.9*
	Minnesota City WWTP, MN0069817	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
	Total WLA	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**
Load Allocations	*Peterson Creek (-529)*	*8.3*	*7.0*	*6.4*	*5.8*	*5.0*
	Rollingstone Creek (-533)	*149.4*	*126.5*	*113.3*	*102.3*	*91.4*
	Watershed load	*130.4*	*109.2*	*97.2*	*87.7*	*74.1*
	Total LA	**288.1**	**242.7**	**216.9**	**195.8**	**170.5**
10% MOS		**32.4**	**27.3**	**24.4**	**22.1**	**19.3**
Total Loading Capacity		**323.5**	**273.0**	**244.3**	**220.9**	**192.8**
Estimated Load Reduction		*4,273.2* *93%*	*2,751.5* *91%*	*no data*	*no data*	*no data*

[§]Limited monitoring data overlapped with continuous flow monitoring records. See Appendix C for data sources.

4.2.6.7 Crow Spring River (07040003-611) *E. coli* TMDL and allocations

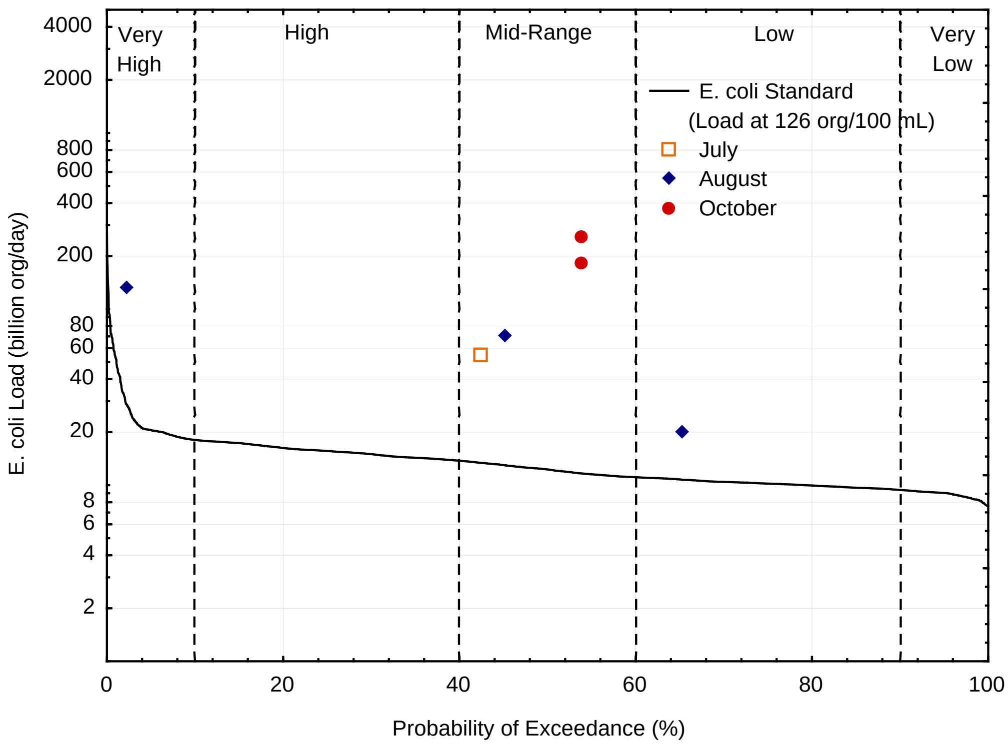

Figure 30. *E. coli* load duration curve for Crow Spring River (07040003-611)

Table 52. Crow Spring River (07040003-611) *E. coli* TMDL and allocations

Crow Spring River 07040003-611 Load Component		Flow Regime: Very High	High	Mid	Low	Very Low
		Billion organisms per day				
Existing Load[§]		***133.1***	***11.4***	***99.9***	***20.0***	***no data***
Wasteload Allocations	*NPDES Permitted Facilities*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*
	Total WLA	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Load Allocations	*Watershed load*	*18.5*	*14.1*	*11.1*	*9.0*	*8.1*
	Total LA	**18.5**	**14.1**	**11.1**	**9.0**	**8.1**
10% MOS		**2.1**	**1.6**	**1.2**	**1.0**	**0.9**
Total Loading Capacity		**20.6**	**15.7**	**12.3**	**10.0**	**9.0**
Estimated Load Reduction		*112.5* *85%*	*0* *0%*	*87.6* *88%*	*10.0* *49%*	*no data*

[§]Limited monitoring data overlapped with continuous flow monitoring records. See Appendix C for data sources.

4.2.7 TMDL Baseline

E. coli TMDLs are based on data from the period 2001-2010. Any activities implemented during or after 2010 that lead to a reduction in loads or an improvement in an impaired stream water quality may be considered as progress towards meeting a WLA or LA.

4.3 Nitrate

4.3.1 Loading Capacity Methodology

The loading capacities for impaired stream reaches receiving a TMDL as a part of this study were determined using LDCs. Flow and LDCs are used to determine the flow conditions (flow regimes) under which exceedances occur. Flow duration curves provide a visual display of the variation in flow rate for the stream. The x-axis of the plot indicates the percentage of time that a flow exceeds the corresponding flow rate as expressed by the y-axis. LDCs take the flow distribution information constructed for the stream and factor in pollutant loading to the analysis. A standard curve is developed by applying a particular pollutant standard or criteria to the stream flow duration curve and is expressed as a load of pollutant per day. The standard curve represents the upper limit of the allowable in-stream pollutant load (loading capacity) at a particular flow. Monitored loads of a pollutant are plotted against this curve to display how they compare to the standard. Monitored values that fall above the curve represent an exceedance of the standard.

For the stream TMDL derivation, flow records generated from the Whitewater and Garvin SWAT models for the period of 2001-2010 were used to develop flow duration curves. The loading capacities were determined by applying the nitrate water quality standard (10 mg/L) to the flow duration curve to produce a nitrate standard curve. Loading capacities were calculated as the median value of the nitrate load (in kg/day) along the nitrate standard curve within each flow regime. A nitrate load duration curve with monitored nitrate data and a TMDL summary table are provided for each stream in Section 4.3.6.

The load duration curve method is based on an analysis that encompasses the cumulative frequency of historic flow data over a specified period. Because this method uses a long-term record of daily flow volumes virtually the full spectrum of allowable loading capacities is represented by the resulting curve. In the TMDL equation tables of this report (Table 56 - Table 61) only five points on the entire loading capacity curve are depicted (the midpoints of the designated flow zones). However, it should be understood that the entire curve represents the TMDL and is what is ultimately approved by EPA.

4.3.2 Load Allocation Methodology

The LAs represent the portion of the loading capacity that is designated for non-regulated sources of nitrate as described in Section 3.6.3, that are located downstream of any other impaired waters with TMDLs located in the watershed. The remainder of the loading capacity (TMDL) after subtraction of the MOS and calculation of the WLA was used to determine the LA for each impaired stream, on an areal basis. Non-point source leaching losses refers to subsurface nitrate loss in “leaky soils below row crops” in areas of shallow depth to bedrock such as the trout stream region of Southeast Minnesota (MPCA 2013). For more background on nitrate refer to Section 3.6.3.2.

4.3.3 Wasteload Allocation Methodology

4.3.3.1 Regulated Construction 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 is construction activities reflects the number of construction sites > 1 acre expected to be active in the impaired lake or stream subwatershed at any one time.

A categorical WLA was assigned to all construction activity in the each impaired stream subwatershed. First, the average annual fraction of the impaired subwatershed area under construction activity over the past 5 years was calculated based on the MPCA Construction Stormwater Permit data from January 1, 2007 to October 6, 2012 (Table 53), area weighted based on the fraction of the subwatershed located in each county. This percentage was multiplied by the watershed runoff load component to determine the construction stormwater WLA. The watershed runoff load component is equal to the total TMDL (loading capacity) minus the sum of the non-watershed runoff load components (upstream loads and MOS).

Table 53. Average Annual NPDES/SDS Construction Stormwater Permit Activity by County (1/1/2007-10/6/2012), for counties located within the Whitewater and Garvin Brook watersheds.

County	Total Area (ac)	Average Annual Construction Activity (% Total Area)
Olmsted	418,743	0.13%
Wabasha	351,374	0.03%
Winona	410,324	0.04%

4.3.3.2 Regulated Industrial Stormwater

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. The WLA for stormwater discharges from sites where there is industrial activity reflects the number of sites in an impaired stream subwatershed for which NPDES Industrial Stormwater Permit coverage is required.

A categorical WLA was assigned to all industrial activity in each impaired stream subwatershed. The industrial stormwater WLA was set equal to the construction stormwater WLA because industrial activities make up a very small fraction of the watershed area.

4.3.3.3 MS4 Regulated Stormwater

Stormwater from MS4 - a conveyance or system of conveyances (roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, storm drains) - is regulated by NPDES Permits for all mandatory, designated, or petition MS4s. All MS4s in the project area are mandatory MS4s, which is based on the U.S. Census definition of an urbanized area: a land area comprising one or more places ("central places") and the adjacent densely settled surrounding area ("urban fringe") that together have a residential population of at least 50,000 and a density of at least 1,000 people per square mile. The definition also includes any other public storm sewer system located fully or partially within an urbanized area.

There are no regulated MS4 communities that discharge within the drainage area of a nitrate impaired stream.

4.3.3.4 Regulated Wastewater

An individual WLA was provided for all NPDES-permitted WWTFs whose surface discharge stations fall within an impaired stream subwatershed. The WLA was calculated as the water quality standard for nitrate (10 mg/L) multiplied by the permitted facility design flow. Continuously discharging municipal WWTF 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. Municipal controlled (pond) discharge WWTF WLAs were calculated based on the maximum daily volume that may be discharged in a 24-hour period.

There are three NPDES permitted WWTFs located within the drainage area of a nitrate impaired stream. In addition to these, a WLA was written for the Crystal Springs State Fish Hatchery. Discharges from this facility are regulated under NPDES permitting. The WLA for the fish hatchery was set equal to the permitted discharge volume multiplied by the nitrate water quality standard (10 mg/L). NPDES permitted WWTFs and WLAs are summarized in Table 54.

Table 54. Individual NPDES permitted facilities located within the drainage area of nitrate impaired streams

Facility NAME	NPDES Permit #	Impaired Stream	Design flow (mgd)	Nitrate effluent (mg/L)	Nitrate WLA (kg/day)
Whitewater Region WWTP	MN0046868	Whitewater River, South Fork (07040003-F17)	1.120	10	42.40
Utica WWTP	MN0022055	Whitewater River, South Fork (07040003-512)	0.228	10	8.63
DNR Crystal Springs State Fish Hatchery	MN0004421		3.200	10	121.13
Altura WWTP	MN0021831		0.359	10	13.59

4.3.3.5 Feedlots Requiring NPDES/SDS Permit Coverage

An AFO is a general term for an area intended for the confined holding of animals, where manure may accumulate, and where vegetative cover cannot be maintained within the enclosure due to the density of animals. AFOs that either (a) have a capacity of 1,000 AUs or more, or (b) meet or exceed the EPA's CAFO threshold and discharge to Waters of the United States, are required to apply for permit coverage through the MPCA. If item (a) is triggered, the permit can be an SDS or NPDES/SDS Permit; if item (b) is triggered, the permit must be an NPDES Permit. These permits require that the feedlots have zero discharge to surface water. There are a total of five NPDES permitted feedlots located within the drainage area of a nitrate impaired stream (Table 55).

Table 55. NPDES permitted feedlots located within the drainage area of nitrate impaired streams

Facility Name	NPDES Permit #	Impaired Stream	Nitrate WLA (kg/day)
Daley Farms of Lewiston LLP	MN0067652	Whitewater River, South Fork (07040003-512)	0.0
Holden Farms Inc., St. Charles	MNG440331	Whitewater River, Middle Fork (07040003-F19)	
Gar-Lin Dairy Site 1	MNG440496	Whitewater River, South Fork (07040003-F17)	
Gar-Lin Dairy Site 2	MNG440496		
Gar-Lin Dairy Site 3	MNG440496		

4.3.4 Margin of Safety

An explicit MOS equal to 10% of the loading capacity was used for the stream TMDLs based on the following considerations:

- Most of the uncertainty in flow is a result of extrapolating flows from the hydrologically-nearest stream gage. The explicit MOS, in part, accounts for this.
- Allocations are a function of flow, which varies from high to low flows. The load duration curve approach minimizes uncertainty associated with the development of TMDLs because the TMDL is a function of monitored flow multiplied by the target value.
- The loading capacity was developed using flow records generated from the Whitewater and Garvin SWAT models for the period 2001-2010, which was calibrated and validated using an extensive monitoring dataset collected in the watershed (see Appendix C).

4.3.5 Seasonal Variation

Critical conditions and seasonal variation are addressed in this TMDL through several mechanisms. The nitrate standard applies year-round, and data was collected throughout this period. The water quality analysis conducted on these data evaluated variability in flow through the use of five flow regimes: from high flows, such as flood events, to low flows, such as baseflow. Through the use of LDCs and monthly summary figures, nitrate loading was evaluated at actual flow conditions at the time of sampling (and by month), and monthly nitrate concentrations were evaluated against precipitation and streamflow.

4.3.6 TMDL Summary

4.3.6.1 Whitewater River, South Fork (07040003-512) Nitrate TMDL and allocations

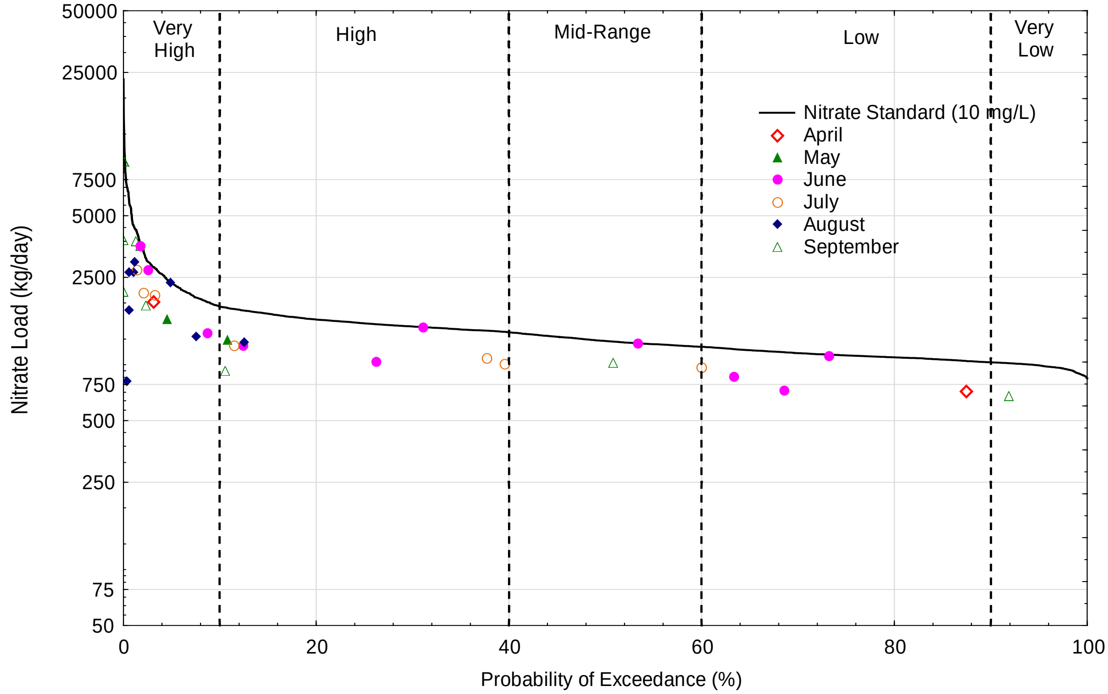

Figure 31. Nitrate load duration curve for Whitewater River, South Fork (07040003-512)

Table 56. Whitewater River, South Fork (07040003-512) Nitrate TMDL and allocations

Whitewater, South Fork 07040003-512 Load Component		Flow Regime Very High	 High	 Mid	 Dry	 Very Dry
		kg/day				
Existing Load		**9,265.3**	**1,739.6**	**1,191.1**	**1,038.7**	**657.3**
Wasteload Allocations	*NPDES Permitted Facilities**	*143.4*	*143.4*	*143.4*	*143.4*	*143.4*
	Construction stormwater (MNR100001)	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*
	Industrial stormwater (MNR50000)	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*
	Total WLA	**143.8**	**143.6**	**143.6**	**143.6**	**143.6**
Load Allocations	*Whitewater River, SF (-F17)***	*1,552.7*	*877.8*	*703.8*	*586.1*	*512.6*
	Non-point source leaching losses	*419.0*	*318.8*	*252.0*	*204.6*	*179.1*
	Atmospheric deposition	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*
	Total LA	**1,973.1**	**1,198.0**	**957.2**	**792.1**	**693.1**
10% MOS		**235.2**	**149.1**	**122.3**	**104.0**	**93.0**
Total Loading Capacity		**2,352.1**	**1,490.7**	**1,223.1**	**1,039.7**	**929.7**
Reductions		*6,913.2*	*248.9*	*0*	*0*	*0*
		75%	*14%*	*0%*	*0%*	*0%*

* See Table 57 for individual facility WLAs

** The load allocation for the upstream reach 07040003-F17 is the sum of its WLA and LA in Table 58

Table 57. NPDES permitted facilities included in the Whitewater River, South Fork (07040003-512) Nitrate TMDL

Facility Name	NPDES Permit	WLA (kg/day)
Utica WWTP	MN0022055	8.63
DNR Crystal Springs State Fish Hatchery	MN0004421	121.13
Altura WWTP	MN0021831	13.59
NPDES Permitted Feedlots		
Daley Farms of Lewiston LLP	MN0067652	0.0
TOTAL		**143.35**

4.3.6.2 Whitewater River, South Fork (07040003-F17) Nitrate TMDL and allocations

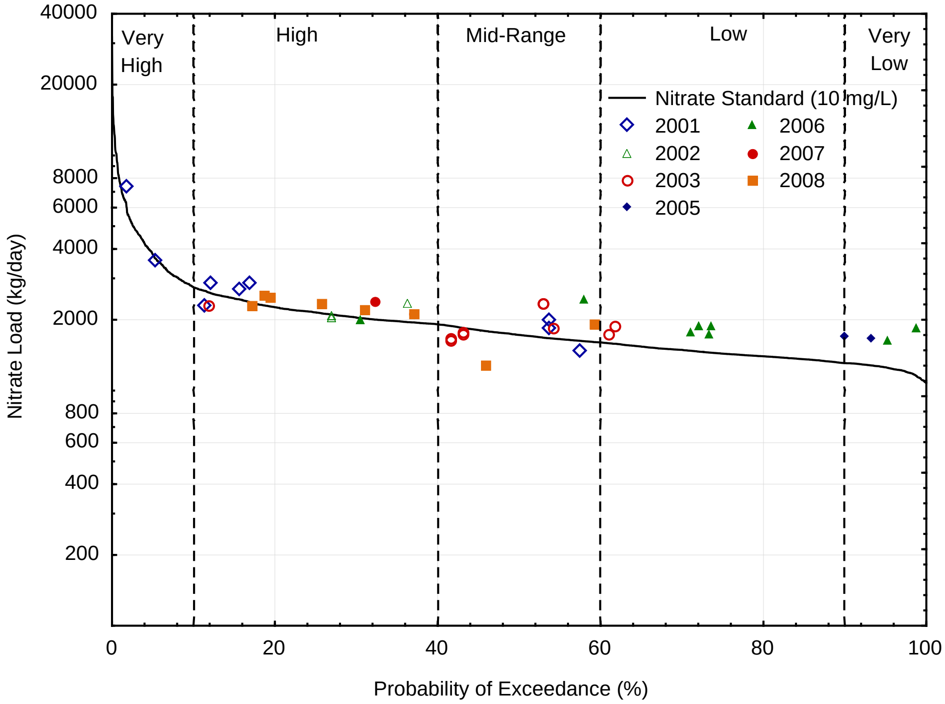

Figure 32. Nitrate load duration curve for Whitewater River, South Fork (07040003-F17)

Table 58. Whitewater River, South Fork (07040003-F17) Nitrate TMDL and allocations

Whitewater, South Fork 07040003-F17 Load Component		Flow Regime				
		Very High	High	Mid	Dry	Very Dry
		kg/day				
Existing Load		***2,497.0***	***1,053.2***	***830.5***	***803.9***	***798.3***
Wasteload Allocations	*NPDES Permitted Facilities**	*42.4*	*42.4*	*42.4*	*42.4*	*42.4*
	Construction stormwater (MNR100001)	*0.6*	*0.3*	*0.3*	*0.2*	*0.2*
	Industrial stormwater (MNR50000)	*0.6*	*0.3*	*0.3*	*0.2*	*0.2*
	Total WLA	**43.6**	**43.0**	**43.0**	**42.8**	**42.8**
Load Allocations	*Non-point source leaching losses*	*1,509.1*	*834.7*	*660.8*	*543.2*	*469.8*
	Atmospheric deposition	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
	Total LA	**1,509.2**	**834.8**	**660.9**	**543.3**	**469.9**
10% MOS		**172.5**	**97.5**	**78.2**	**65.1**	**57.0**
Total Loading Capacity		**1,725.3**	**975.3**	**782.1**	**651.2**	**569.7**
Estimated Load Reduction		*771.7*	*77.9*	*48.4*	*152.7*	*228.6*
		31%	*7%*	*6%*	*19%*	*29%*

*See Table 59 for individual facility WLAs

Table 59. NPDES permitted facilities included in the Whitewater River, South Fork (07040003-F17) Nitrate TMDL

Facility Name	Permit	Nitrate WLA (kg/day)
Whitewater Region WWTP	MN0046868	42.4
NPDES Permitted Feedlots		
Gar-Lin Dairy Site 3	MNG440496	0.0
Gar-Lin Dairy Site 2	MNG440496	0.0
Gar-Lin Dairy Site 1	MNG440496	0.0
TOTAL		**42.4**

4.3.6.3 Whitewater River, Middle Fork (07040003-F19) Nitrate TMDL and allocations

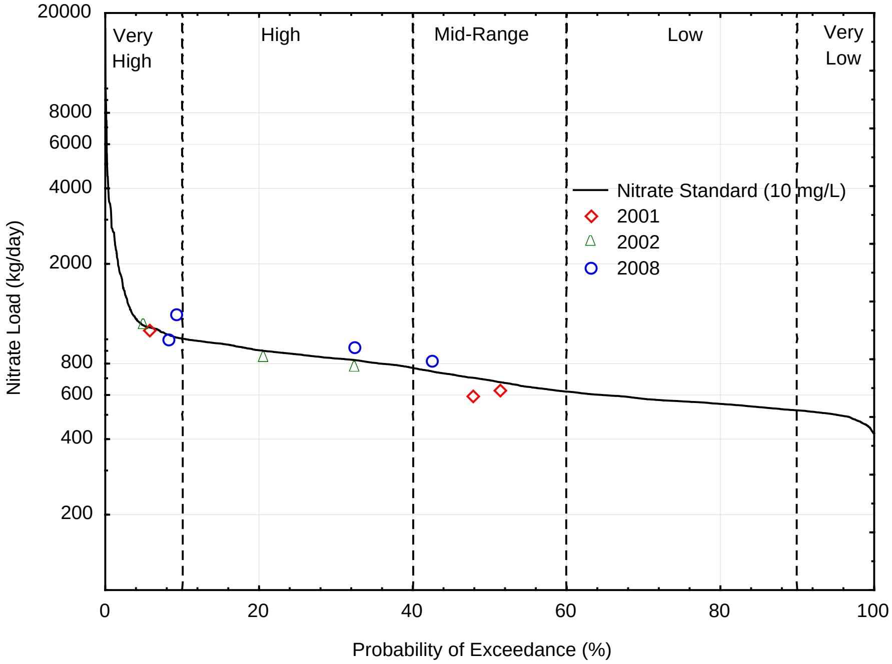

Figure 33. Nitrate load duration curve for Whitewater River, Middle Fork (07040003-F19)

Table 60. Whitewater River, Middle Fork (07040003-F19) Nitrate TMDL and allocations

Whitewater River, Middle Fork 07040003-F19 Load Component		Flow Regime				
		Very High	High	Mid	Dry	Very Dry
		kg/day				
Existing Load*		*1,113.7*	*844.6*	*627.7*	*no data*	*no data*
Wasteload Allocations	*NPDES permitted feedlots*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
	Construction stormwater (MNR100001)	*0.7*	*0.5*	*0.4*	*0.3*	*0.3*
	Industrial stormwater (MNR50000)	*0.7*	*0.5*	*0.4*	*0.3*	*0.3*
	Total WLA	**1.4**	**1.0**	**0.8**	**0.6**	**0.6**
Load Allocations	*Crow Spring River (-611)***	*211.8*	*161.0*	*126.6*	*105.0*	*93.0*
	Non-point source leaching losses	*808.1*	*620.7*	*490.0*	*402.8*	*356.3*
	Atmospheric Deposition	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*
	Total LA	**1,020.9**	**782.7**	**617.6**	**508.8**	**450.3**
10% MOS		**113.6**	**87.1**	**68.7**	**56.6**	**50.1**
Total Loading Capacity		**1,135.9**	**870.8**	**687.1**	**566.0**	**501.0**
Estimated Load Reduction		*0* *0%*	*0* *0%*	*0* *0%*	*no data*	*no data*

* Limited monitoring data overlapped with continuous flow monitoring records. See Appendix C for data sources.

** The load allocation for the upstream impaired reach (07040003-611) is the sum of its WLA and LA in Table 62

4.3.6.4 Crow Spring River (07040003-611) Nitrate TMDL and allocations

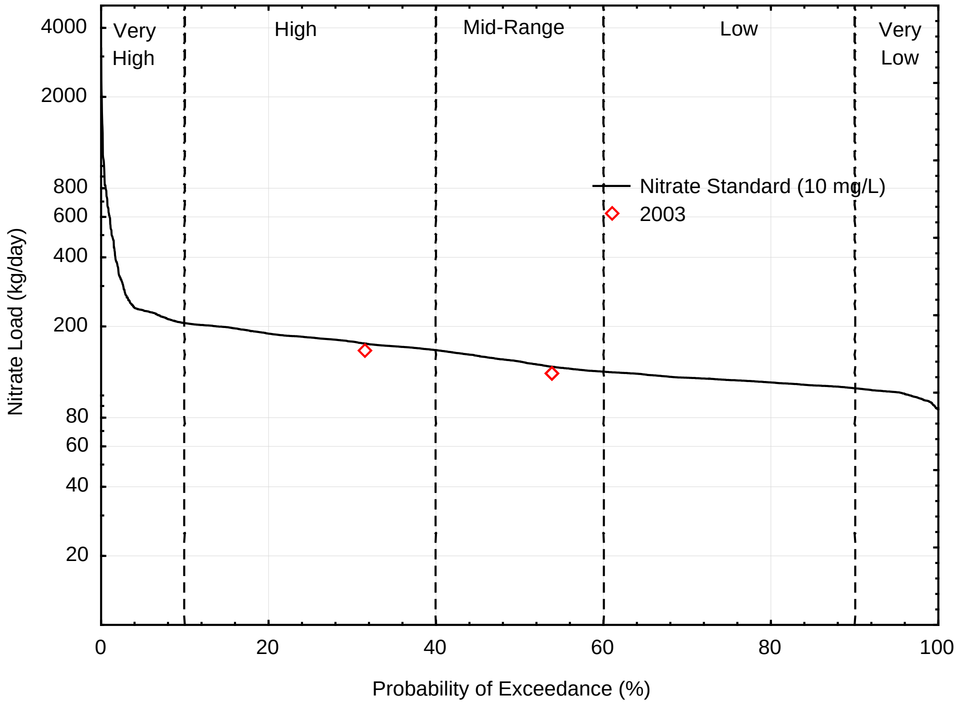

Figure 34. Nitrate load duration curve for Crow Spring River (07040003-611)

Table 61. Crow Spring River (07040003-611) Nitrate TMDL and allocations

Crow Spring River 07040003-611 Load Component		Flow Regime				
		Very High	High	Mid	Dry	Very Dry
		kg/day				
Existing Load*		***no data***	***no data***	***no data***	***no data***	***no data***
Wasteload Allocations	*NPDES Permitted Facilities*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*
	Construction stormwater (MNR100001)	*0.3*	*0.2*	*0.2*	*0.1*	*0.1*
	Industrial stormwater (MNR50000)	*0.3*	*0.2*	*0.2*	*0.1*	*0.1*
	Total WLA	**0.6**	**0.4**	**0.4**	**0.2**	**0.2**
Load Allocations	*Non-point source leaching losses*	*211.2*	*160.5*	*126.2*	*104.7*	*92.7*
	Atmospheric Deposition	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
	Total LA	**211.3**	**160.6**	**126.3**	**104.8**	**92.8**
10% MOS		**23.5**	**17.9**	**14.1**	**11.7**	**10.3**
Total Loading Capacity		**235.4**	**178.9**	**140.8**	**116.7**	**103.3**
Estimated Load Reduction		*no data*	*no data*	*no data*	*no data*	*no data*

* Limited monitoring data overlapped with continuous flow monitoring records. See Appendix C for data sources.

4.3.7 TMDL Baseline

Nitrate TMDLs are based on data from the period 2001-2010. Any activities implemented during or after 2010 that lead to a reduction in loads or an improvement in an impaired stream water quality may be considered as progress towards meeting a WLA or LA.

4.4 Turbidity/TSS

4.4.1 Loading Capacity Methodology

The loading capacities for impaired stream reaches receiving a TMDL as a part of this study were determined using LDCs. Flow and LDCs are used to determine the flow conditions (flow regimes) under which exceedances occur. Flow duration curves provide a visual display of the variation in flow rate for the stream. The x-axis of the plot indicates the percentage of time that a flow exceeds the corresponding flow rate as expressed by the y-axis. LDCs take the flow distribution information constructed for the stream and factor in pollutant loading to the analysis. A standard curve is developed by applying a particular pollutant standard or criteria to the stream flow duration curve and is expressed as a load of pollutant per day. The standard curve represents the upper limit of the allowable in-stream pollutant load (loading capacity) at a particular flow. Monitored loads of a pollutant are plotted against this curve to display how they compare to the standard. Monitored values that fall above the curve represent an exceedance of the standard.

For the stream TMDL derivation, flow records generated from the Whitewater and Garvin SWAT models for the period 2001-2010, were used to develop flow duration curves. The loading capacities were determined by applying the TSS water quality standard (10 mg/L for class 2A waters and 30 mg/L for class 2B waters) to the flow duration curve to produce a TSS standard curve. The TSS loading capacities were calculated as the median load (in kg/day) along the TSS standard curve within each flow regime. A TSS load duration curve with monitored TSS data and a TMDL summary table are provided for each stream in Section 4.4.6.

The load duration curve method is based on an analysis that encompasses the cumulative frequency of historic flow data over a specified period. Because this method uses a long-term record of daily flow volumes virtually the full spectrum of allowable loading capacities is represented by the resulting curve. In the TMDL equation tables of this report (Table 65 - Table 79) only five points on the entire loading capacity curve are depicted (the midpoints of the designated flow zones). However, it should be understood that the entire curve represents the TMDL and is what is ultimately approved by EPA.

4.4.2 Load Allocation Methodology

The LAs represent the portion of the loading capacity that is designated for non-regulated sources of nitrate as described in Section 3.6.3, that are located downstream of any other impaired waters with TMDLs located in the watershed. The remainder of the loading capacity (TMDL) after subtraction of the MOS and calculation of the WLA was used to determine the LA for each impaired stream, on an areal basis.

4.4.3 Wasteload Allocation Methodology

4.4.3.1 Regulated Construction 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 is construction activities reflects the number of construction sites > 1 acre expected to be active in the impaired lake or stream subwatershed at any one time.

A categorical WLA was assigned to all construction activity in the each impaired stream or lake subwatershed. First, the average annual fraction of the impaired subwatershed area under construction activity over the past five years was calculated based on the MPCA Construction Stormwater Permit data from January 1, 2007 to October 6, 2012 (Table 62), area weighted based on the fraction of the subwatershed located in each county. This percentage was multiplied by the watershed runoff load component to determine the construction stormwater WLA. The watershed runoff load component is equal to the total TMDL (loading capacity) minus the sum of the non-watershed runoff load components (upstream loads and MOS).

Table 62. Average Annual NPDES/SDS Construction Stormwater Permit Activity by County (1/1/2007-10/6/2012), for counties located within the Whitewater and Garvin Brook watersheds.

County	Total Area (ac)	Average Annual Construction Activity (% Total Area)
Olmsted	418,743	0.13%
Wabasha	351,374	0.03%
Winona	410,324	0.04%

4.4.3.2 Regulated Industrial Stormwater

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. The WLA for stormwater discharges from sites where there is industrial activity reflects the number of sites in an impaired stream subwatershed for which NPDES Industrial Stormwater Permit coverage is required.

A categorical WLA was assigned to all industrial activity in each impaired stream subwatershed. The industrial stormwater WLA was set equal to the construction stormwater WLA because industrial activities make up a very small fraction of the watershed area.

4.4.3.3 MS4 Regulated Stormwater

Stormwater from MS4 - a conveyance or system of conveyances (roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, storm drains) - is regulated by NPDES Permits for all mandatory, designated, or petition MS4s. All MS4s in the project area are mandatory MS4s, which is based on the U.S. Census definition of an urbanized area: a land area comprising one or more places ("central places") and the adjacent densely settled surrounding area ("urban fringe") that together have a residential population of at least 50,000 and a density of at least 1,000 people per square mile. The definition also includes any other public storm sewer system located fully or partially within an urbanized area. There are no regulated MS4 communities located within the drainage area impaired streams included in the TSS TMDL.

4.4.3.4 Regulated Wastewater

Minnesota's TSS water quality standard is intended to protect aquatic life from the damaging effects of inorganic non-volatile suspended solids (NVSS) to the gills and filter feeding organs of fish and aquatic invertebrates. TSS associated with municipal wastewater discharges are predominantly organic volatile suspended solids (VSS), which do not tend to persist in the environment. WLAs developed for these TMDLs will be expressed in terms of TSS. NPDES permits for WWTFs may contain water quality based effluent limits that account for the NVSS characteristics of the discharge. Such limits would be consistent with the assumptions and requirements of the TMDLs' WLAs.

An individual WLA was provided for all NPDES-permitted WWTFs whose surface discharge stations fall within an impaired stream subwatershed. The WLA was calculated as the permitted discharge concentration multiplied by the permitted facility design flow. Continuously discharging municipal WWTF 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. Municipal controlled (pond) discharge WWTF WLAs were calculated based on the maximum daily volume that may be discharged in a 24-hour period. There are a total of seven NPDES permitted WWTFs located with the drainage are of TSS impaired streams.

In addition to these, a WLA was written for the Crystal Springs State Fish Hatchery and Plainview Milk Products Coop. Discharges from these facilities are regulated under NPDES permitting. The WLA for each facility was calculated as the permitted discharge concentration multiplied by the permitted facility design flow. NPDES permitted WWTFs and WLAs are summarized in Table 63.

Table 63. Individual NPDES permit holder located with the drainage area of TSS impaired streams.

Facility Name	NPDES Permit #	Impaired Stream	TSS limit (mg/L)	TSS WLA (kg/day)
Whitewater Region WWTP	MN0046868	Whitewater River, South Fork (07040003-F16)	30	127.2
Utica WWTP	MN0022055	Whitewater River, South Fork (07040003-512)	20*	17.3
DNR Crystal Springs State Fish Hatchery	MN0004421		20*	242.3
Altura WWTP	MN0021831		20*	27.2
Plainview Elgin WWTP	MN0055361	Whitewater River, North Fork (07040003-554)	15*	151.6
Plainview Milk Products Coop	MN0000311		15*	25.6
Stockton WWTP	MNG580079	Garvin Brook (07040003-595)	45	104.6
Minnesota City WWTP	MN0069817		30	3.5
Rollingstone WWTP	MNG580078	Rollingstone Creek (07040003-533)	45	135.7

* Denotes a proposed reduction in current permitted effluent limit to achieve the stream loading capacity. NPDES permits for these wastewater treatment facilities may contain water quality based effluent limits that account for the NVSS characteristics of the discharge. Such limits would be consistent with the assumptions and requirements of the TMDLs' WLAs.

4.4.3.5 Feedlots Requiring NPDES/SDS Permit Coverage

An AFO is a general term for an area intended for the confined holding of animals, where manure may accumulate, and where vegetative cover cannot be maintained within the enclosure due to the density of animals. AFOs that either (a) have a capacity of 1,000 AUs or more, or (b) meet or exceed the EPA's CAFO threshold and discharge to Waters of the United States, are required to apply for permit coverage through the MPCA. If item (a) is triggered, the permit can be an SDS or NPDES/SDS Permit; if item (b) is triggered, the Permit must be an NPDES Permit. These permits require that the feedlots have zero discharge to surface water.

There are a total of nine NPDES permitted feedlots located within the drainage area of a TSS impaired stream (Table 64).

Table 64. NPDES permitted feedlots located within the drainage area of a TSS impaired stream

Facility Name	NPDES Permit #	Impaired Stream	TSS WLA (kg/day)
Daley Farms of Lewiston LLP	MN0067652	Whitewater River South Fork (07030004-512)	0.0
Diamond K Dairy Inc	MN0064629	Whitewater River (07040003-539)	
Gar-Lin Dairy Site 1	MNG440496	Whitewater River, South Fork (07040003-516)	
Gar-Lin Dairy Site 2	MNG440496		
Gar-Lin Dairy Site 3	MNG440496		
Holden Farms Inc, St. Charles	MNG440331	Whitewater River Middle Fork (07030004-F19)	
Schell's Pine Grove Farm	MNG440040	Whitewater River (07040003-537)	
Shea Dairy Inc	MN0070181	Whitewater River North Fork (07030004-554)	

4.4.4 Margin of Safety

An explicit MOS equal to 10% of the loading capacity was used for the stream TMDLs based on the following considerations:

- Most of the uncertainty in flow is a result of extrapolating flows from the hydrologically-nearest stream gage. The explicit MOS, in part, accounts for this.
- Allocations are a function of flow, which varies from high to low flows. This variability is accounted for through the development of a TMDL for each of five flow regimes.

4.4.5 Seasonal Variation

The TSS water quality standard applies for the period April through September which corresponds to the open water season when aquatic organisms are most active and when high stream TSS concentrations generally occur. TSS loading varies with the flow regime and season. Spring is associated with large flows from snowmelt, the summer is associated with the growing season as well as periodic storm events and receding streamflows, and the fall brings increasing precipitation and rapidly changing agricultural landscapes.

Critical conditions and seasonal variation are addressed in this TMDL through several mechanisms. The TSS standard applies during the open water months, and data was collected throughout this period. The water quality analysis conducted on these data evaluated variability in flow through the use of five flow regimes: from high flows, such as flood events, to low flows, such as baseflow. Through the use of LDCs and monthly summary figures, TSS loading was evaluated at actual flow conditions at the time of sampling (and by month).

4.4.6 TMDL Summary

4.4.6.1 Whitewater River, South Fork (07040003-512) Total Suspended Solids TMDL and allocations

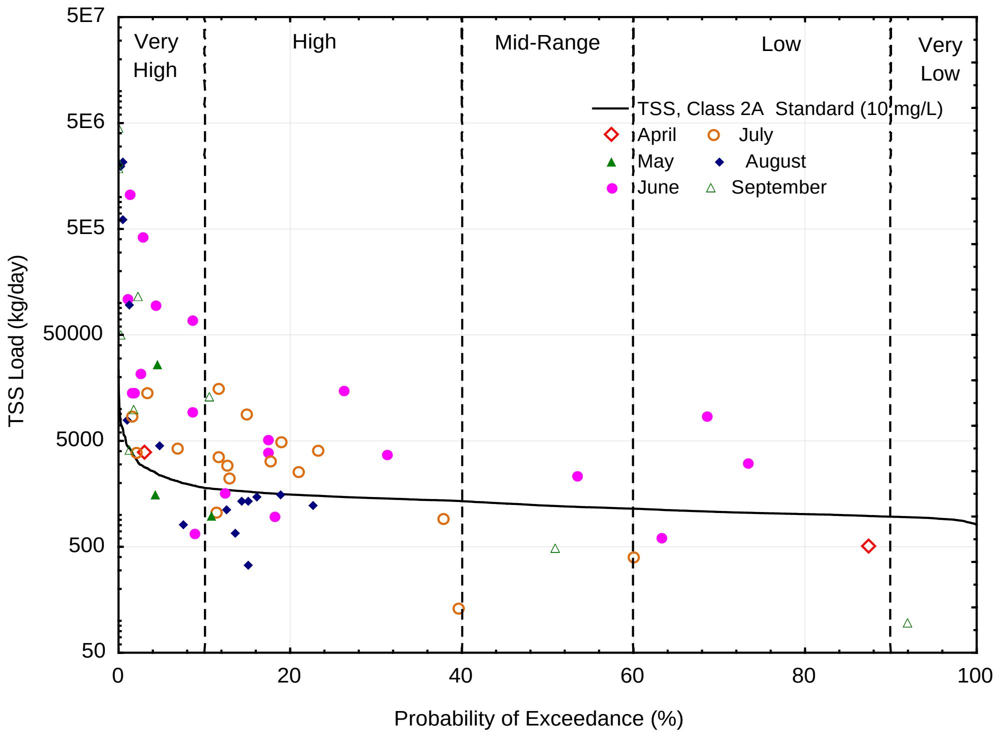

Figure 35. Total suspended solids load duration curve for Whitewater River, South Fork (07040003-512)

Table 65. Whitewater River, South Fork (07040003-512) total suspended solids TMDL and allocations

Whitewater River, South Fork 07040003-512 Load Component		Flow Regime: Very High (kg/day)	High	Mid	Dry	Very Dry
Existing Load		21,341	1,941	486	1,886	95
Wasteload Allocations	*NPDES Permitted Facilities**	286.8	286.8	286.8	286.8	286.8
	Construction stormwater (MNR100001)	0.1	0.07	0.04	0.02	0.01
	Industrial stormwater (MNR50000)	0.1	0.07	0.04	0.02	0.01
	Total WLA	**287.0**	**286.9**	**286.9**	**286.8**	**286.8**
Load Allocations	*Whitewater River, SF (F17)*	1,568.3	890.3	713.7	593.5	519.9
	Watershed runoff	261.8	163.9	100.3	55.6	29.9
	Total LA	**1,830.1**	**1,054.2**	**814.0**	**649.1**	**549.8**
10% MOS		**235.2**	**149.0**	**122.3**	**104.0**	**92.9**
Total Loading Capacity		**2,352.3**	**1,490.1**	**1,223.2**	**1,039.9**	**929.5**
Estimated Load Reduction		18,989 89%	451 23%	0 0%	846 45%	0 0%

*See Table 66 for individual facility WLAs

Table 66. NPDES permitted facilities included in the Whitewater River, South Fork (07040003-512) TSS TMDL

Facility Name	NPDES Permit	Design Flow (MGD)	Existing Effluent Limit (mg/L)	Proposed Effluent Limit (mg/L)	WLA (kg/day)	Proposed Reduction (%)
Utica WWTP	MN0022055	0.228*	45	20**	17.3	56%
DNR Crystal Springs State Fish Hatchery	MN0004421	3.2	30	20**	242.3	33%
Altura WWTP	MN0021831	0.359	45	20**	27.2	56%
NPDES Permitted Feedlots						
Daley Farms of Lewiston LLP	MN0067652	*0.0*	*(n/a)*	*(n/a)*	0.0	*(n/a)*
TOTAL					**286.8**	

*Estimated as secondary pond surface area (1.4 ac) multiplied by 6 inches (allowable daily discharge).

** Denotes a proposed reduction in current permitted effluent limit to achieve the stream loading capacity. NPDES permits for these wastewater treatment facilities may contain water quality based effluent limits that account for the NVSS characteristics of the discharge. Such limits would be consistent with the assumptions and requirements of the TMDLs' WLA.

4.4.6.2 Whitewater River, South Fork (07040003-F17) Total Suspended Solids TMDL and allocations

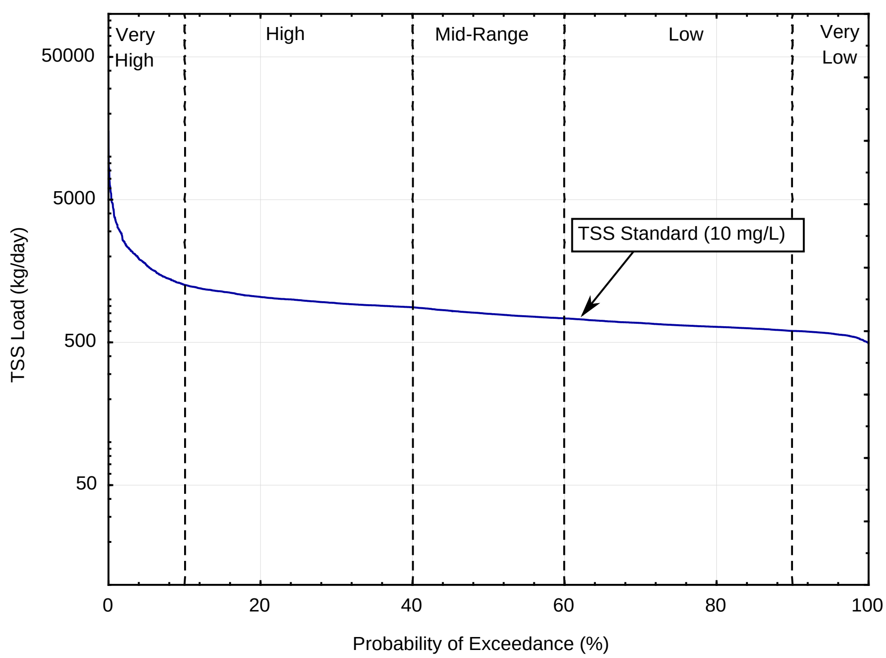

Figure 36. Total suspended solids load duration curve for Whitewater River, South Fork (07040003-F17)

Table 67. Whitewater River, South Fork (07040003-F17) total suspended solids TMDL and allocations

Whitewater River, South Fork 07040003-F17 Load Component		Flow Regime				
		Very High	High	Mid	Dry	Very Dry
		kg/day				
Existing Load		*no data*				
Wasteload Allocations	*Construction stormwater (MNR100001)*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
	Industrial stormwater (MNR50000)	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
	Total WLA	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**
Load Allocations	*Whitewater River, SF (F16)*	*1,552.7*	*877.8*	*703.8*	*586.1*	*512.6*
	Watershed runoff	*15.5*	*12.4*	*9.9*	*7.4*	*7.3*
	Total LA	**1,568.2**	**890.2**	**713.7**	**593.5**	**519.9**
10% MOS		**174.3**	**98.9**	**79.3**	**65.9**	**57.8**
Total Loading Capacity		**1,742.5**	**989.1**	**793.0**	**659.4**	**577.7**

4.4.6.3 Whitewater River, Middle Fork (07040003-F19) Total Suspended Solids TMDL and allocations

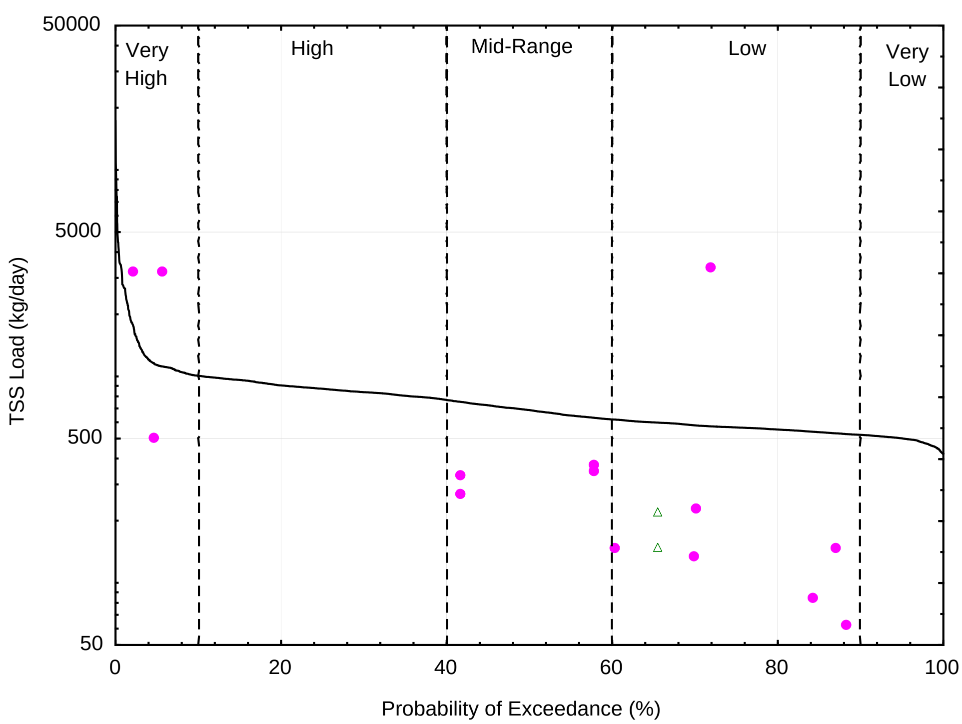

Figure 37. Total suspended solids load duration curve for Whitewater River, Middle Fork (07040003-F19)

Table 68. Whitewater River, Middle Fork (07040003-F19) total suspended solids TMDL and allocations

Whitewater River, Middle Fork 0704003-F19 Load Component		Flow Regime: Very High (kg/day)	High	Mid	Dry	Very Dry
Existing Load		***3,239.5***	***no data***	***342.5***	***148.5***	***no data***
Wasteload Allocations	*Holden Farms Inc., St. Charles (MNG440331)**	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
	Construction stormwater (MNR100001)	*0.6*	*0.5*	*0.4*	*0.3*	*0.3*
	Industrial stormwater (MNR50000)	*0.6*	*0.5*	*0.4*	*0.3*	*0.3*
	Total WLA	**1.2**	**1.0**	**0.8**	**0.6**	**0.6**
Load Allocations	*Whitewater River, MF (515)*	*307.0*	*212.9*	*163.2*	*123.7*	*104.7*
	Watershed runoff	*714.1*	*569.9*	*454.4*	*385.2*	*345.7*
	Total LA	**1,021.1**	**782.8**	**617.6**	**508.9**	**450.4**
10% MOS		**113.6**	**87.1**	**68.7**	**56.6**	**50.1**
Total Loading Capacity		**1,135.9**	**870.9**	**687.1**	**566.1**	**501.1**
Estimated Load Reduction		*2,103.6* *65%*	*no data*	*0* *0%*	*0* *0%*	*no data*

*NPDES Permitted Feedlot

4.4.6.4 Whitewater River, North Fork (07040003-523) Total Suspended Solids TMDL and allocations

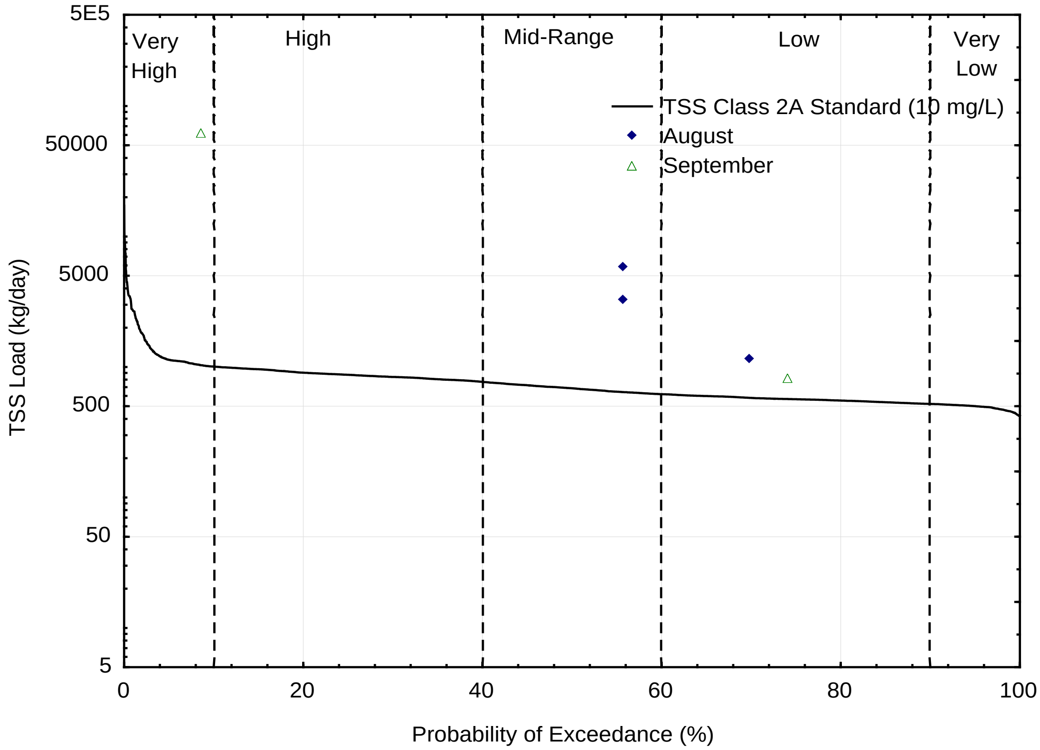

Figure 38. Total suspended solids load duration curve for Whitewater River, North Fork (07040003-523)

Table 69. Whitewater River, North Fork (07040003-523) total suspended solids TMDL and allocations

Whitewater River, North Fork 07040003-523 Load Component		Flow Regime				
		Very High	High	Mid	Dry	Very Dry
		kg/day				
Existing Load		***62,818***	***no data***	***4,561***	***991***	***no data***
Wasteload Allocations	*Construction stormwater (MNR100001)*	*0.04*	*0.02*	*0.02*	*0.02*	*0.02*
	Industrial stormwater (MNR50000)	*0.04*	*0.02*	*0.02*	*0.02*	*0.02*
	Total WLA	**0.1**	**<0.1**	**<0.1**	**<0.1**	**<0.1**
Load Allocations	*Whitewater River, NF (554)*	*2,187.0*	*1,562.8*	*1,237.8*	*993.5*	*861.0*
	Whitewater River, MF (F19)	*1,022.3*	*783.7*	*618.4*	*509.5*	*451.0*
	Watershed runoff	*95.2*	*60.7*	*49.2*	*39.5*	*44.0*
	Total LA	**3,304.5**	**2,407.2**	**1,905.4**	**1,542.5**	**1,356.0**
10% MOS		**367.2**	**267.5**	**211.7**	**171.4**	**150.7**
Total Loading Capacity		**3,671.7**	**2,674.7**	**2,117.1**	**1,713.9**	**1,506.7**
Estimated Load Reduction		*59,146* *94%*	*no data*	*2,444* *54%*	*0* *0%*	*no data*

4.4.6.5 Rollingstone Creek (07040003-533) Total Suspended Solids TMDL and allocations

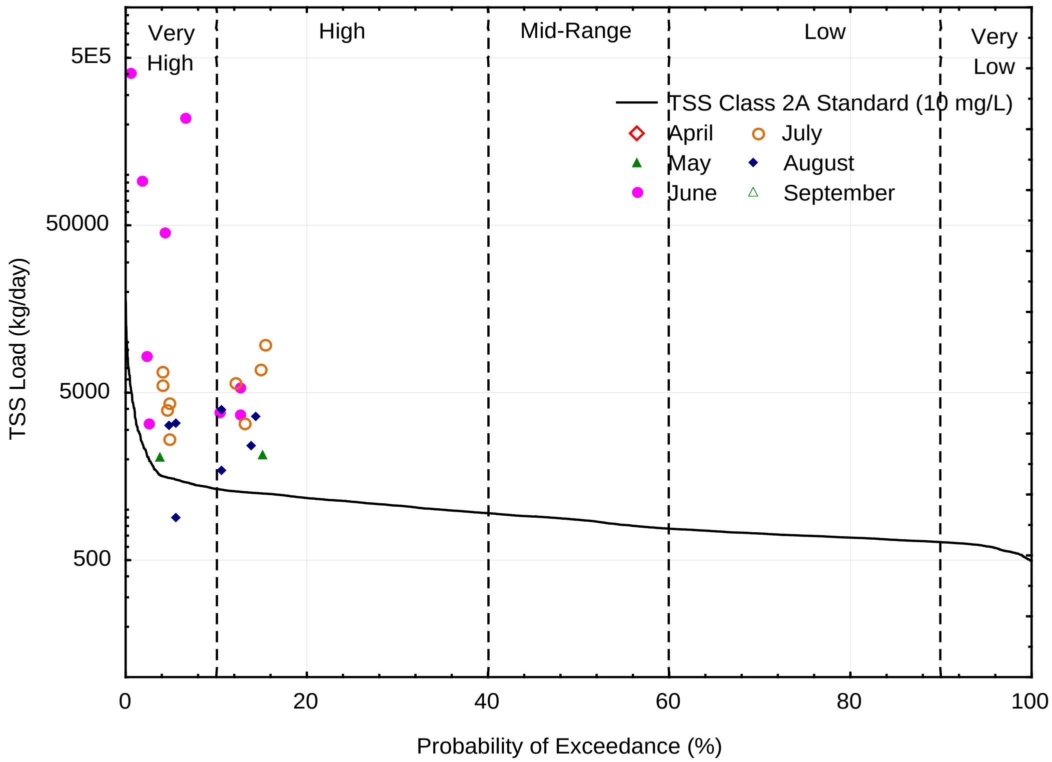

Figure 39. Total suspended solids load duration curve for Rollingstone Creek (07040003-533)

Table 70. Rollingstone Creek (07040003-533) total suspended solids TMDL and allocations

Rollingstone Creek 07040003-533 Load Component		Flow Regime				
		Very High	High	Mid	Dry	Very Dry
		kg/day				
Existing Load		***21,318***	***7,850***	***9,108***	***2,082***	***2,206***
Wasteload Allocations	*Rollingstone WWTP (MNG580078)*	*135.7*	*135.7*	*135.7*	*135.7*	*135.7*
	Construction stormwater (MNR10001)	*0.4*	*0.3*	*0.3*	*0.3*	*0.2*
	Industrial Stormwater (MNR50000)	*0.4*	*0.3*	*0.3*	*0.3*	*0.2*
	Total WLA	**136.5**	**136.3**	**136.3**	**136.3**	**136.1**
Load Allocations	*Watershed runoff*	*1,049.2*	*867.4*	*763.3*	*675.5*	*589.0*
	Total LA	**1,049.2**	**867.4**	**763.3**	**675.5**	**589.0**
10% MOS		**131.7**	**111.5**	**100.0**	**90.2**	**80.6**
Total Loading Capacity		**1,317.4**	**1,115.2**	**999.6**	**902.0**	**805.7**
Estimated Load Reduction		*20,001* *94%*	*6,735* *86%*	*8,108* *89%*	*1,180* *57%*	*1,400* *63%*

*See table Table 71 for individual facility WLAs

Table 71. NPDES permitted facilities included in Rollingstone Creek (07040003-533) TSS TMDL

Facility Name	NPDES Permit	Design Flow (MGD)	Existing Effluent Limit (mg/L)	Proposed Effluent Limit (mg/L)	WLA (kg/day)	Proposed Reduction (%)
Rollingstone WWTP	MNG580078	0.797	45	45	135.7	0%
TOTAL					**135.7**	

*Estimated as secondary pond surface area (4.89 ac) multiplied by 6 inches (allowable daily discharge)

4.4.6.6 Logan Branch Creek (07040003-536) Total Suspended Solids TMDL and allocations

The water quality target for this reach has been lowered from 65 mg/L TSS (class 2B TSS standard, CHF ecoregion) to 10 mg/L (class 2A TSS standard, CHF ecoregion) to protect downstream waters. Logan Branch (07040003-536) is an upstream reach to Whitewater River, North Fork (07040003-554), which has a use classification of 2A.

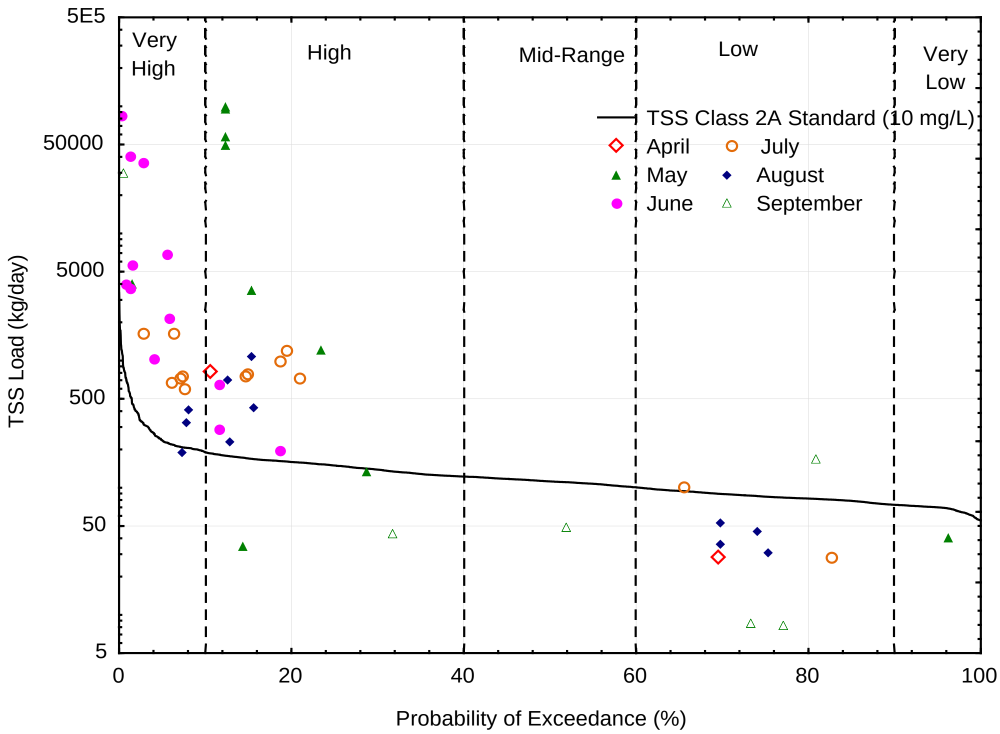

Figure 40. Total suspended solids load duration curve for Logan Branch Creek (07040003-536)

Table 72. Logan Branch Creek (07040003-536) total suspended solids TMDL and allocations

Logan Branch Creek 07040003-536 Load Component		Flow Regime: Very High	High	Mid	Dry	Very Dry
		kg/day				
Existing Load		*2,145*	*769*	*49*	*33*	*41*
Wasteload Allocations	*Construction stormwater (MNR100001)*	*0.3*	*0.2*	*0.1*	*0.1*	*0.1*
	Industrial stormwater (MNR50000)	*0.3*	*0.2*	*0.1*	*0.1*	*0.1*
	Total WLA	**0.6**	**0.4**	**0.2**	**0.2**	**0.2**
Load Allocations	*Watershed runoff*	*211.9*	*134.2*	*100.6*	*76.2*	*62.8*
	Total LA	**211.9**	**134.2**	**100.6**	**76.2**	**62.8**
10% MOS		**23.6**	**14.9**	**11.2**	**8.5**	**7.0**
Total Loading Capacity		**236.1**	**149.5**	**112.0**	**84.9**	**70.0**
Estimated Load Reduction		*1,909* *89%*	*619* *81%*	*0* *0%*	*0* *0%*	*0* *0%*

4.4.6.7 Whitewater River (07040003-537) Total Suspended Solids TMDL and allocations

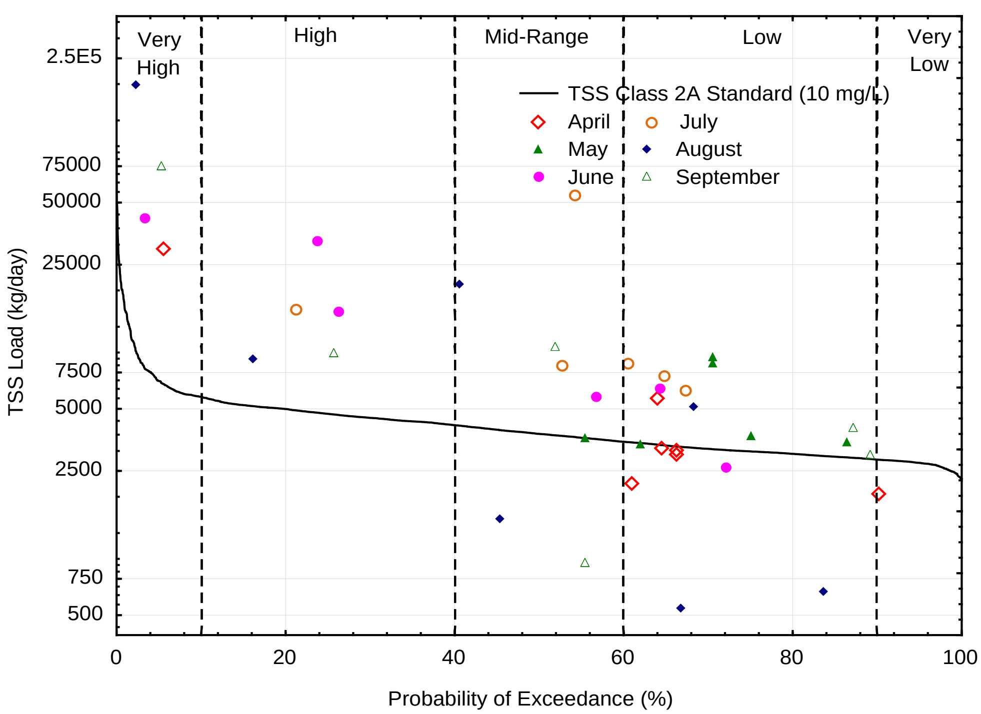

Figure 41. Total suspended solids load duration curve for Whitewater River (07040003-537)

Table 73. Whitewater River (07040003-537) total suspended solids TMDL and allocations

Whitewater River 07040003-537 Load Component		Flow Regime				
		Very High	High	Mid	Dry	Very Dry
		kg/day				
Existing Load		*185,743*	*14,967*	*8,142*	*3,448*	*1,622*
Wasteload Allocations	*Schell's Pine Grove Farm (MNG440040)**	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
	Construction stormwater (MNR100001)	*0.3*	*0.2*	*0.2*	*0.1*	*0.1*
	Industrial stormwater (MNR50000)	*0.3*	*0.2*	*0.2*	*0.1*	*0.1*
	Total WLA	**0.6**	**0.4**	**0.4**	**0.2**	**0.2**
Load Allocations	*Whitewater River , NF (523)*	*3,304.5*	*2,407.2*	*1,905.3*	*1,542.6*	*1,356.0*
	Whitewater River , SF (512)	*2,117.0*	*1,341.0*	*1,100.8*	*935.8*	*836.5*
	Watershed runoff	*720.4*	*507.6*	*397.6*	*321.2*	*269.7*
	Total LA	**6,141.9**	**4,255.8**	**3,403.7**	**2,799.6**	**2,462.2**
10% MOS		**682.5**	**472.9**	**378.2**	**311.1**	**273.6**
Total Loading Capacity		**6,825.0**	**4,729.1**	**3,782.3**	**3,110.9**	**2,736.0**
Estimated Load Reduction		*178,918*	*10,238*	*4,360*	*337*	*0*
		96%	*68%*	*54%*	*10%*	*0%*

*NPDES Permitted Feedlot

4.4.6.8 Whitewater River (07040003-539) Total Suspended Solids TMDL and allocations

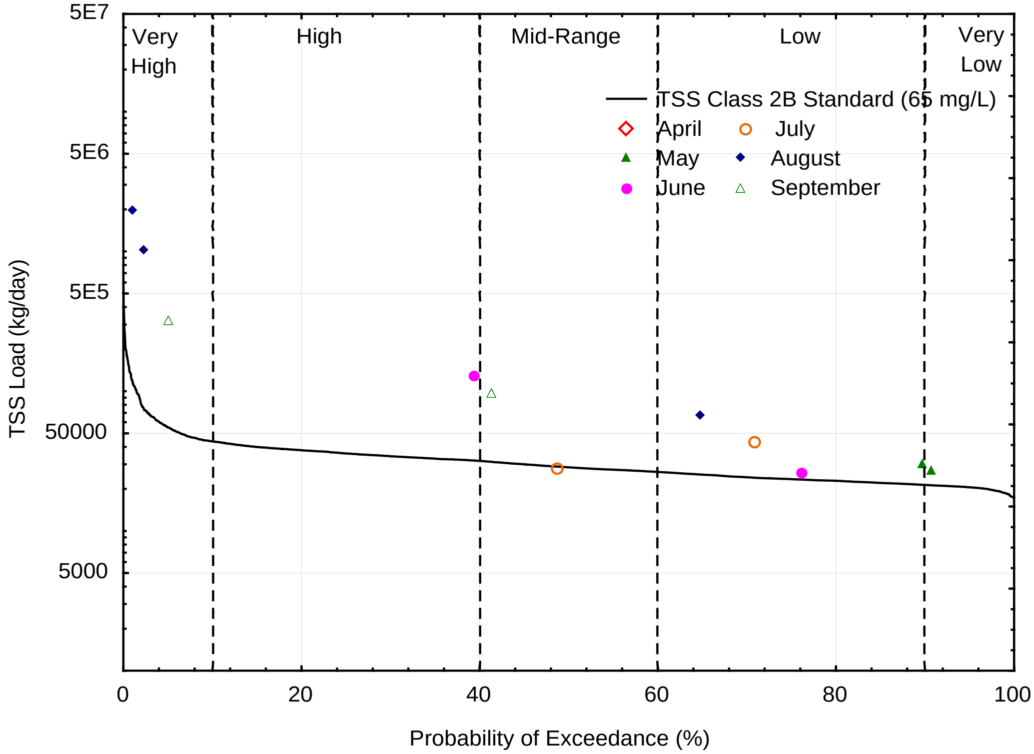

Figure 42. Total suspended solids load duration curve for Whitewater River (07040003-539)

Table 74. Whitewater River (07040003-539) total suspended solids TMDL and allocations

Whitewater River 07040003-539 Load Component		Flow Regime				
		Very High	High	Mid	Dry	Very Dry
		kg/day				
Existing Load		***1,040,335***	***128,949***	***61,936***	***36,780***	***26,975***
Wasteload Allocations	*Diamond K Dairy, Inc. (MN0064629)**	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
	Construction stormwater (MNR10001)	*16.6*	*10.7*	*8.5*	*7.0*	*6.1*
	Industrial Stormwater (MNR50000)	*16.6*	*10.7*	*8.5*	*7.0*	*6.1*
	Total WLA	**33.2**	**21.4**	**17.0**	**14.0**	**12.2**
Load Allocations	*Whitewater River (537)*	*6,142.5*	*4,256.2*	*3,404.0*	*2,799.9*	*2,462.4*
	Watershed load	*43,444.0*	*28,002.0*	*22,260.6*	*18,326.8*	*16,002.6*
	Total LA	**49,586.5**	**32,258.2**	**25,664.6**	**21,126.7**	**18,465.0**
10% MOS		**5,513.3**	**3,586.6**	**2,853.5**	**2,349.0**	**2,053.0**
Total Loading Capacity		**55,133.0**	**35,866.2**	**28,535.1**	**23,489.7**	**20,530.2**
Estimated Load Reduction		*985,202*	*93,083*	*33,401*	*13,291*	*6,445*
		95%	*72%*	*54%*	*36%*	*24%*

*NPDES Permitted Feedlot

4.4.6.9 Whitewater River, North Fork (07040003-553) Total Suspended Solids TMDL and allocations

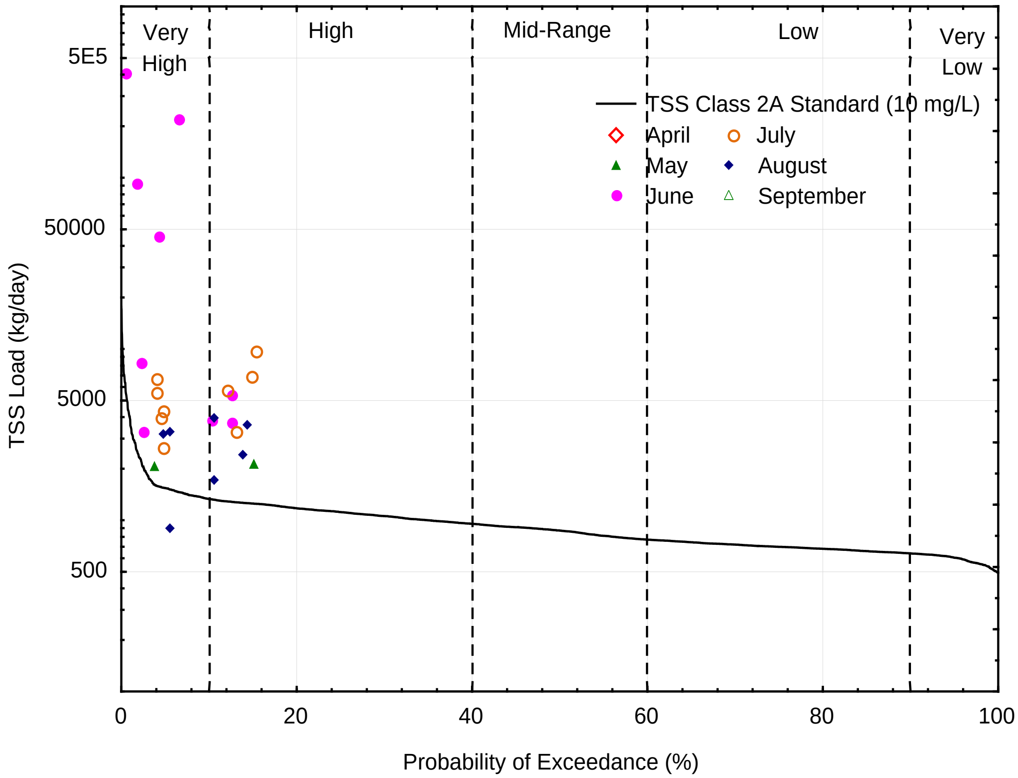

Figure 43. Total suspended solids load duration curve for Whitewater River, North Fork (07040003-553)

Table 75. Whitewater River, North Fork (07040003-553) total suspended solids TMDL and allocations

Whitewater River, North Fork 07040003-553 Load Component		Flow Regime				
		Very High	High	Mid	Dry	Very Dry
		kg/day				
Existing Load		*4,344*	*3,777*	*no data*	*no data*	*no data*
Wasteload Allocations	*Shea Dairy Inc., (MN0070181)**	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
	Construction stormwater (MNR10001)	*1.3*	*1.0*	*0.7*	*0.6*	*0.5*
	Industrial Stormwater (MNR50000)	*1.3*	*1.0*	*0.7*	*0.6*	*0.5*
	Total WLA	**2.6**	**2.0**	**1.4**	**1.2**	**1.0**
Load Allocations	*Watershed runoff*	*1354.1*	*1002.2*	*782.2*	*628.6*	*542.9*
	Total LA	**1,386.1**	**1,002.2**	**782.2**	**628.6**	**542.9**
10% MOS		**154.2**	**111.6**	**87.1**	**70.0**	**60.4**
Total Loading Capacity		**1,541.9**	**1,115.8**	**870.7**	**699.8**	**604.3**
Estimated Load Reduction		*2,803* *65%*	*2,661* *70%*	*no data*	*no data*	*no data*

*NPDES Permitted Feedlot

4.4.6.10 Whitewater River, North Fork (07040003-554) Total Suspended Solids TMDL and allocations

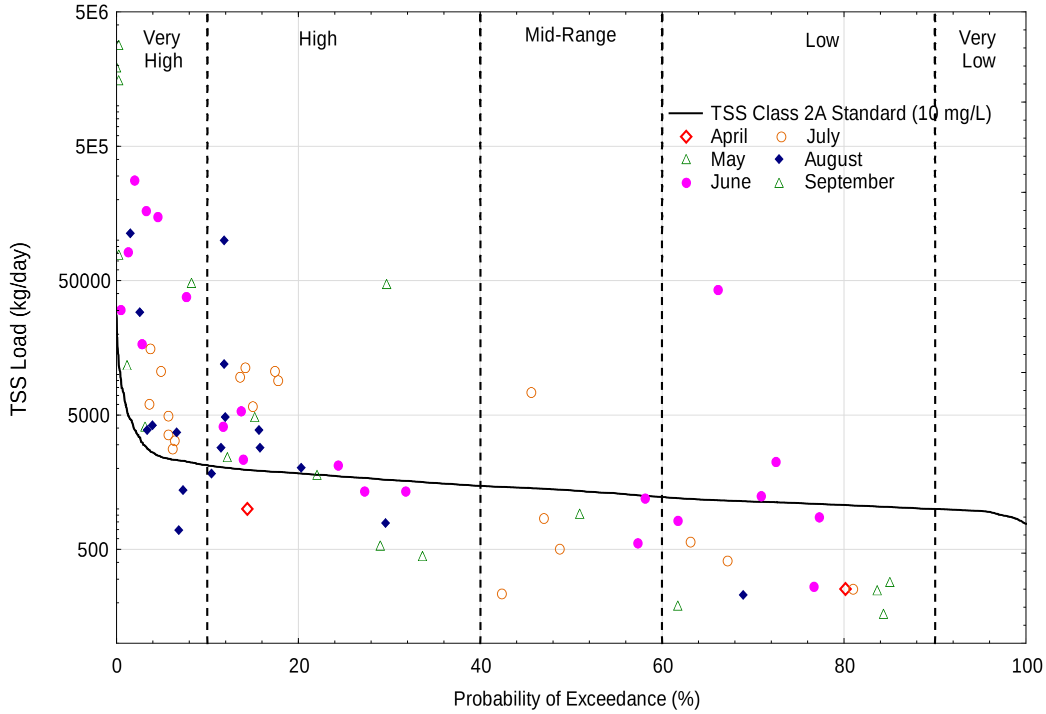

Figure 44. Total suspended solids load duration curve for Whitewater River, North Fork (07040003-554)

Table 76. Whitewater River, North Fork (07040003-554) total suspended solids TMDL and allocations

Whitewater River, North Fork 07040003-554 Load Component		Flow Regime				
		Very High	High	Mid	Dry	Very Dry
		kg/day				
Existing Load		***29,154***	***2,389***	***80***	***290***	***no data***
Wasteload Allocations	*NPDES Permitted Facilities**	*177.2*	*177.2*	*177.2*	*177.2*	*177.2*
	Construction stormwater (MNR10001)	*0.3*	*0.2*	*0.1*	*0.09*	*0.07*
	Industrial Stormwater (MNR50000)	*0.3*	*0.2*	*0.1*	*0.09*	*0.07*
	Total WLA	**177.8**	**177.6**	**177.4**	**177.4**	**177.3**
Load Allocations	*Whitewater River, NF (553)*	*1,387.7*	*1,004.1*	*783.7*	*629.8*	*543.9*
	Logan Branch (552)	*212.5*	*134.5*	*100.9*	*76.4*	*63.0*
	Watershed runoff	*409.0*	*246.5*	*175.7*	*110.0*	*76.8*
	Total LA	**2,009.2**	**1,385.1**	**1,060.3**	**816.2**	**683.7**
10% MOS		**243.0**	**173.6**	**137.5**	**110.4**	**95.7**
Total Loading Capacity		**2,430.0**	**1,736.3**	**1,375.2**	**1,103.8**	**956.7**
Estimated Load Reduction		*26,724*	*652*	*0*	*0*	*no data*
		92%	*27%*	*0%*	*0%*	

*See Table 77 for individual facility WLAs

Table 77. NPDES permitted facilities included in the Whitewater River, North Fork (07040003-554) TSS TMDL

Facility Name	NPDES Permit	Design Flow (MGD)	Existing Effluent Limit (mg/L)	Proposed Effluent Limit (mg/L)	WLA (kg/day)	Proposed Reduction (%)
Plainview Milk Products	MN000311	0.45	30	15*	25.55	50%
Plainview Elgin WWTP	MN0055361	2.67	30	15*	151.61	50%
TOTAL					**177.2**	

* Denotes a proposed reduction in current permitted effluent limit to achieve the stream loading capacity. NPDES permits for these wastewater treatment facilities may contain water quality based effluent limits that account for the NVSS characteristics of the discharge. Such limits would be consistent with the assumptions and requirements of the TMDLs' WLA.

4.4.6.11 Stockton Valley Creek (07040003-559) Total Suspended Solids TMDL and allocations

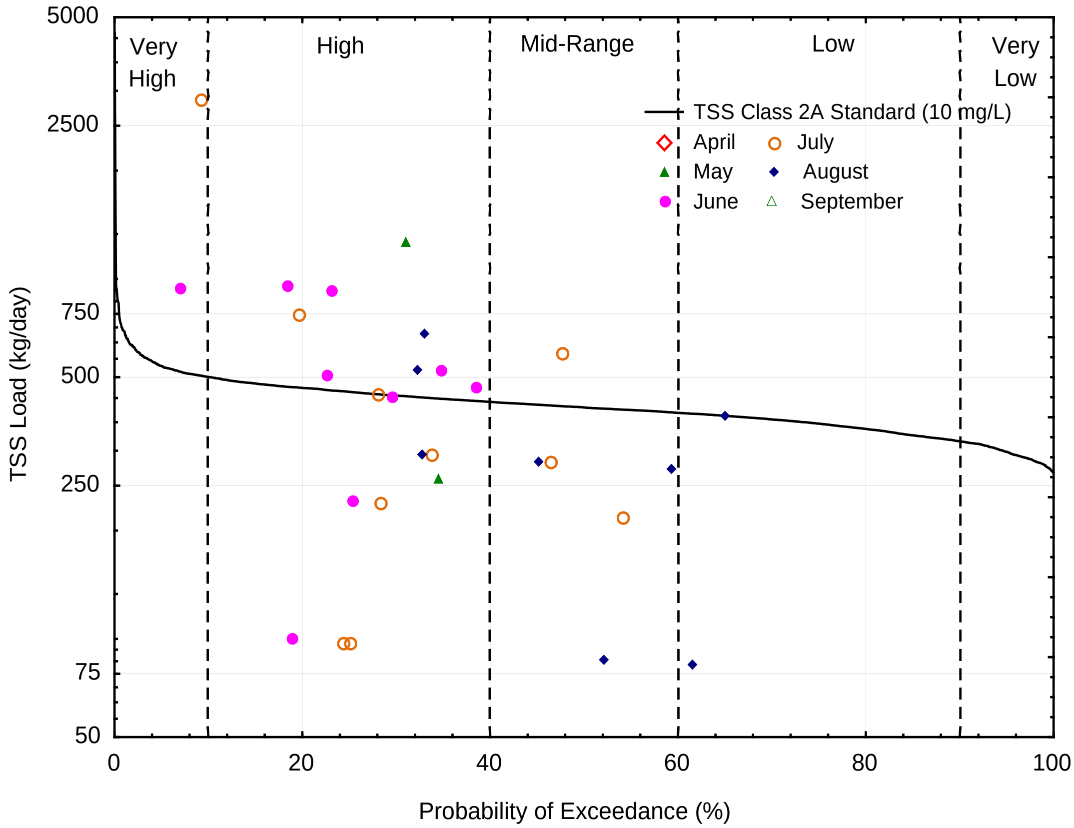

Figure 45. Total suspended solids load duration curve for Stockton Valley Creek (07040003-559)

Table 78. Stockton Valley Creek (07040003-559) total suspended solids TMDL and allocations

Stockton Valley Creek 07040003-559 Load Component		Flow Regime				
		Very High	High	Mid	Dry	Very Dry
		kg/day				
Existing Load		*2,982*	*448*	*286*	*235*	*no data*
Wasteload Allocations	*Construction stormwater (MNR10001)*	*0.2*	*0.2*	*0.1*	*0.1*	*0.1*
	Industrial Stormwater (MNR50000)	*0.2*	*0.2*	*0.1*	*0.1*	*0.1*
	Total WLA	**0.4**	**0.4**	**0.2**	**0.2**	**0.2**
Load Allocations	*Watershed runoff*	*483.2*	*409.5*	*370.5*	*334.0*	*279.0*
	Total LA	**483.2**	**409.5**	**370.5**	**334.0**	**279.0**
10% MOS		**53.7**	**45.5**	**41.2**	**37.1**	**31.0**
Total Loading Capacity		**537.3**	**455.4**	**411.9**	**371.3**	**310.2**
Estimated Load Reduction		*2,445* *82%*	*0* *0%*	*0* *0%*	*0* *0%*	*no data*

4.4.6.12 Garvin Brook (07040003-595) Total Suspended Solids TMDL and allocation

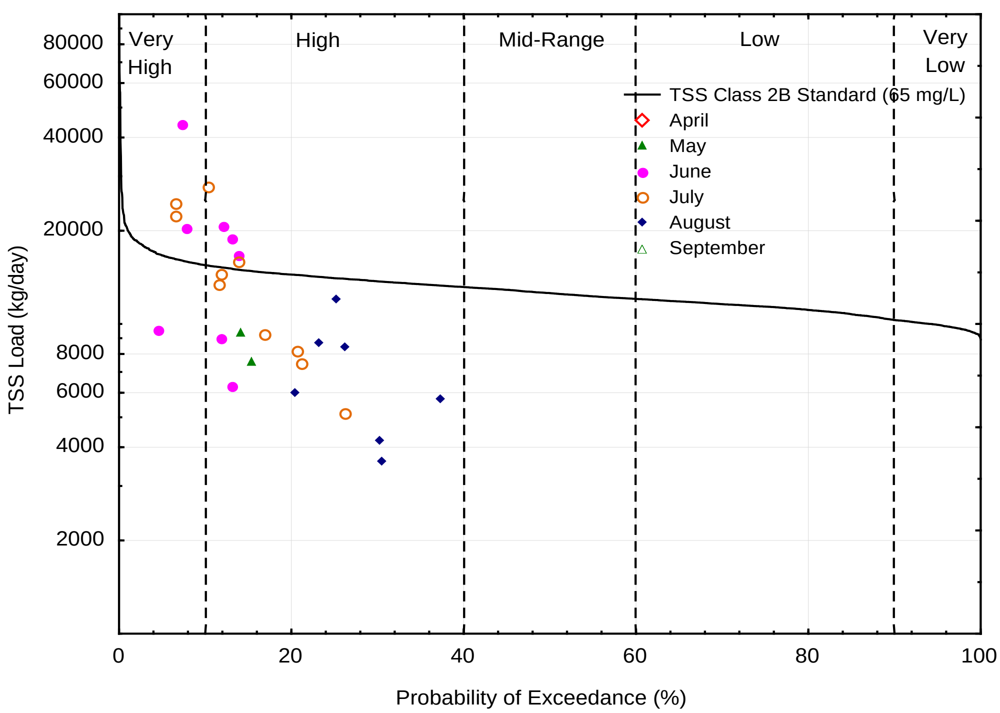

Figure 46. Total suspended solids load duration curve for Garvin Brook (07040003-595)

Table 79. Garvin Brook (07040003-595) total suspended solids TMDL and allocations

Garvin Brook 07040003-595 Load Component		Flow Regime				
		Very High	High	Mid	Dry	Very Dry
		kg/day				
Existing Load		***24,441***	***8,741***	***no data***	***no data***	***no data***
Wasteload Allocations	*NPDES Permitted Facilities**	*108.1*	*108.1*	*108.1*	*108.1*	*108.1*
	Construction stormwater (MNR10001)	*5.3*	*4.5*	*4.0*	*3.6*	*3.1*
	Industrial Stormwater (MNR50000)	*5.3*	*4.5*	*4.0*	*3.6*	*3.1*
	Total WLA	**118.7**	**117.1**	**116.1**	**115.3**	**114.3**
Load Allocations	*Rollingstone Creek (533)*	*1,185.7*	*1,003.8*	*899.6*	*811.7*	*725.2*
	Stockton Valley Creek (559)	*483.6*	*409.8*	*370.8*	*334.3*	*279.2*
	Watershed load	*13,205.0*	*11,122.2*	*9,935.2*	*8,986.9*	*7,826.9*
	Total LA	**14,874.3**	**12,535.8**	**11,205.6**	**10,132.9**	**8,831.3**
10% MOS		**1,665.9**	**1,405.9**	**1,258.0**	**1,138.7**	**994.0**
Total Loading Capacity		**16,658.9**	**14,058.8**	**12,579.7**	**11,386.9**	**9,939.6**
Estimated Load Reduction		*7,782* *32%*	*0* *0%*	*no data*	*no data*	*no data*

*See Table 80 for individual facility WLAs

Table 80. NPDES permitted facilities included in the Garvin Brook (07040003-595) TSS TMDL

Facility Name	NPDES Permit	Design Flow (MGD)	Existing Effluent Limit (mg/L)	Proposed Effluent Limit (mg/L)	WLA (kg/day)	Proposed Reduction (%)
Stockton WWTP	MNG580078	0.6142	45	45	104.6	0%
Minnesota City WWTP	MN0069817	0.0304	30	30	3.5	0%
TOTAL					**107.1**	

*Estimated as secondary pond surface area (3.77 ac) multiplied by 6 inches (allowable daily discharge)

4.4.7 TMDL Baseline

TSS TMDLs are based on data from the period 2001-2010. Any activities implemented during or after 2010 that lead to a reduction in loads or an improvement in an impaired stream water quality may be considered as progress towards meeting a WLA or LA.

4.5 Impairments not addressed by TMDLs

For two turbidity impaired streams (07040003-515 and 07040003-F16), TSS TMDLs were not calculated because none of the samples exceeded the South River Nutrient Region TSS standard of 65 mg/L. These reaches will be recommended for de-listing in the next assessment cycle. DO and temperature stressors can sometimes be linked back to a mass pollutant, but those links were not able to be made in the Mississippi River-Winona Watershed. Therefore, a TMDL to address these stressors was not recommended at this time. Physical habitat and physical connectivity are not pollutants, nor linked to mass pollutants, and therefore a TMDL calculation cannot be made for these stressors. A list of the aquatic life impairments not addressed by TMDL calculations in this report are provided in Table 81.

Table 81. Mississippi River-Winona Watershed aquatic life use impairments not addressed by TMDLs

AUID	Waterbody Name	Listed Pollutant or Stressor	Reason
07040003-515	Whitewater River, Middle Fork	Turbidity	Proposed de-listing due to shift in TSS standard from 30 to 65 mg/L
07040003-F16	Whitewater River, South Fork	Turbidity	Proposed de-listing due to shift in TSS standard from 30 to 65 mg/L
07040003-512	Whitewater River, South Fork	Macroinvertebrate Bioassessments	Physical habitat
07040003-566	Beaver Creek	Macroinvertebrate Bioassessments	Physical habitat
07040003-569	Gorman Creek	Macroinvertebrate Bioassessments	Physical habitat and physical connectivity
07040003-581	Bear Creek	Fish/ Macroinvertebrate Bioassessments	Physical habitat; dissolved oxygen and temperature stressors not linked to pollutants; and nitrate TMDL deferred while nitrate water quality standard for the protection of aquatic life is developed
07040003-592	Big Trout Creek	Macroinvertebrate Bioassessments	Physical habitat
07040003-609	Unnamed Creek	Macroinvertebrate Bioassessments	Physical habitat

5 Future Growth Consideration/Reserve Capacity

Potential changes in population and land use over time in the Mississippi River-Winona Watershed could result in changing sources of pollutants. The urbanized area of Rochester is located several miles west of the Mississippi River-Winona Watershed. The population of the city of Rochester increased by 24.4% and the city of Rochester municipal boundary increased by 36.5% between 2000 and 2010 (U.S. Census Bureau). Continued growth of this city may result in the expansion of the urban boundary into the Mississippi River-Winona Watershed in the future. In addition, the number of registered feedlots is decreasing while the number of animal units per feedlot is increasing, which may result in additional NPDES permitted facilities in the watershed. Possible changes and how they may or may not impact TMDL allocations are discussed below.

5.1 New or Expanding Permitted MS4 WLA Transfer Process

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

1. New development occurs within a 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 (see Section 4.1.3). One transfer rate was defined for each impaired lake or stream as the total watershed runoff LA (kg/day or billion org/day) divided by the watershed area downstream of any upstream impaired waterbody (acres). In the case of a load transfer, the amount transferred from LA to WLA will be based on the area (acres) of land coming under permit coverage multiplied by the transfer rate (kg/ac-day or billion org/ac-day). The MPCA will make these allocation shifts. 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.

Table 82. Transfer rates for any future MS4 discharger in the impaired lake watersheds

Lake name	WLA transfer rates	
	(kg/ac-yr)	(kg/ac-day)
Winona (Northwest)	0.082	0.00022
Winona (Southeast)	0.078	0.00021

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

Through both regulatory and non-regulatory approaches, several Federal, State and Local agencies have been and continue to work toward the goal of reducing pollutant loads in the Mississippi River-Winona Watershed. Strong partnerships that were strengthened during the WRAPS process such as those between counties, SWCDs, Natural Resource Conservation Service (NRCS), DNR, and U.S. Fish and Wildlife Service have and will continue to lead to watershed wide implementation of conservation practices. Civic Engagement efforts initiated during the WRAPS will strengthen the relationship between the watershed peoples and the agencies which provide technical assistance and incentives to attain water quality improvements.

On November 4, 2008, Minnesota voters approved the Clean Water, Land & 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 GW.

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

In response to this funding, several state agencies have strengthened their partnerships by coming together to focus high level water planning in order to best utilize these funds. The interagency Minnesota Water Quality Framework (Figure 46) as applied to Minnesota's 80 major watersheds clearly illustrates the cycle of assessment, watershed planning and implementation activities, and informs an adaptive management approach to WRAPS. Since the majority of the pollutant reductions activities will rely on voluntary adoption of BMPs, civic engagement is important. Citizenry of the watershed were engaged throughout the TMDL and WRAPS process. They gave input to the strategies defined in the WRAPS to address restoration of impaired waters as well as strategies to protect waters.

All agencies involved in the process have and continue to pursue the implementation of BMPs in the watershed through the use of funds including those administered by the Minnesota Board of Water and Soil Resources (BWSR), CWL, Federal 319 program, and the Environmental Quality Incentives Program (EQIP).

Watershed technical staff maintains contact with landowners interested in installing water quality improvement projects in the watershed and keep them regularly updated on funding as it becomes available. Over the long term, active participation will help build and sustain local civic infrastructure and leadership for watershed stewardship initiatives.

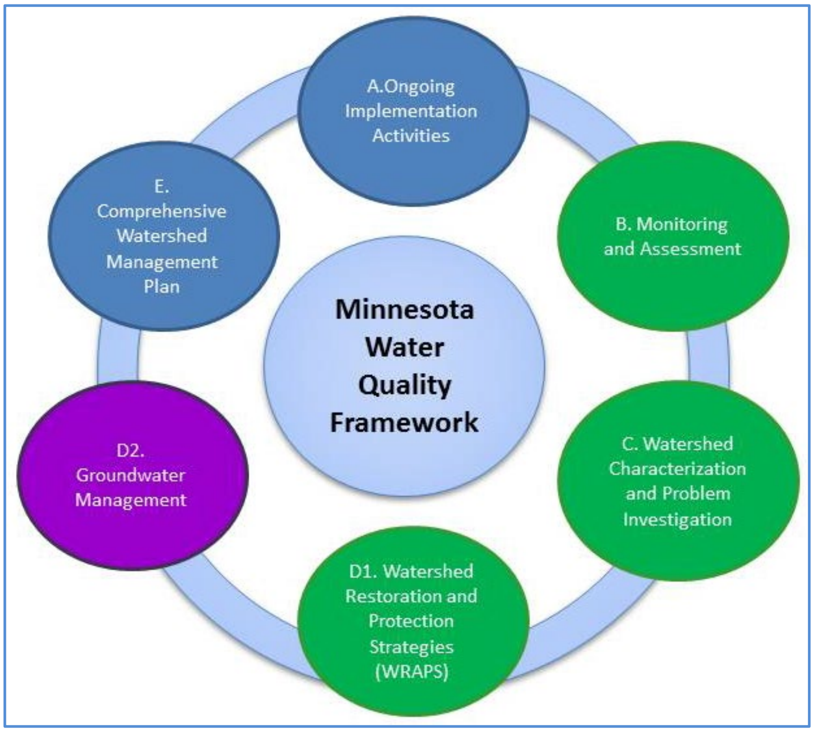

Figure 47. The Minnesota Water Quality Framework was developed to help achieve cleaner water via comprehensive watershed management using regulatory and non-regulatory means.

Minn. Stat. § 114D of the 2014 Minnesota Statute covers the Clean Water Legacy Act. Minn. Stat. § 114D.26, subd. 1, includes specifics on the WRAPS requirements. These requirements will be adhered to in the Mississippi River-Winona Watershed as the WRAPS is completed by the end of 2015.

> *Subdivision 1.*
>
> *The Pollution Control Agency shall develop watershed restoration and protection strategies (WRAPS). To ensure effectiveness and accountability in meeting the goals of this chapter, each WRAPS shall:*
>
> > *(1) identify impaired waters and waters in need of protection;*
> >
> > *(2) identify biotic stressors causing impairments or threats to water quality;*
> >
> > *(3) summarize watershed modeling outputs and resulting pollution load allocations, wasteload allocations, and priority areas for targeting actions to improve water quality;*
> >
> > *(4) identify point sources of pollution for which a national pollutant discharge elimination system permit is required under section 115.03;*
> >
> > *(5) identify nonpoint sources of pollution for which a national pollutant discharge elimination system permit is not required under section 115.03, with sufficient specificity to prioritize and geographically locate watershed restoration and protection actions;*
> >
> > *(6) describe the current pollution loading and load reduction needed for each source or source category to meet water quality standards and goals, including wasteload and load allocations from TMDL's;*

(7) contain a plan for ongoing water quality monitoring to fill data gaps, determine changing conditions, and gauge implementation effectiveness; and

(8) contain an implementation table of strategies and actions that are capable of cumulatively achieving needed pollution load reductions for point and nonpoint sources, including:

(i) water quality parameters of concern;

(ii) current water quality conditions;

(iii) water quality goals and targets by parameter of concern;

(iv) strategies and actions by parameter of concern and the scale of adoptions needed for each;

(v) a timeline for achievement of water quality targets;

(vi) the governmental units with primary responsibility for implementing each watershed restoration or protection strategy; and

(vii) a timeline and interim milestones for achievement of watershed restoration or protection implementation actions within 10 years of strategy adoption.

[From: 2014 Minn. Stats, https://www.revisor.leg.state.mn.us/statutes/?id=114D&view=chapter]

6.1 Non-regulatory

At the local level, the Winona, Wabasha and Olmsted County and SWCD offices, as well as other local entities, currently implement programs that target improving water quality and have been actively involved in projects to improve water quality in the past. Willing landowners within this watershed have implemented many practices in the past including: conservation tillage, buffer strips, urban BMPs, gully stabilizations, prescribed grazing, manure management, etc. It is assumed that these activities will continue. Potential state funding of restoration and protection projects include Clean Water Fund grants as well as grant funds through the state's Legislative-Citizen Commission on Minnesota Resources and the Lessard-Sams Outdoor Heritage Council. At the federal level, funding can be provided through Section 319 grants that provide cost-share dollars to implement activities in the watershed, as well as NRCS practice funds through programs like EQIP (Environmental Qualities Incentive Program). Various other funding and cost-share sources exist, which will be listed in the Mississippi River-Winona WRAPS Report. The implementation strategies described in this plan have demonstrated to be effective in reducing nutrient, sediment and bacteria loading to lakes and streams. Monitoring will continue and adaptive management will be in place to evaluate the progress made towards achieving water quality goals.

Website addresses for more information on current and past efforts:

- Mississippi River-Winona Watershed Webpage: http://ourwatershed.info/
- Olmsted County SWCD: http://www.co.olmsted.mn.us/pw/oswcd/Pages/default.aspx
- Wabasha SWCD: http://wabashaswcd.com/
- Whitewater River Watershed Project: http://www.whitewaterwatershed.org/index.htm
- Winona County SWCD: http://www.winonaswcd.org/

6.1.1 Lake Winona

Healthy Lake Winona is a newly found group that was formed in response to citizens learning of the nutrient impairment on Lake Winona during one of the Citizen Summits held in the watershed. Their draft mission statement is: *develop a citizen/government partnership to create and collaborate on strategies to conserve and improve the quality of surface and ground water within Winona's watershed. The Partnership will engage private and public resources to implement a series of long and short term goals to meet its mission.*

http://healthylakewinona.weebly.com/

Large internal load reductions (94%-100%) are needed in Lake Winona Northwest and Lake Winona Southeast to meet in-lake water quality standards. This magnitude of reductions will be achieved by management activities that flip shallow lakes from the turbid to clear water states and may include lake drawdowns, alum treatments, fish kills, and/or fish stocking. Proper implementation of these management activities will require cooperation between local government units, such as the Whitewater Joint Powers Board, Winona County and city of Winona (partly through the MS4 NPDES Permit), the DNR, Winona State University, as well as groups like Healthy Lake Winona.

6.2 Regulatory

6.2.1 Regulated 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. They are required to 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.

6.2.2 Regulated 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. They are required to properly select, install and maintain all BMPs required under the permit.

6.2.3 Municipal Separate Storm Sewer System (MS4) Permits

Stormwater discharges associated with MS4s are regulated through NPDES/State Disposal System (NPDES/SDS) Permits (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. MS4 Permits require the implementation of BMPs to address WLAs. In addition, the owner or operator is required to develop a stormwater pollution prevention program (SWPPP) that incorporates BMPs applicable to their MS4. 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 control; and
- Pollution prevention/good housekeeping.

6.2.4 Wastewater & State Disposal System (SDS) Permits

The MPCA issues permits for WWTFs that discharge into waters of the state. The permits have site specific limits on bacteria that are based on water quality standards. Permits regulate discharges with the goals of 1) protecting public health and aquatic life, and 2) assuring that every facility treats wastewater. In addition, SDS Permits set limits and establish controls for land application of sewage.

6.2.5 Subsurface Sewage Treatment Systems Program (SSTS)

Subsurface Sewage Treatment Systems (SSTS), commonly known as septic systems, are regulated by Minn. Stat. 115.55 and 115.56.

These regulations detail:

- Minimum technical standards for individual and mid-size SSTS;
- A framework for local administration of SSTS programs and;
- Statewide licensing and certification of SSTS professionals, SSTS product review and registration, and establishment of the SSTS Advisory Committee.

6.2.6 Feedlot Rules

The MPCA regulates the collection, transportation, storage, processing and disposal of animal manure and other livestock operation wastes. 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.

An additional concern related to feedlots is the effect of groundwater appropriations on surface water streamflow. Streamflow depletion can affect water quality in the stream or in the aquifer. For example, in many areas, groundwater discharge cools stream temperatures in the summer and warms stream temperatures in the winter, providing a suitable year-round habitat for fish. Reductions in groundwater discharge to streams caused by pumping can degrade habitat by warming stream temperatures during the summer and cooling stream temperatures during the winter

7 Monitoring Plan

7.1 Lake and Stream Monitoring

Volunteers throughout the watershed conduct stream and lake condition monitoring through the MPCA Volunteer Monitoring Program. The MPCA currently monitors the Mississippi River-Winona near Beaver (S001-742) for Flow, Total Phosphorus, Ortho Phosphorus, Nitrite + Nitrate Nitrogen, Total Kjeldahl Nitrogen, TSS, Turbidity, and Total Volatile Solids. This site as well as others in the watershed will also be sampled starting in 2020 as part of the Watershed Approach. Also, there are 15 Citizen Stream Monitoring Program sites within the watershed where water transparency and stream qualitative conditions are recorded.

If funding is available, the SWCDs will set up a monitoring program to monitor for nutrients, *E. coli*, and flow. Ideally it would be a twice per month plus storm event program. If funding is not available for new monitoring programs, monitoring will be done following the MPCA's 10-year monitoring cycle.

The DNR conducts lake and stream surveys to collect information about game fish populations which are then used to evaluate abundance, relative abundance size (length and weight), condition, age and growth, natural reproduction/recruitment, and effects of management actions (stocking and regulations). Other information collected for lake population assessments include basic water quality information (temperature, DO profile, secchi, pH, and alkalinity), water level and for fish disease and parasites. Additional information collected for lake surveys include lab water chemistry (TP, alkalinity, TDS, Chl-a, Conductivity, pH), watershed characteristics, shoreline characteristics, development, substrates and aquatic vegetation. In the last few years, the DNR has begun near-shore sampling to develop fish IBIs at lakes in watersheds that have ongoing assessments.

The frequency of sampling depends on importance/use. The most important/heavily used lakes are sampled about every five years. Less important/heavily used lakes are sampled every 7, 10, 12, or 15 years. If there is a management action (regulation or stocking) that needs to be evaluated more quickly, sampling could occur every other year. Full surveys are often only done about every 20 years.

7.2 BMP Monitoring

On-site monitoring of implementation practices should also take place in order to better assess BMP effectiveness. A variety of criteria such as land use, soil type, and other watershed characteristics, as well as monitoring feasibility, will be used to determine which BMPs to monitor. Under these criteria, monitoring of a specific type of implementation practice can be accomplished at one site but can be applied to similar practices under similar criteria and scenarios. Effectiveness of other BMPs can be extrapolated based on monitoring results.

8 Implementation Strategy Summary

8.1 Permitted Sources

8.1.1 MS4

The MPCA oversees all regulated MS4 entities in stormwater management accounting activities. All regulated MS4s in the watershed fall under the category of Phase II. MS4 NPDES/SDS Permits require regulated municipalities to implement BMPs to reduce pollutants in stormwater runoff to the Maximum Extent Practicable (MEP).

All owners or operators of regulated MS4s (also referred to as "permittees") are required to satisfy the requirements of the MS4 general permit. The MS4 general permit requires the permittee to develop a SWPPP that addresses all permit requirements, including the following six minimum control measures:

- Public education and outreach
- Public participation
- Illicit Discharge Detection and Elimination (IDDE) Program
- Construction-site runoff controls;
- Post-construction runoff controls; and
- Pollution prevention and municipal good housekeeping measures

A SWPPP is a management plan that describes the MS4 permittee's activities for managing stormwater within their jurisdiction or regulated area. In the event a TMDL study has been completed, approved by EPA prior to the effective date of the general permit, and assigns a WLA to an MS4 permittee, that permittee must document the WLA in their application and provide an outline of the BMPs to be implemented in the current permit term to address any needed reduction in loading from the MS4.

The MPCA requires applicants submit their application materials and SWPPP document to the MPCA for review. Prior to extension of coverage under the general permit, all application materials are placed on 30-day public notice by the MPCA, to ensure adequate opportunity for the public to comment on each permittee's stormwater management program. Upon extension of coverage by the MPCA, the permittees are to implement the activities described within their SWPPP, and submit annual reports to the MPCA by June 30 of each year. These reports document the implementation activities which have been completed within the previous year, analyze implementation activities already installed, and outline any changes within the SWPPP from the previous year.

The MPCA has assigned nutrient loads for the TMDLs of this study to the regulated MS4s. The pollutant LAs for each MS4 entity are outlined in section 4.0 of the TMDL. The MS4 General Permit, which became effective August 1, 2013, requires permittees to develop compliance schedules for any TMDL that received EPA-approval prior to the effective date of the General Permit. This schedule must identify BMPs that will be implemented over five-year permit term, timelines for their implementation, an assessment of progress, and a long term strategy for continued progress toward ultimately achieving those WLAs. Because this TMDL will be approved after the effective date of the General Permit, MS4s will not be required to report on WLAs contained in this TMDL until the effective date of the next General Permit, expected in 2018.

Reasonable assurance that the WLAs calculated for this TMDL will be implemented is provided by regulatory actions. According to 40 CFR 122.44(d)(1)(vii)(B), NPDES Permit effluent limits must be consistent with assumptions and requirements of all WLAs in an approved TMDL. The MPCA's stormwater program and its NPDES Permit program are the state programs responsible for ensuring that implementation activities are initiated and maintained, and effluent limits are consistent with the WLAs calculated from the TMDLs. The NPDES program requires construction and industrial sites to create SWPPPs which summarize how stormwater will be minimized from construction and industrial sites.

8.1.2 Construction Stormwater

The WLA for stormwater discharges from sites where there is construction activity reflects the number of construction sites greater than one acre expected to be active in the watershed at any one time, and the BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at construction sites are defined in 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. It should be noted that all local construction stormwater requirements must also be met.

8.1.3 Industrial Stormwater

The WLA for stormwater discharges from sites where there is industrial activity reflects the number of sites in the watershed for which NPDES 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. It should be noted that all local stormwater management requirements must also be met.

8.1.4 Wastewater

The MPCA issues permits for WWTFs that discharges into waters of the state. The permits have site specific limits that are based on water quality standards. Permits regulate discharges with the goals of 1) protecting public health and aquatic life, and 2) assuring that every facility treats wastewater. In addition, SDS permits set limits and establish controls for land application of sewage.

8.2 Non-Permitted Sources

8.2.1 Adaptive Management

The response of the lakes and streams will be evaluated as management practices are implemented. This evaluation will occur every five years after the commencement of implementation actions; for the next 25 years. Data will be evaluated and decisions will be made as to how to proceed for the next five years. The management approach to achieving the goals should be adapted as new information is collected and evaluated.

8.2.2 Best Management Practices

A variety of BMPs to restore and protect the lakes and streams within the Mississippi River-Winona Watershed will be outlined and prioritized in the WRAPS report, set to be completed in early 2016.

8.2.3 Public Participation

A crucial part in the success of the WRAPS that will be designed to address the impaired lakes and streams and protect the non-impaired water bodies will be participation from local citizens. In order to gain support from these citizens, various types of public participation opportunities will be necessary. A variety of educational avenues will continue to be used throughout the watershed. These include (but are not limited to): press releases, meetings, workshops, focus groups, trainings, websites, etc. Local staff (conservation district, watershed, county, etc.) and board members work to educate the residents of the watersheds about ways to clean up their lakes and streams on a regular basis. Education will continue throughout the watershed.

8.2.4 Technical Assistance

The counties and SWCDs within the watershed provide assistance to landowners for a variety of projects that benefit water quality. Assistance provided to landowners varies from agricultural and rural BMPs to urban and lakeshore BMPs. This technical assistance includes education and one-on-one training. Many opportunities for technical assistance are as a result of educational workshops or trainings. It is important that these outreach opportunities for watershed residents continue. Marketing is necessary to motivate landowners to participate in voluntary cost-share assistance programs.

Programs such as state cost share, Clean Water Legacy funding, EQIP, and Conservation Reserve Program (CRP) are available to help implement the best conservation practices that each parcel of land is eligible for to target the best conservation practices per site. Conservation practices may include, but are not limited to: stormwater bioretention, septic system upgrades, feedlot improvements, invasive species control, wastewater treatment practices, agricultural and rural BMPs and internal loading reduction. More information about types of practices and implementation of BMPs will be discussed in the Mississippi River-Winona WRAPS Report.

8.2.5 Partnerships

Continued partnerships between state government, watershed groups, SWCDs, counties, cities, townships, citizens, and businesses, are one mechanism through which water quality will be protected and improved. One example of an outcome of such partnerships is development and/or updating ordinances to protect the areas water resources.

8.3 Cost

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

8.3.1 Phosphorus

A detailed analysis of the cost to implement the phosphorus 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 total phosphorus removed per year (Foraste et al. 2012). Multiplying that by the needed 1,427 pounds per year (647 kg/year) reduction for the two lake basins in this study provides a total cost of approximately $3.14 million.

8.3.2 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 septic systems. 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 ITPHSS was estimated at $7,500/system (EPA 2011). Multiplying those unit costs by an estimated 86 ITPHSS and 27,538 AU in the seven impaired reach subwatersheds provides a total cost of approximately $10.29 million.

8.3.3 Nitrate

The Minnesota Nutrient Reduction Strategy determined a statewide nitrate reduction of 20% by the year 2025 (45% reduction by 2040) is needed to help achieve the goals of the Gulf of Mexico (MPCA 2014). Through a separate, related study, Nitrogen in Minnesota Surface Waters, the University of Minnesota developed a tool to evaluate the expected N reductions to Minnesota waters from individual or collective BMPs adopted on lands well-suited for the practices (Lazarus et al. 2014). The tool, called "Nitrogen BMP watershed planning tool" (NBMP), enables planners to gauge the potential for reducing N loads to surface waters from watershed croplands, and to assess the potential costs (and savings) of achieving various N reduction goals. The tool also enables the user to identify which combinations of BMPs will be most cost-effective for achieving N reductions at a HUC8 watershed or statewide scale.

Impaired subwatersheds in the Mississippi-River Winona Watershed (AUIDs 07040003-512,-611, -F17, -F19; Table 8) cover 93,193 acres, or 22% of the total watershed area of approximately 414,000 acres. Focus will be placed on these impaired subwatersheds for nitrate BMP implementation. By taking 22% of the $5.86 million cost estimated using one NBMP tool scenario (Figure 47), it is estimated it will cost $1.30 million to address nitrate issues in the impaired subwatersheds.

Watershed: Mississippi River - Winona | 0.414 million acres in watershed or state | 37

Practice	% suitable	% adoption	% treated	% treated, combined	acres treated (000), combined
Corn acres receiving target N rate, no inhibitor or timing shift	24.9%	60%	15.0%	13.6%	56.16
Fall N target rate acres receiving N inhibitor	1.5%	55%	0.8%	0.8%	3.17
Fall N applications switched to spring, % of fall-app. acres	1.5%	45%	0.7%	0.3%	1.17
Fall N switch to split spring/sidedressing, % of fall acres	1.5%	45%	0.7%	0.3%	1.17
Restored wetlands	0.8%	50%	0.4%	0.4%	1.73
Tile line bioreactors	0.4%	20%	0.1%	0.0%	0.00
Controlled drainage	0.4%	50%	0.2%	0.1%	0.46
Saturated buffers	0.4%	50%	0.2%	0.2%	0.92
Riparian buffers	2.5%	90%	2.3%	2.3%	9.33
Corn grain &soybean acres planted w/cereal rye cover crop	34.3%	55%	18.8%	17.5%	72.21
Short season crops planted to a cereal rye cover crop	2.5%	50%	1.8%	1.2%	4.82
Perennial crop % of corn & soybean area (marginal only)	3.7%	10%	0.4%	0.4%	1.48

Weather scenario: Wet year- 30% of preplant N is lost, yield reduced

For wet spring scenario 2, fertilizer & manure N lost: 30%

The rate of sidedressed N is increased to offset the lost preplant N.

N load reduction with these adoption rates: 20.9% of all nonpoint source load; 22.1% of cultivated ag land source load

More results===>

Treatment cost before fertilizer cost savings & corn yield impacts	$7.11	million/year
N fertilizer cost savings & corn yield impacts	-$1.24	
Net BMP treatment cost	$5.86	million/year

Figure 48. Mississippi River-Winona scenario from the NBMP tool illustrating a potential strategy to achieve the 20% nitrate reduction interim goal

8.3.4 TSS

Utilizing numbers developed by the *Group of 16* (G16), an interagency work group (Board of Water Resources, USDA, MPCA, Minnesota Association of SWCDs, Minnesota Association of Watershed Districts, Natural Resources and Conservation Service) who assessed restoration costs for several TMDLs, it was determined that implementing the Mississippi River-Winona TSS TMDLs will cost approximately $76 million over 10 years. This was based on total area of the watershed (647 square miles) multiplied by the cost estimate of $117,000/square mile for a watershed based treatment approach.

8.4 Adaptive Management

This list of implementation elements and the more detailed WRAPS report that will be prepared following this TMDL assessment focuses on adaptive management. Continued monitoring and “course corrections” responding to monitoring results are the most appropriate strategy for attaining the water quality goals established in this TMDL. Management activities will be changed or refined to efficiently meet the TMDL and lay the groundwork for de-listing the impaired water bodies.

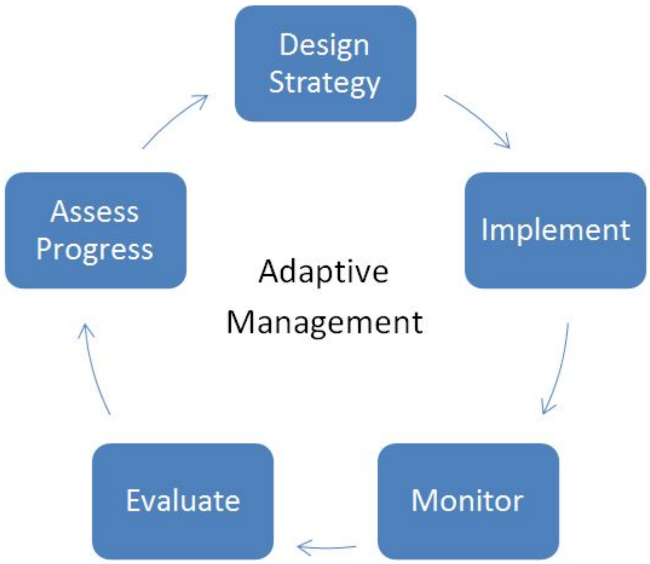

Figure 49. Adaptive Management

9 Public Participation

September 19, 2011 – Citizen Advisory Panel
Purpose – Initial meeting of Citizen Advisory Panel to include an overview of water quality impairments, the watershed approach, and various initiatives completed in the watershed.

November 15, 2011 – Citizen Advisory Panel
Purpose – Overview of water quality initiatives and solicit feedback from panel members.

March 29, 2012 – Citizen Advisory Panel
Purpose - Overview of *E. coli* data results from 2011 and results of corn stalk nitrate tests updates were presented.

June 6, 2012 – Whitewater Watershed Technical Committee
Purpose – Advise the technical committee on project work in the Whitewater Watershed. Meeting included updates on Mississippi – Winona grant progress (field transects, data analysis on water quality data, and citizen summit work).

June 26, 2012 – Citizen Summit I
Purpose - Provide an opportunity for people to discuss concerns and ideas about ways to protect local water quality.

November 14, 2012 – Citizen Advisory Panel
Purpose – Overview of *E. coli* monitoring data, Citizen Summit work, watershed survey and newsletter.

November 28, 2012 – Whitewater Farmer-Led Council
Purpose – Presentation on modeling project, updates on incentives provided.

February 19, 2013 – Citizen Summit II
Purpose – Provide an update of first Citizen Summit, and overviews of data analysis and watershed surveys, and solicit feedback on presented information.

April 19, 2013 – Whitewater Farmer-Led Council
Review of projects in watershed and incentives that are available to members.

April 26, 2013 – Whitewater Farmer-Led Council
Review of modeling project.

July 12, 2013 – Winona County Water Plan Technical Committee
Purpose – Update on various water resource activities affecting Winona County with discussion of County Water Plan process and timeline.

August 20, 2013 – Whitewater Farmer-Led Council meeting
Purpose – Members provided input to consultant on specific farming practices in use.

January 21, 2014 – Whitewater Farmer-Led Council
Purpose – Review of state’s Nitrogen Study and discussion of Nitrogen strategies.

August 21, 2014 – Whitewater Farmer-Led Council

Purpose – Present results of modeling work showing how different agricultural practices can improve water quality.

October 21, 2014 – Citizen Advisory Panel
Purpose – Present progress made since the 2013 Citizen Summit, provide updates on project work and solicit feedback on plans for next Citizen Summit.

November 12, 2014 – Citizen Summit III
Purpose – Provide updates on recent watershed work, citizen input received on 10-year Mississippi River-Winona Watershed strategy.

February 24, 2015 – Whitewater Farmer-Led Council
Purpose – Overview of projects within the watershed to include Agricultural Certainty Program and watershed approach.

August 24, 2015 - September 24, 2015 - Formal public notice period for this Mississippi River-Winona Watershed TMDL Study

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11 Appendix A: TPEC Supporting Information

Table 83. Boller Lake watershed runoff flow and phosphorus load by land cover

NLCD 2011 Land Cover Type	TPEC (kg/ha/yr)	Area (km2)	Flow (hm3/yr)	TP (kg/yr)
Barren Land	0.05	0.0585	0.0132	0.3
Cultivated Crops	0.433	1.2312	0.2782	53.3
Deciduous Forest	0.1	15.5704	3.5185	155.7
Developed, High Intensity	0.5	0.1164	0.0263	5.8
Developed, Low Intensity	0.5	0.4261	0.0963	21.3
Developed, Medium Intensity	0.5	1.4999	0.3389	75.0
Developed, Open Space	0.5	2.3411	0.5290	117.1
Emergent Herbaceous Wetlands	0.1	0.1212	0.0274	1.2
Evergreen Forest	0.1	0.0300	0.0068	0.3
Herbaceous	0.1	2.0338	0.4596	20.3
Mixed Forest	0.1	0.0045	0.0010	0.0
Open Water	0.05	0.1205	0.0272	0.6
Hay/Pasture	0.25	6.0035	1.3566	150.1
Shrub/Scrub	0.1	0.0270	0.0061	0.3
Woody Wetlands	0.1	0.1601	0.0362	1.6
Total		**29.7441**	**6.7213**	**602.9***

* The actual load used in BATHTUB is slightly less to account for a 1.19 kg/yr reduction in phosphorus load from the Crestview ponds.

Table 84. Winona (Northwest) direct drainage runoff flow and phosphorus load by land cover

NLCD 2011 Land Cover Type	TPEC (kg/ha/yr)	Area (km2)	Flow (hm3/yr)	TP (kg/yr)
Barren Land	0.05	0.0000	0.0000	0.0
Cultivated Crops	0.433	0.0000	0.0000	0.0
Deciduous Forest	0.1	2.2063	0.4986	22.1
Developed, High Intensity	0.5	0.0892	0.0202	4.5
Developed, Low Intensity	0.5	0.2502	0.0565	12.5
Developed, Medium Intensity	0.5	0.6002	0.1356	30.0
Developed, Open Space	0.5	0.6496	0.1468	32.5
Emergent Herbaceous Wetlands	0.1	0.0049	0.0011	0.0
Evergreen Forest	0.1	0.0000	0.0000	0.0
Herbaceous	0.1	0.0827	0.0187	0.8
Mixed Forest	0.1	0.0000	0.0000	0.0
Open Water	0.05	0.0165	0.0037	0.1
Hay/Pasture	0.25	0.0000	0.0000	0.0
Shrub/Scrub	0.1	0.0000	0.0000	0.0
Woody Wetlands	0.1	0.0323	0.0073	0.3
Total		**3.9319**	**0.8885**	**102.8***

* The actual load used in BATHTUB is slightly less to account for a 7.02 kg/yr reduction in phosphorus load from the Woodlawn ponds.

Table 85. Winona (northwest) MS4 stormwater runoff flow and phosphorus load by land cover

NLCD 2011 Land Cover Type	TPEC (kg/ha/yr)	Area (km2)	Flow (hm3/yr)	TP (kg/yr)
Barren Land	0.05	0.0000	0.0000	0.0
Cultivated Crops	0.433	0.0000	0.0000	0.0
Deciduous Forest	0.1	0.0010	0.0002	0.0
Developed, High Intensity	0.5	0.3181	0.0719	15.9
Developed, Low Intensity	0.5	1.1454	0.2588	57.3
Developed, Medium Intensity	0.5	1.7353	0.3921	86.8
Developed, Open Space	0.5	0.3950	0.0893	19.8
Emergent Herbaceous Wetlands	0.1	0.0398	0.0090	0.4
Evergreen Forest	0.1	0.0000	0.0000	0.0
Herbaceous	0.1	0.0543	0.0123	0.5
Mixed Forest	0.1	0.0000	0.0000	0.0
Open Water	0.05	0.0059	0.0013	0.0
Hay/Pasture	0.25	0.0000	0.0000	0.0
Shrub/Scrub	0.1	0.0000	0.0000	0.0
Woody Wetlands	0.1	0.0154	0.0035	0.2
Total		**3.7103**	**0.8384**	**180.8**

Table 86. Winona (Southeast) direct drainage runoff flow and phosphorus load by land cover

NLCD 2011 Land Cover Type	TPEC (kg/ha/yr)	Area (km2)	Flow (hm3/yr)	TP (kg/yr)
Barren Land	0.05	0.0000	0.0000	0.0
Cultivated Crops	0.433	0.0000	0.0000	0.0
Deciduous Forest	0.1	0.6027	0.1362	6.0
Developed, High Intensity	0.5	0.0429	0.0097	2.1
Developed, Low Intensity	0.5	0.1025	0.0232	5.1
Developed, Medium Intensity	0.5	0.2615	0.0591	13.1
Developed, Open Space	0.5	0.2269	0.0513	11.3
Emergent Herbaceous Wetlands	0.1	0.0481	0.0109	0.5
Evergreen Forest	0.1	0.0000	0.0000	0.0
Herbaceous	0.1	0.0263	0.0059	0.3
Mixed Forest	0.1	0.0000	0.0000	0.0
Open Water	0.05	0.0345	0.0078	0.2
Hay/Pasture	0.25	0.0008	0.0002	0.0
Shrub/Scrub	0.1	0.0014	0.0003	0.0
Woody Wetlands	0.1	0.0042	0.0010	0.0
Total		**1.3517**	**0.3054**	**38.7**

Table 87. Winona (Southeast) MS4 stormwater runoff flow and phosphorus load by land cover

NLCD 2011 Land Cover Type	TPEC (kg/ha/yr)	Area (km2)	Flow (hm3/yr)	TP (kg/yr)
Barren Land	0.05	0.0000	0.0000	0.0
Cultivated Crops	0.433	0.0000	0.0000	0.0
Deciduous Forest	0.1	0.0000	0.0000	0.0
Developed, High Intensity	0.5	0.0851	0.0192	4.3
Developed, Low Intensity	0.5	0.6816	0.1540	34.1
Developed, Medium Intensity	0.5	0.7824	0.1768	39.1
Developed, Open Space	0.5	0.2378	0.0537	11.9
Emergent Herbaceous Wetlands	0.1	0.0042	0.0009	0.0
Evergreen Forest	0.1	0.0000	0.0000	0.0
Herbaceous	0.1	0.0039	0.0009	0.0
Mixed Forest	0.1	0.0000	0.0000	0.0
Open Water	0.05	0.0059	0.0013	0.0
Hay/Pasture	0.25	0.0000	0.0000	0.0
Shrub/Scrub	0.1	0.0000	0.0000	0.0
Woody Wetlands	0.1	0.0000	0.0000	0.0
Total		**1.8008**	**0.4069**	**89.5**

12 Appendix B: BATHTUB Supporting Information

Table 88. Boller's Lake Model Predicted Values

Segment:		1	Segname 1	
		Predicted Values--->		
Variable		**Mean**	**CV**	**Rank**
TOTAL P	MG/M3	70.8	0.10	66.8%

Table 89. Boller's Lake Model Water and Phosphorus Balances

Overall Water Balance					Averaging Period =		1.00	years
				Area	Flow	Variance	CV	Runoff
Trb	**Type**	**Seg**	**Name**	**km²**	**hm³/yr**	**(hm3/yr)²**	**-**	**m/yr**
1	1	1	Trib 1	29.7441	6.7213	0.00E+00	0.00	0.23
PRECIPITATION				0.2327	0.2071	0.00E+00	0.00	0.89
TRIBUTARY INFLOW				29.7441	6.7213	0.00E+00	0.00	0.23
***TOTAL INFLOW				29.9768	6.9284	0.00E+00	0.00	0.23
ADVECTIVE OUTFLOW				29.9768	6.7097	0.00E+00	0.00	0.22
***TOTAL OUTFLOW				29.9768	6.7097	0.00E+00	0.00	0.22
***EVAPORATION					0.2187	0.00E+00	0.00	

Overall Mass Balance Based Upon				Predicted		Outflow & Reservoir Concentrations				
Component:				TOTAL P						
				Load		Load Variance			Conc	Export
Trb	**Type**	**Seg**	**Name**	**kg/yr**	**%Total**	**(kg/yr)²**	**%Total**	**CV**	**mg/m³**	**kg/km²/yr**
1	1	1	Trib 1	601.8	98.4%	0.00E+00		0.00	89.5	20.2
PRECIPITATION				10.1	1.6%	2.53E+01	100.0%	0.50	48.5	43.2
TRIBUTARY INFLOW				601.8	98.4%	0.00E+00		0.00	89.5	20.2
***TOTAL INFLOW				611.8	100.0%	2.53E+01	100.0%	0.01	88.3	20.4
ADVECTIVE OUTFLOW				475.3	77.7%	2.26E+03		0.10	70.8	15.9
***TOTAL OUTFLOW				475.3	77.7%	2.26E+03		0.10	70.8	15.9
***RETENTION				136.5	22.3%	2.25E+03		0.35		

Overflow Rate (m/yr)	28.8	Nutrient Resid. Time (yrs)	0.0493
Hydraulic Resid. Time (yrs)	0.0635	Turnover Ratio	20.3
Reservoir Conc (mg/m3)	71	Retention Coef.	0.223

Table 90. Lake Winona (Northwest Bay) Calibrated Model Predicted & Observed Values

Segment:		1	Segname 1				
		Predicted Values--->			Observed Values--->		
Variable		**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P	MG/M3	84.9	0.16	73.7%	84.9	0.11	73.8%

Table 91. Lake Winona (Northwest Bay) Calibrated Model Water and Phosphorus Balances

Overall Water Balance					Averaging Period =		1.00	years
				Area	Flow	Variance	CV	Runoff
Trb	**Type**	**Seg**	**Name**	**km^2**	**hm^3/yr**	**$(hm3/yr)^2$**	**-**	**m/yr**
1	1	1	Boller's Lake		6.7097	4.50E-01	0.10	
2	1	1	Winona MS4	3.7103	0.8384	7.03E-03	0.10	0.23
3	1	1	Direct Drainage	3.9319	0.8885	7.89E-03	0.10	0.23
PRECIPITATION				0.3412	0.3037	0.00E+00	0.00	0.89
TRIBUTARY INFLOW				7.6422	8.4366	4.65E-01	0.08	1.10
***TOTAL INFLOW				7.9834	8.7403	4.65E-01	0.08	1.09
ADVECTIVE OUTFLOW				7.9834	8.4195	4.65E-01	0.08	1.05
***TOTAL OUTFLOW				7.9834	8.4195	4.65E-01	0.08	1.05
***EVAPORATION					0.3207	0.00E+00	0.00	

Overall Mass Balance Based Upon				Predicted		Outflow & Reservoir Concentrations				
Component:				TOTAL P						
				Load		Load Variance			Conc	Export
Trb	**Type**	**Seg**	**Name**	**kg/yr**	**%Total**	**$(kg/yr)^2$**	**%Total**	**CV**	**mg/m^3**	**$kg/km^2/yr$**
1	1	1	Boller's Lake	475.0	50.2%	1.64E+04	84.1%	0.27	70.8	
2	1	1	Winona MS4	180.8	19.1%	2.37E+03	12.2%	0.27	215.7	48.7
3	1	1	Direct Drainage	95.8	10.1%	6.65E+02	3.4%	0.27	107.8	24.4
PRECIPITATION				14.7	1.5%	5.38E+01	0.3%	0.50	48.3	43.0
INTERNAL LOAD				180.7	19.1%	0.00E+00		0.00		
TRIBUTARY INFLOW				751.7	79.4%	1.94E+04	99.7%	0.19	89.1	98.4
***TOTAL INFLOW				947.0	100.0%	1.95E+04	100.0%	0.15	108.4	118.6
ADVECTIVE OUTFLOW				714.6	75.5%	1.60E+04		0.18	84.9	89.5
***TOTAL OUTFLOW				714.6	75.5%	1.60E+04		0.18	84.9	89.5
***RETENTION				232.4	24.5%	8.00E+03		0.38		

Overflow Rate (m/yr)	24.7	Nutrient Resid. Time (yrs)	0.0505
Hydraulic Resid. Time (yrs)	0.0669	Turnover Ratio	19.8
Reservoir Conc (mg/m3)	85	Retention Coef.	0.245

Table 92. Lake Winona (Northwest Bay) TMDL Goal Scenario Model Predicted & Observed Values

Segment:		1	Segname 1				
		Predicted Values--->			Observed Values--->		
Variable		Mean	CV	Rank	Mean	CV	Rank
TOTAL P	MG/M3	60.0	0.18	59.9%	84.9	0.11	73.8%

Table 93. Lake Winona (Northwest Bay) TMDL Scenario Model Water and Phosphorus Balances

Overall Water Balance					Averaging Period =		1.00	years
				Area	Flow	Variance	CV	Runoff
Trb	Type	Seg	Name	km^2	hm^3/yr	$(hm3/yr)^2$	-	m/yr
1	1	1	Boller's Lake		6.7097	4.50E-01	0.10	
2	1	1	Winona MS4	3.7103	0.8384	7.03E-03	0.10	0.23
3	1	1	Direct Drainage	3.9319	0.8885	7.89E-03	0.10	0.23
PRECIPITATION				0.3412	0.3037	0.00E+00	0.00	0.89
TRIBUTARY INFLOW				7.6422	8.4366	4.65E-01	0.08	1.10
***TOTAL INFLOW				7.9834	8.7403	4.65E-01	0.08	1.09
ADVECTIVE OUTFLOW				7.9834	8.4195	4.65E-01	0.08	1.05
***TOTAL OUTFLOW				7.9834	8.4195	4.65E-01	0.08	1.05
***EVAPORATION					0.3207	0.00E+00	0.00	

Overall Mass Balance Based Upon				Predicted		Outflow & Reservoir Concentrations				
Component:				TOTAL P						
				Load		Load Variance			Conc	Export
Trb	Type	Seg	Name	kg/yr	%Total	$(kg/yr)^2$	%Total	CV	mg/m^3	$kg/km^2/yr$
1	1	1	Boller's Lake	402.6	62.6%	1.18E+04	86.9%	0.27	60.0	
2	1	1	Winona MS4	125.8	19.6%	1.15E+03	8.5%	0.27	150.0	33.9
3	1	1	Direct Drainage	88.8	13.8%	5.72E+02	4.2%	0.27	100.0	22.6
PRECIPITATION				14.7	2.3%	5.38E+01	0.4%	0.50	48.3	43.0
INTERNAL LOAD				11.2	1.7%	0.00E+00		0.00		
TRIBUTARY INFLOW				617.2	96.0%	1.35E+04	99.6%	0.19	73.2	80.8
***TOTAL INFLOW				643.1	100.0%	1.35E+04	100.0%	0.18	73.6	80.6
ADVECTIVE OUTFLOW				505.4	78.6%	9.73E+03		0.20	60.0	63.3
***TOTAL OUTFLOW				505.4	78.6%	9.73E+03		0.20	60.0	63.3
***RETENTION				137.7	21.4%	3.35E+03		0.42		
	Overflow Rate (m/yr)			24.7		Nutrient Resid. Time (yrs)			0.0526	
	Hydraulic Resid. Time (yrs)			0.0669		Turnover Ratio			19.0	
	Reservoir Conc (mg/m3)			60		Retention Coef.			0.214	

Table 94. Lake Winona (Southeast Bay) Calibrated Model Predicted & Observed Values

Segment:		1	Segname 1				
		Predicted Values--->			Observed Values--->		
Variable		Mean	CV	Rank	Mean	CV	Rank
TOTAL P	MG/M3	52.8	0.26	54.3%	52.8	0.08	54.3%

Table 95. Lake Winona (Southeast Bay) Calibrated Model Water and Phosphorus Balances

Overall Water Balance					Averaging Period =		1.00	years
				Area	Flow	Variance	CV	Runoff
Trb	Type	Seg	Name	km^2	hm^3/yr	$(hm3/yr)^2$	-	m/yr
1	1	1	Direct Drainage	1.3517	0.3054	9.33E-04	0.10	0.23
2	1	1	Winona NW		8.4195	7.09E-01	0.10	
3	1	1	Winona MS4	1.8008	0.4069	1.66E-03	0.10	0.23
PRECIPITATION				0.9008	0.8017	0.00E+00	0.00	0.89
TRIBUTARY INFLOW				3.1525	9.1318	7.11E-01	0.09	2.90
***TOTAL INFLOW				4.0533	9.9335	7.11E-01	0.08	2.45
ADVECTIVE OUTFLOW				4.0533	9.0868	7.11E-01	0.09	2.24
***TOTAL OUTFLOW				4.0533	9.0868	7.11E-01	0.09	2.24
***EVAPORATION					0.8468	0.00E+00	0.00	

Overall Mass Balance Based Upon				Predicted		Outflow & Reservoir Concentrations				
Component:				TOTAL P						
				Load		Load Variance			Conc	Export
Trb	Type	Seg	Name	kg/yr	%Total	$(kg/yr)^2$	%Total	CV	mg/m^3	$kg/km^2/yr$
1	1	1	Direct Drainage	38.7	4.3%	1.09E+02	0.3%	0.27	126.7	28.6
2	1	1	Winona NW	714.8	79.3%	3.70E+04	97.2%	0.27	84.9	
3	1	1	Winona MS4	89.4	9.9%	5.80E+02	1.5%	0.27	219.8	49.7
PRECIPITATION				38.7	4.3%	3.75E+02	1.0%	0.50	48.3	43.0
INTERNAL LOAD				19.7	2.2%	0.00E+00		0.00		
TRIBUTARY INFLOW				843.0	93.5%	3.77E+04	99.0%	0.23	92.3	267.4
***TOTAL INFLOW				901.4	100.0%	3.81E+04	100.0%	0.22	90.7	222.4
ADVECTIVE OUTFLOW				479.9	53.2%	1.82E+04		0.28	52.8	118.4
***TOTAL OUTFLOW				479.9	53.2%	1.82E+04		0.28	52.8	118.4
***RETENTION				421.5	46.8%	2.15E+04		0.35		
	Overflow Rate (m/yr)			10.1		Nutrient Resid. Time (yrs)			0.2475	
	Hydraulic Resid. Time (yrs)			0.4649		Turnover Ratio			4.0	
	Reservoir Conc (mg/m3)			53		Retention Coef.			0.468	

Table 96. Lake Winona (Southeast Bay) TMDL Goal Scenario Model Predicted & Observed Values

Segment:		1	Segname 1				
		Predicted Values--->			Observed Values--->		
Variable		**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P	MG/M3	40.0	0.25	42.1%	52.8	0.08	54.3%

Table 97. Lake Winona (Southeast Bay) TMDL Goal Scenario Model Water and Phosphorus Balances

Overall Water Balance					Averaging Period =		1.00	years
				Area	Flow	Variance	CV	Runoff
Trb	Type	Seg	Name	km^2	hm^3/yr	$(hm3/yr)^2$	-	m/yr
1	1	1	Direct Drainage	1.3517	0.3054	9.33E-04	0.10	0.23
2	1	1	Winona NW		8.4195	7.09E-01	0.10	
3	1	1	Winona MS4	1.8008	0.4069	1.66E-03	0.10	0.23
PRECIPITATION				0.9008	0.8017	0.00E+00	0.00	0.89
TRIBUTARY INFLOW				3.1525	9.1318	7.11E-01	0.09	2.90
***TOTAL INFLOW				4.0533	9.9335	7.11E-01	0.08	2.45
ADVECTIVE OUTFLOW				4.0533	9.0868	7.11E-01	0.09	2.24
***TOTAL OUTFLOW				4.0533	9.0868	7.11E-01	0.09	2.24
***EVAPORATION					0.8468	0.00E+00	0.00	

Overall Mass Balance Based Upon				Predicted	Outflow & Reservoir Concentrations					
Component:				TOTAL P						
				Load		Load Variance			Conc	Export
Trb	Type	Seg	Name	kg/yr	%Total	$(kg/yr)^2$	%Total	CV	mg/m^3	$kg/km^2/yr$
1	1	1	Direct Drainage	30.5	4.8%	6.76E+01	0.4%	0.27	100.0	22.6
2	1	1	Winona NW	505.2	79.5%	1.85E+04	96.3%	0.27	60.0	
3	1	1	Winona MS4	61.0	9.6%	2.70E+02	1.4%	0.27	150.0	33.9
PRECIPITATION				38.7	6.1%	3.75E+02	2.0%	0.50	48.3	43.0
TRIBUTARY INFLOW				596.7	93.9%	1.88E+04	98.0%	0.23	65.3	189.3
***TOTAL INFLOW				635.5	100.0%	1.92E+04	100.0%	0.22	64.0	156.8
ADVECTIVE OUTFLOW				363.5	57.2%	9.71E+03		0.27	40.0	89.7
***TOTAL OUTFLOW				363.5	57.2%	9.71E+03		0.27	40.0	89.7
***RETENTION				272.0	42.8%	9.82E+03		0.36		

Overflow Rate (m/yr)	10.1	Nutrient Resid. Time (yrs)	0.2659
Hydraulic Resid. Time (yrs)	0.4649	Turnover Ratio	3.8
Reservoir Conc (mg/m3)	40	Retention Coef.	0.428

13 Appendix C: LDC Supporting Information

Table 98. Data source summary for load duration analysis, *E. coli* TMDLs

Impaired Reach Name/AUID	Flow Data Source	Flow Data Range (years)	Water Quality Station	Water Quality Data Range (years)	Comments
Whitewater River, Middle Fork 07040003-515	Whitewater SWAT model subbasin 97	2001-2010	S002-074	2010-2012	WQ station S002-074 near outlet subbasin 97.
Peterson Creek 07040003-529	Garvin SWAT model subbasin 47		S000-839	2001-2002	WQ station S000-839 near outlet subbasin 47. Class 2A
Rollingstone Creek 07040003-533	Garvin SWAT model subbasin 10		S001-532	2002, 2009-2011	WQ S001-532 at outlet of Garvin SWAT subbasin10. Reach outlet is Garvin SWAT subbasin 7.
Whitewater River 07040003-539	Whitewater SWAT model subbasin 1		S001-767	2010-2011	WQ station S001-767 near outlet subbasin 1. Class 2B
Logan Branch 07040003-552	Whitewater SWAT model subbasin 53		S002-545	2004	WQ station S002-545 near outlet subbasin 53. Class 2A
Garvin Brook 07040003-595	Garvin SWAT model subbasin 6		S000-826	2001-2002	WQ station S000-826 near outlet Garvin subbasin 6. Data as fecal coliform. Class 2B
Crow Spring (Middle Fork Whitewater River Tributary) 07040003-611	Whitewater SWAT model subbasin 95, area weighted to WQ station S003-707,		S003-707	2003, 2010	Drainage area at WQ station S003-707 = 5490 ac Drainage at subbasin 95 outlet = 7915 ac Class 2A

Table 99. Data source summary for load duration analysis, Nitrate TMDLs

Impaired Reach Name/AUID	Flow Data Source	Flow Data Range	Water Quality Station	Water Quality Data Range (years)	Comments
Whitewater River, South Fork 07040003-512	Whitewater SWAT subbasin 46	2001-2010	S000-321	2009-2012	Class 2A
Whitewater River, South Fork 07040003-F17	Whitewater SWAT subbasin 101		S000-288	2001-2003, 2005-2008	Class 2A
Whitewater River, Middle Fork 07040003-F19	Whitewater SWAT subbasin 59		Nitrate:S007-140	2001-02, 2008	Class 2A
Crow Spring (Middle Fork Whitewater River Tributary) 07040003-611	Whitewater SWAT subbasin 95		Not available for 2001-2010		Class 2A

Table 100. Data source summary for load duration analysis, TSS TMDLs

Impaired Reach Name/AUID	Flow Data Source (2001-2010)	Water Quality Data		Use Classfication/Comments Class 2A water quality target = 10 mg/L TSS Class 2B water quality target = 65 mg/L TSS
		Water Quality Station	Sample Dates	
Whitewater River, South Fork 07040003-512	Whitewater SWAT subbasin 77	S000-321	2001-02, 2009-12	Class 2A
Whitewater River, South Fork 07040003-F16	Whitewater SWAT subbasin 101	S000-288	2001-03, 2005-09	Class 2B Class 2A target applied to protect downstream reach 07040003-F17
Whitewater River, South Fork 07040003-F17	Whitewater SWAT subbasin 104	(none available)		Class 2A
Whitewater River, Middle Fork 07040003-515	Whitewater SWAT subbasin 97	S002-074	2005	Class 2B Class 2A target applied to protect downstream reach 07040003-F19 Very few observed data
Whitewater River, Middle Fork 07040003-F19	Whitewater SWAT subbasin 59	S001-825	2005-2010	Class 2A
Whitewater River, North Fork 07040003-523	Whitewater SWAT subbasin 57	S001-744	2005	Class 2A
Rollingstone Creek 07040003-533	Garvin SWAT subbasin 10	S001-532	2002,2009-2010	Class 2A
Logan Branch 07040003-536	Whitewater SWAT subbasin 63	S002-072	2001-2002	Class 2B Class 2A target applied to protect downstream reach 07040003-554

Impaired Reach Name/AUID	Flow Data Source (2001-2010)	Water Quality Data		Use Classfication/Comments Class 2A water quality target = 10 mg/L TSS Class 2B water quality target = 65 mg/L TSS
		Water Quality Station	Sample Dates	
Whitewater River 07040003-537	Whitewater SWAT subbasin 16	S001-742	2005, 2008-2010	Class 2A
Whitewater River 07040003-539	Whitewater SWAT subbasin 1	S001-767	2010	Class 2B
Whitewater River, North Fork 07040003-553	Whitewater SWAT subbasin 37	S000-978	2001-02,2005	Class 2A
Whitewater River, North Fork 07040003-554	Whitewater SWAT subbasin 47	S000-451	2001-02, 2009-10	Class 2A
Stockton Valley Creek 07040003-559	Gavin SWAT subbasin 46	S001-529	2001-02	Class 2A
Garvin Brook 07040003-595	Garvin SWAT subbasin 8	S000-826	2001-02	Class 2B

14 Appendix D. Watershed Impairments by Designated Use

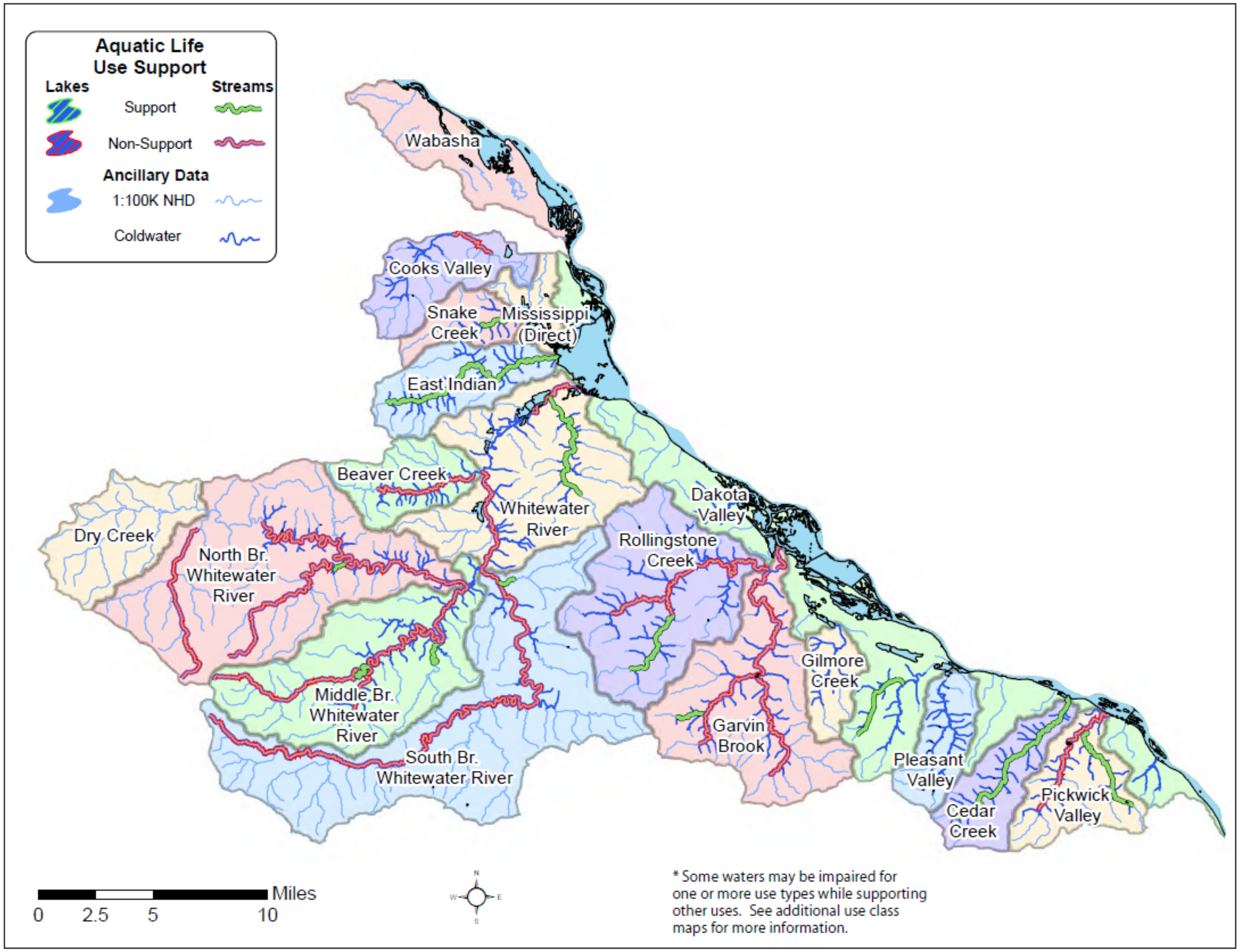

Figure 50. Aquatic Life Use support in the Mississippi River (Winona) Watershed

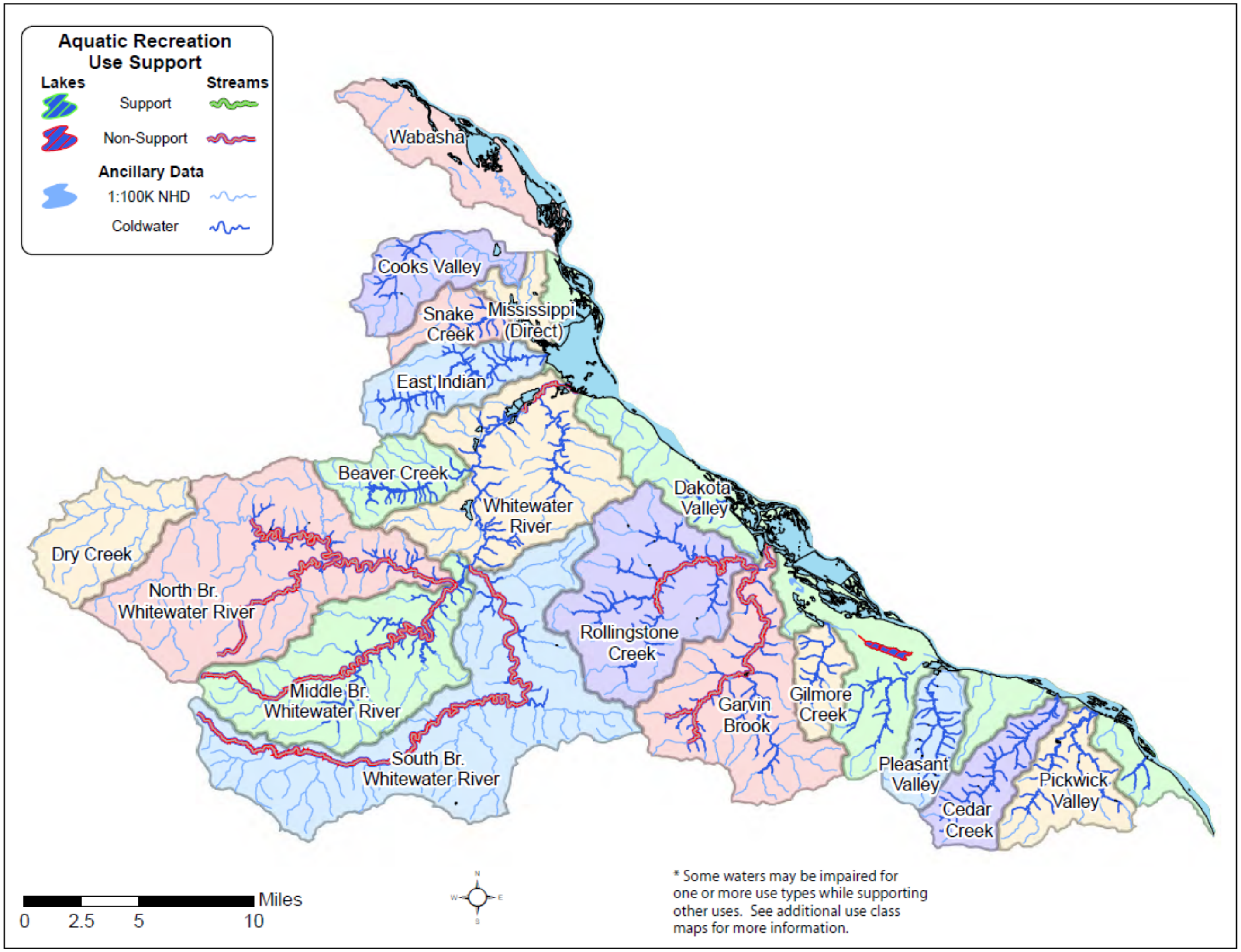

Figure 51. Aquatic Recreation Use support in the Mississippi River (Winona) Watershed